Energy Fuels Resources (USA) Inc.
225 Union Blvd. Suite 600
Lakewood, CO, US, 80228
303 974 2140
www.energyfuels.com

July 12, 2018

VIA EXPRESS DELIVERY

Mr. Scott Anderson
Director
Division of Waste Management and Radiation Control
Utah Department of Environmental Quality
195 North 1950 West
P.O. Box 144880
Salt Lake City, UT 84114-4880

RE: White Mesa Uranium Mill, Blanding, Utah
Radioactive Materials License No. UT100479
Groundwater Discharge Permit No. UGW370004
Cells 5A and 5B License and GWDP Amendment Request

Dear Mr. Anderson:

This is written to transmit a formal request by Energy Fuels Resources (USA) Inc. ("Energy Fuels") to amend its Radioactive Materials License No. UT1900479 (the "License") and Groundwater Discharge Permit No. UGW370004 (the "GWDP") in order to obtain approval of the Director (the "Director") of the Division of Waste Management and Radiation Control (the "DWMRC") to construct, operate and (when operations are complete) reclaim proposed new tailings impoundment Cells 5A and 5B at its White Mesa Mill (the "Mill"). The construction of Cells 5A and 5B is an essential element of future operations at the Mill as their construction is necessary in order to continue providing sufficient impoundment surface area for the evaporation of Mill process water, and to provide additional tailings capacity which is necessary to accommodate the tailings volume associated with routine ore processing operations.

At this time, Energy Fuels does not anticipate the construction of Cells 5A and 5B immediately upon the Director's approval of the License and GWDP amendments; however, authorization is being sought in advance to allow the Mill to respond to expected improvements in uranium market conditions. While the new cells have not yet been constructed, they were contemplated, described and assessed previously, being a critical component of the U.S. Nuclear Regulatory Commission's initial 1979 Final Environmental Statement and attendant licensing of the facility. More specifically, the initial environmental analysis and license application for the facility contemplated a six-cell impoundment system, including existing Cells 1, 2, 3 and 4 (comprised of two separate 40-acre cells), as well as Cell 5 (also comprised of two separate 40-acre cells) and Cell 1-E, which has not been constructed.

In accordance with R313-22-33, a License application shall be approved if the Director determines that:

a) the applicant and all personnel who will be handling the radioactive material are qualified by reason of training and experience to use the material in question for the purpose requested in accordance with these rules in a manner as to minimize danger to public health and safety or the environment;

b) the applicant's proposed equipment, facilities, and procedures are adequate to minimize danger to public health and safety or the environment;

c) the applicant's facilities are permanently located in Utah, otherwise the applicant shall seek reciprocal recognition as required by Section R313-19-30;

d) the issuance of the license will not be inimical to the health and safety of the public;

e) the applicant satisfies applicable special requirements in Sections R313-22-50, R313-22-54, and R313-22-75, and Rules R313-24, R313-25, R313-32, R313-34, R313-36, or R313-38; and

f) in the case of an application for a license to receive and possess radioactive material for commercial waste disposal by land burial, or for the conduct of other activities which the Director determines will significantly affect the quality of the environment, the Director, before commencement of construction of the plant or facility in which the activity will be conducted, has concluded, after weighing the environmental, economic, technical and other benefits against environmental costs and considering available alternatives, that the action called for is the issuance of the proposed license, with any appropriate conditions to protect environmental values. The Director shall respond to the application within 60 days. Commencement of construction prior to a response and conclusion shall be grounds for denial of a license to receive and possess radioactive material in the plant or facility.

With regard to the forgoing requirements of R313-22-33, Energy Fuels' License Renewal Application dated February 28, 2007, provided the information required above and is incorporated here by reference.

In addition to these requirements, R313-24-3 requires that each new license application, renewal, or major amendment shall contain an environmental report describing the proposed action, a statement of its purposes, and the environment affected. The environmental report shall present a discussion of the following:

a) An assessment of the radiological and nonradiological impacts to the public health from the activities to be conducted pursuant to the license or amendment;

b) An assessment of any impact on waterways and groundwater resulting from the activities conducted pursuant to the license or amendment;

c) Consideration of alternatives, including alternative sites and engineering methods, to the activities to be conducted pursuant to the license or amendment; and

d) Consideration of the long-term impacts including decommissioning, decontamination, and reclamation impacts, associated with activities to be conducted pursuant to the license or amendment.

In order to fulfill the requirements of R313-24-3 Energy Fuels' has prepared the attached *Environmental Report In Support of Construction, Cells 5A and 5B, White Mesa Mill Blanding, Utah.* To support this license amendment request, Energy Fuels has also completed and attached *Form DWMRC-01.*

If you have any questions regarding this submittal, please contact me at sbakken@energyfuels.com or 303-389-4132.

Sincerely,

ENERGY FUELS RESOURCES (USA) INC.
Scott A. Bakken
Sr. Director, Regulatory Affairs

Att Attachment A – Form DWMRC-01
Attachment B – Environmental Report in Support of Construction, Cells 5A and 5B
Volume 1: Environmental Report, Appendices A through C
Volume 2: Appendix D
Volume 3: Appendices E through H

ec: D. Frydenlund, P. Goranson, K. Weinel, L. Shumway, D. Turk (EFRI)

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e) the applicant satisfies applicable special requirements in Sections R313-22-50, R313-22-54, and R313-22-75, and Rules R313-24, R313-25, R313-32, R313-34, R313-36, or R313-38; and

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With regard to the forgoing requirements of R313-22-33, Energy Fuels' License Renewal Application dated February 28, 2007, provided the information required above and is incorporated here by reference.

In addition to these requirements, R313-24-3 requires that each new license application, renewal, or major amendment shall contain an environmental report describing the proposed action, a statement of its purposes, and the environment affected. The environmental report shall present a discussion of the following:

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d) Consideration of the long-term impacts including decommissioning, decontamination, and reclamation impacts, associated with activities to be conducted pursuant to the license or amendment.

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If you have any questions regarding this submittal, please contact me at sbakken@energyfuels.com or 303-389-4132.

Sincerely,

ENERGY FUELS RESOURCES (USA) INC.
Scott A. Bakken
Sr. Director, Regulatory Affairs

Att Attachment A – Form DWMRC-01
Attachment B – Environmental Report in Support of Construction, Cells 5A and 5B
Volume 1: Environmental Report, Appendices A through C
Volume 2: Appendix D
Volume 3: Appendices E through H

ec: D. Frydenlund, P. Goranson, K. Weinel, L. Shumway, D. Turk (EFRI)

Attachment A

Form DWMRC-01

Print Form

DWMRC-01
01/16

UTAH DEPARTMENT OF ENVIRONMENTAL QUALITY
DIVISION OF WASTE MANAGEMENT AND RADIATION CONTROL
APPLICATION FOR RADIOACTIVE MATERIAL LICENSE

INSTRUCTIONS: Complete all applicable items. Use supplemental sheets where necessary. Mail to: **Utah Department of ironmental Quality, Division of Waste Management and Radiation Control, P.O. Box 144880, Salt Lake City, Utah 84114-4880.** If your application contains 25 pages, or more, an electronic copy must also be submitted on a CD or DVD nonrewriteable disk. This electronic copy shall consist of either a PDF searchable text document or a Microsoft Office Word document. (See R313-12-111.) Upon approval of this application, the applicant will receive a Radioactive Material License, issued in accordance with the requirements contained in the current Radiation Control Rules as adopted by the Board.

1. THIS IS AN APPLICATION FOR:

- ○ A New License
- ◉ Amendment to License Number UT 1900479
- ○ Renewal of License Number UT

2. NAME, MAILING ADDRESS, & ZIP CODE

Name: Energy Fuels Resources (USA) Inc.
Address: 225 Union Blvd.
Suite 600
City: Lakewood State: CO
Zip Code: 80228

3. STORAGE/USE LOCATION

Address: White Mesa Uranium Mill
6425 S. Highway 191
P.O. Box 809
City: Blanding State: UT Zip Code: 84511

addition to above address, use at temporary job sites?

4. NAME OF PERSON TO BE CONTACTED ABOUT THIS APPLICATION

Name: Scott A. Bakken
Telephone No. 3033894132
Email: sbakken@energyfuels.com

SUBMIT ITEMS 5 THROUGH 11 ON 8 1/2" X 11" PAPER. **KEY ALL RESPONSES TO THE RESPECTIVE ITEM AND/OR SUB ITEM OF THE LICENSING GUIDE.** STAPLE THIS FORM TO THE PAPERS.

5. RADIOACTIVE MATERIAL TO BE POSSESSED

6. PURPOSE FOR WHICH LICENSED MATERIAL WILL BE USED

7. INDIVIDUAL(S) RESPONSIBLE FOR RADIATION SAFETY PROGRAM AND THEIR TRAINING AND EXPERIENCE

8. TRAINING FOR INDIVIDUALS WORKING IN OR FREQUENTING RESTRICTED AREAS

9. FACILITIES AND EQUIPMENT

10. RADIATION SAFETY PROGRAM

11. WASTE MANAGEMENT

12. LICENSE FEES:

Fee Category: Amount Enclosed $ 0.00

13. CERTIFICATION: The applicant, or official executing this certification on behalf of the applicant named in Item 2, certifies that this application is prepared in conformity with current Radiation Control Rules adopted by the Utah Radiation Control Board and that all information contained herein, including any supplements attached hereto, are true and correct to the best of his/her knowledge and belief.

Signature- Certifying Official	Typed/Printed Name	Title	Date
[signature]	William Paul Goranson	Chief Operating Officer	07/12/2018

Print Form

Addendum
Application for Amendment
State of Utah Radioactive Materials License No. UT1900479

This is an Addendum to the Form DWMRC-01 Application for Amendment of Utah Radioactive Materials License No. UT1900479 for the White Mesa Uranium Mill (the "Mill").

Reference is made to the Environmental Report In Support of Construction, Cells 5A and 5B, White Mesa Uranium Mill, Blanding, Utah (the "Environmental Report"), prepared by Energy Fuels Resources (USA) Inc. ("Energy Fuels") and submitted to the Division of Waste Management and Radiation Control ("DWMRC") on July 12, 2018, and all documents incorporated by reference in the Environmental Report. This Application for Amendment incorporates by reference the Environmental Report cited above as well as its respective Appendices.

The Applicant, Energy Fuels, hereby responds to Items 5 through 11 of Form DWMRC-01, as follows:

5. RADIOACTIVE MATERIAL TO BE POSSESSED

This amendment request does not impact the types and quantities of radioactive material to be possessed by Energy Fuels under the License. As an element of the February 2007 License Renewal Application the following materials and quantities were listed and remain unaffected by this Amendment:

- An unlimited quantity of natural uranium in any chemical and/or physical form; and
- Byproduct material, as defined in Utah Code Section 19-3-102, in the form of uranium wastes tailings and other uranium byproduct waste generated by Energy Fuels' milling operations under the License.

6. PURPOSE FOR WHICH LICENSED MATERIAL WILL BE USED

Energy Fuels proposes to continue to operate the Mill and use the licensed material as described in Volume 1, Section 2 and elsewhere in the February 2007 License Renewal Application, except this Amendment Request adds to the operation Cells 5A and 5B for which approval for construction and operation is being requested.

7. INDIVIDUAL(S) RESPONSIBLE FOR RADIATION SAFETY PROGRAM AND THEIR TRAINING AND EXPERIENCE

The Radiation Safety Officer at the Mill, currently Mr. David E. Turk, is the individual responsible for the radiation safety program at the Mill. Mr. Turk's training and experience were provided with the February 2007 License Renewal Application and are incorporated here by reference. The Mill currently expects a change in the Radiation Safety Officer at the Mill. A replacement Radiation Safety Officer will meet the applicable requirements of NRC Regulatory Guide 8.31.

8. TRAINING FOR INDIVIDUALS WORKING IN OR FREQUENTING RESTRICTED AREAS

The Mill's training program is described in Volume 1, Section 6.3.3 and elsewhere in the February 2007 License Renewal Application Documents and is incorporated here by reference.

9. FACILITIES AND EQUIPMENT

The Mill's facilities and equipment are described in detail in Volume 1, Section 4, and elsewhere in the February 2007 License Renewal Application Documents and are incorporated here by reference.

10. RADIATION SAFETY PROGRAM

The Mill's Radiation Safety Program is described in detail in Volume 1, Section 6.4 and elsewhere in the February 2007 License Renewal Application Documents and is incorporated here by reference.

11. WASTE MANAGEMENT

The Mill's waste management facilities, equipment and programs are described in detail in Volume 1, Section 5, and elsewhere in the February 2007 License Renewal Application Documents, which are incorporated here by reference. The addition of Cells 5A and 5B augments the current waste management facilities and is supported here by an Environmental Report.

Attachment B

Environmental Report in Support of Construction Cells 5A and 5B

Environmental Report
In Support of Construction

Cells 5A and 5B

White Mesa Uranium Mill
Blanding, Utah

Prepared by

Energy Fuels Resources (USA) Inc.
225 Union Blvd., Suite 600
Lakewood, Colorado 80228

July 2018

Introduction

Energy Fuels Resources (USA) Inc. ("Energy Fuels") is seeking an amendment to its Radioactive Materials License No. UT1900479 (the "License") and Groundwater Discharge Permit No. UGW370004 (the "GWDP") in order to obtain the approval of the Director (the "Director") of the Division of Waste Management and Radiation Control (the "DWMRC") to construct, operate and (when operations are complete) reclaim proposed new tailings impoundment Cells 5A and 5B at its White Mesa Uranium Mill (the "Mill"). The construction of Cells 5A and 5B are an essential element of future operations at the Mill as their construction and operation is necessary in order to continue providing sufficient impoundment surface area for the evaporation of Mill process water. These cells will also provide additional tailings capacity, which is necessary to accommodate the tailings volume associated with routine ore processing operations.

At this time, Energy Fuels does not anticipate the construction of Cells 5A and 5B immediately upon the Director's approval of the License and GWDP amendments; however, authorization is being sought in advance to allow the Mill to respond to expected improvements in uranium market conditions.

While the new cells have not yet been constructed, they were contemplated, described and assessed previously, being a critical component of the initial environmental analysis and attendant licensing of the facility. See the *Environmental Report, White Mesa Uranium Project San Juan County, Utah*, January 30, 1978, prepared by Dames & Moore (the "1978 ER") and the *Final Environmental Statement Related to Operation of the White Mesa Uranium Project Energy Fuels Inc.*, May 1979 (the "FES"), prepared by the United States Nuclear Regulatory Commission ("NRC").

These initial environmental analyses and the License contemplated a six-cell impoundment system (see Section 3.2.4.7 of the FES). These cells are Cell 1-I (now referred to as Cell 1), Cell 1-E, which has not been constructed, existing Cells 2, 3 and 4 (comprised of two separate 40-acre cells) and Cell 5, which will also be comprised of two separate 40-acre cells (Cells 5A and 5B). Cells 5A and 5B have therefore been specifically contemplated and included in the License (see Figure 3.4 of the FES). As depicted in this figure, the size and location of the six-cell impoundment system (Cells 1, 2, 3, 4, 5 and 1-E) is consistent with the original conceptual design and licensing of the Mill.

The information required for an amendment to the License is found at R313-24-3. More specifically, the regulations state the following:

> (1) Each new license application, renewal, or major amendment shall contain an environmental report describing the proposed action, a statement of its purposes, and the environment affected. The environmental report shall present a discussion of the following:

(a) An assessment of the radiological and non-radiological impacts to the public health from the activities to be conducted pursuant to the license or amendment;

(b) An assessment of any impact on waterways and groundwater resulting from the activities conducted pursuant to the license or amendment;

(c) Consideration of alternatives, including alternative sites and engineering methods, to the activities to be conducted pursuant to the license or amendment; and

(d) Consideration of the long-term impacts including decommissioning, decontamination, and reclamation impacts, associated with activities to be conducted pursuant to the license or amendment.

In order to fulfill the requirements above, Energy Fuels considered and used the information topics and format cited by NRC in its guidance document *Standard Review Plan for In Situ Leach Uranium Extraction License Applications, Final Report*, June 2003 ("NUREG 1569") for the recently approved *White Mesa Uranium Mill License Renewal Application, State of Utah Radioactive Materials License No. UT1900479*, February 28, 2007 (the "License Renewal Application") and supporting *Environmental Report*, dated February 28, 2007 (the "2007 ER").

This Report is not in support of an application for the License or renewal of the License as a whole, which are addressed in the License Renewal Application and the 2007 ER, nor is it an application for approval of the siting and use of Cells 5A and 5B, which have already been evaluated and approved and are included in the License as part of the approval of the tailings management system for the Mill. Rather, this Report is in support of the more detailed amendments to the License required in connection with the actual construction and operation of Cells 5A and 5B. Because the License Renewal Application provided current environmental information and assessments, the scope of this Environmental Report can be limited in some respects, focusing on pathways and assessments directly related to the construction and operation of the new tailings cells. Accordingly, topical headings suggested by NUREG 1569 and the guidance document *Regulatory Guide 3.8, Preparation of Environmental Reports for Uranium Mills, Revision 2, October 1982* ("Reg Guide 3.8"), have been included in this Report; however, where previously provided information is sufficient and unaffected by this amendment request, the prior information is incorporated by reference. Specifically, the following environmental evaluations that have been performed for the Mill are incorporated by reference into, updated or supplemented by this Report:

- the 1978 ER;
- the FES;
- the Environmental Assessment ("EA") prepared by the NRC in September 1985 for the Mill License renewal at that time (the "1985 EA") (see NRC, 1985);
- the EA prepared by NRC in February 1997 for the Mill License renewal at that time (the "1997 EA") (see NRC, 1997);

- the EA prepared by NRC in February 2000 for the Mill's Reclamation Plan (the "2000 EA) (see NRC, 2000);
- the EA prepared by NRC in August 2002 in connection with a License amendment issued by NRC authorizing receipt and processing at the Mill of certain alternate feed materials from the Maywood site in New Jersey (the "2002 EA") (see NRC, 2002);
- the Statements of Basis prepared in December 2004 by the State of Utah Department of Environmental Quality ("UDEQ") DWMRC in connection with the issuance of the GWDP revisions (the "GWDP Statement of Basis") (see UDEQ, 2004);
- the Environmental Report in Support of the License Renewal Application, State of Utah Radioactive Materials License No. UT1900479, prepared by Denison Mines (USA) Inc., February 28, 2007 (the "2007 ER") (see Denison, 2007);
- the Reclamation Plan, Revision 5.1B, Radioactive Materials License No. UT1900479, prepared by Energy Fuels Resources (USA) Inc., February 2018 ("Reclamation Plan, Rev. 5.1B") (see Energy Fuels, 2018); and
- Background Groundwater Quality Reports, Sources Assessment Reports (SARs), Pyrite Investigation Report and pH Report as discuss in Section 1.5.4.

Energy Fuels' assessment of the pathways to be considered for construction and operation of Cells 5A and 5B is principally focused on the examination of potential airborne releases from the cells and the groundwater considerations typically attendant to the design of a tailings cell. These are the only two significant pathways that could be impacted by Cells 5A and 5B installation and operation. In addition, a cultural resource inventory has been performed on the surface area that will be impacted by the construction of Cells 5A and 5B, as required by License Condition 9.7, which will be provided to the Director in a separate report. It is important to note that the Director has approved the design, construction, operation and (when operations are complete) reclamation of directly adjacent Cells 4A and 4B. For Cells 5A and 5B, two liner designs are being proposed in this amendment request with one option being identical to the liner design and underlying ground conditions for Cells 4A and 4B. As demonstrated in this amendment request, the second option provides equal protection to the environment while offering efficiencies in the installation process, and also offers an additional leak detection layer. The decision on which liner design to use will be made by Energy Fuels prior to the start of cell construction.

Contents

Tables

Figures

Appendices

1. Proposed Activities

This Report is in support of a License and GWDP amendment application to construct, operate and (when operations are complete) reclaim proposed new tailings impoundment Cells 5A and 5B at the Mill. The construction of Cells 5A and 5B are an essential element of future operations at the Mill as their construction is necessary in order to continue providing sufficient impoundment surface area for the evaporation of Mill process water. These cells will also provide additional tailings capacity which is necessary to accommodate the tailings volume associated with routine ore processing operations.

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This Report is not in support of an application for the License or renewal of the License as a whole, nor is it an application for approval of the siting and use of Cells 5A and 5B, which have already been evaluated and approved and are included in the License as part of the approval of the tailings management system for the Mill. Rather, this Report is in support of the more detailed amendments to the License required in connection with the actual construction and operation of Cells 5A and 5B. The scope of this Environmental Report is, therefore, limited in some respects, focusing on pathways and assessments directly related to the construction and operation of the new cells.

2. Site Characterization

2.1 Site Location and Layout

The Mill is regionally located in central San Juan County, Utah, approximately 6 miles (9.5 km) south of the city of Blanding (see **Figure 2.1-1**). The Mill can be reached by taking a private road for approximately 0.5 miles west of U.S. Highway 191. Within San Juan County, the Mill is located on fee land and mill site claims, covering approximately 5,415 acres, encompassing all or part of Sections 21, 22, 27, 28, 29, 32, and 33 of T37S, R22E, and Sections 4, 5, 6, 8, 9, and 16 of T38S, R22E, Salt Lake Base and Meridian (see **Figure 2.1-2**).

All operations authorized by the License are conducted within the confines of the existing site boundary. The milling facility currently occupies approximately 50 acres and the current tailings disposal cells encompass another approximately 290 acres (see **Figure 2.1-2**).

The Mill site is located on a gently sloping mesa that, from the air, appears similar to a peninsula, as it is surrounded by steep canyons and washes and is connected to the Abajo Mountains to the north by a narrow neck of land. On the mesa, the topography is relatively flat, sloping at less than one (1) percent to the south and nearly horizontal from east to west (see **Figure 2.1-1**).

2.2 Use of Adjacent Lands and Water

Approximately 61% of San Juan County is federally owned land administered by the U.S. Bureau of Land Management ("BLM"), the National Park Service, and the U.S. Forest Service. Primary land uses include livestock grazing, wildlife range, recreation, and exploration for minerals, oil, and gas. Approximately 25% of the county is Native American land owned either by the Navajo Nation or the Ute Mountain Ute Tribe. The area within 5 miles of the Mill site is predominantly range land owned by Blanding residents. The Mill site, including tailings cells, encompasses approximately 300 acres.
A more detailed discussion of land use at the Mill site, in surrounding areas, and in southeastern Utah, is presented in the FES (Section 2.5). Results of archaeological studies conducted at the site and in the surrounding areas as part of the 1978 ER are also documented in the FES (Section 2.5.2.3).

Source: BLM Utah Surface Management (6/1/2018)

2.3 Population Distribution and Socioeconomic Profile

Demographic information is generally derived from information obtained by the U.S. Census Bureau. These records are updated on a five year frequency for population centers that exceed 65,000 people and on a ten year frequency for lesser populations. As such, the local population update for the area of interest was last recorded in the year 2010, and it is that database which was utilized to formulate the demographic information provided in this Report. According to the 2010 census, the population density of San Juan County, in which the Mill is located, is 1.9 individuals per square mile. The town of Blanding, UT, approximately 6 miles north of the Mill, is the largest population center near the Mill site, with 3,375 persons, during the 2010 census, or 3,690 persons based on the July 1, 2017, census estimate. The White Mesa community is located approximately five miles southeast of the Mill site. Approximately 242 Ute Mountain Ute tribal members reside in the White Mesa community (see **Figure 2.1-2**). The Navajo Reservation is located approximately 19 miles southeast of the Mill. The nearest community on the Navajo Reservation is Montezuma Creek, a community of approximately 335 individuals in Utah. The nearest residence to the Mill is located approximately 1.6 miles to the north-northeast of the Mill. **Table 2.3-1** provides population centers located within 50 miles of the Mill site.

Table 2.3- 1 Population Centers within 50 Miles of the Mill Site

Population Center	Population	Approximate Distance from Mill Site (miles)
Blanding, UT	3,690[2]	6
White Mesa, UT	242[1]	4
Bluff, UT	258[1]	15
Montezuma Creek, UT	335[1]	20
Aneth, UT	501[1]	27
Mexican Hat, UT	31[1]	30
Monticello, UT	1,995[2]	27
Eastland/Ucolo UT	249[3]	32
Dove Creek, UT	733[2]	37
Towaoc	1,087[1]	50

Source: [1], 2010 Census. [2], July 1, 2017 Census Estimate. [3], Based on 1978 population estimate.

San Juan County, Utah is the largest and poorest county in Utah. As of March 2018, the unemployment rate in San Juan County was 7.3%, compared to 3.1% for Utah as a whole, and 3.9% for the nation as a whole. When operating, the Mill is one of the largest private employers in San Juan County, employing up to 60 to 140 full time employees. As such, the Mill's employees represent a significant economic base for the city of Blanding and rural residents of San Juan County. In addition, the Company pays local taxes to San Juan County, further supporting the development t of the local economic base. The Mill also provides income to local minorities, typically employing a high percentage of minority workers ranging from 45 to 75% Native Americans.

Source: U.S. Bureau of Labor Statistics, web pages accessed June 2018

2.4 Historic, Scenic and Cultural Resources

A discussion of the historic, scenic, archaeological, cultural and natural significance of the Mill site and nearby areas was included in Section 2.3 of the 1978 ER and Section 2.5.2 of the FES.
An updated discussion on archaeological sites (as adapted from Section 2.5.2.3 of the FES), including the current status of excavation, was also most recently included in Section 1.3 of the Reclamation Plan, Rev. 5.1B.
As part of this license amendment request, an archaeological survey is being performed on the surface area that will be impacted by the construction of Cells 5A and 5B, as required by License Condition 9.7. The results of this survey will be included in **Appendix A** and summarized in a revised Report.

2.5 Geology and Soils

2.5.1 Regional Geology

The Mill site lies within a region designated as the Canyon Lands section of the Colorado Plateau physiographic province. Elevations in the region range from approximately 3,000 feet in the bottom of canyons to over 11,000 feet among the peaks of the Henry, Abajo and La Sal Mountains. The average elevation for the area, excluding deeper canyons and isolated mountain peaks, is about 5,000 feet.

The sedimentary rocks exposed in southeastern Utah have a total thickness of approximately 6,000 to 7,000 feet. These sedimentary units range in age from Pennsylvanian to Late Cretaceous; older rock units which underlie those of Pennsylvanian age are not exposed in the Mill site area.

Structural features in the Mill site area have been divided into three main categories on the basis of origin or mechanism of the stress that created the structure. These categories are: (1) structures related to large-scale regional uplifting or down warping directly related to movements in the basement complex (the Monument Uplift and the Blanding Basin); (2) structures due to diapiric deformation of thick sequences of evaporate deposits, salt plugs and salt anticlines (the Paradox Fold and Fault Belt); and (3) structures formed due to magmatic intrusions (the Abajo Mountains). A generalized stratigraphic column for the region is provided as **Figure 2.5-1**.

The Summerville Formation, Entrada Sandstone, and Navajo Sandstone are the deepest units of concern encountered at the site.

2.5.2 Local Geology

The Mill site is located on the western edge of the Blanding Basin, sometimes referred to as the Great Sage Plain, lying east of the north/south-trending Monument Uplift, south of the Abajo Mountains and adjacent to the northwest-trending Paradox Fold and Fault Belt. The Abajo Mountains are the most prominent topographic feature in the region, rising over 4,000 ft above the surface of the plain. The lithology of the immediate area is composed of thousands of feet of multi-colored pre-Tertiary age marine and non-marine sedimentary rocks. Erosion on the regionally-uplifted sedimentary strata has produced an array of eroded canyons and mesas.

The Mill is more specifically located on White Mesa and rests on alluvial windblown silt and sand, which covers sandstones and shales of Jurassic and Cretaceous age. The surface of the mesa is nearly flat, with a surface relief of 98 feet. The maximum relief between White Mesa and the adjacent Cottonwood Canyon is about 750 feet.

2.5.3 Site-Specific Geology

This section is based on the report titled *Hydrogeology of the White Mesa Uranium Mill and Recommended Locations of New Perched Wells to Monitor Proposed Cells 5A and 5B*, July 11, 2018, prepared by Hydro Geo Chem, Inc. (“HGC”), a copy of which is attached to this Report as **Appendix B**.

The Mill is located within the Blanding Basin of the Colorado Plateau physiographic province. Typical of large portions of the Colorado Plateau province, the rocks underlying the site are relatively underformed. The average elevation of the site is approximately 5,600 ft (1,707 m) above mean sea level (amsl).

The site is underlain by unconsolidated alluvium and indurated sedimentary rocks consisting primarily of sandstone and shale. The indurated rocks are relatively flat lying with dips generally less than 3°. The alluvial materials consist mostly of aeolian silts and fine-grained aeolian sands with a thickness varying from a few feet to as much as 25 to 30 ft (7.6 to 9.1 m) across the site. The alluvium is underlain by the Dakota Sandstone and Burro Canyon Formation, which are sandstones having a total thickness ranging from approximately 100 to 140 feet (31 to 43 m). Beneath the Burro Canyon Formation lies the Morrison Formation, consisting, in descending order, of the Brushy Basin Member, the Westwater Canyon Member, the Recapture Member, and the Salt Wash Member. The Brushy Basin and Recapture Members of the Morrison Formation, classified as shales, are very fine-grained and have a very low permeability. The Westwater Canyon and Salt Wash Members also have a low average vertical permeability due to the presence of interbedded shales. See **Figure 2.5-1** for a generalized stratigraphic column for the region.

Beneath the Morrison Formation lies the Summerville Formation, an argillaceous sandstone with interbedded shales, and the Entrada Sandstone. Beneath the Entrada lies the Navajo Sandstone. The Navajo and Entrada Sandstones constitute the primary aquifer in the area of the site. The Entrada and Navajo Sandstones are separated from the Burro Canyon Formation by approximately 1,000 to 1,100 feet (305 to 335 m) of materials having a low average vertical permeability. Groundwater within this system is under artesian pressure in the vicinity of the site and is used only as a secondary source of water at the site.

2.5.4 Soils

A discussion of the soils aspects of the Mill site was provided in Section 2.10.1 of the 1978 ER and Section 2.8 of the FES. There have been no significant changes in soil conditions since that time. A description of existing soil conditions, including the results of a geotechnical investigation performed within the proposed limits of Cells 5A and 5B is provided in Section 2.4 of the Cells 5A and 5B Design Report in **Appendix D**.

2.6 Seismology

A discussion of the seismicity of the region was provided in Section 2.5 of the 1978 ER and Section 2.7.3 of the FES. An updated discussion of physiography and topography; rock units; structure; relationship of earthquakes to tectonic structures; and potential earthquake hazards to the Mill area (as reproduced from the 1978 ER), was also most recently included in Section 1.6.2 of the Reclamation Plan, Rev. 5.1B. Further, Section 1.6.3 of the Reclamation Plan, Rev. 5.1B provides a discussion of a site-specific probabilistic seismic hazard analysis that was conducted for the Mill site.

2.7 Hydrology

2.7.1 Ground Water

The site is located within a region that has a dry to arid continental climate, with average annual precipitation of approximately 13.3 inches and an average annual lake evaporation rate of approximately 47.6 inches. Recharge to aquifers occurs primarily along the mountain fronts (e.g., the Henry, Abajo, and La Sal Mountains), and along the flanks of folds such as Comb Ridge Monocline.

Although the water quality and productivity of the Navajo/Entrada aquifer are generally good, the depth of the aquifer (approximately 1,200 feet below land surface ("bls") makes access difficult. The Navajo/Entrada aquifer is capable of yielding significant quantities of water to wells (hundreds of gallons per minute ("gpm")). Water in wells completed across these units at the site rises approximately 800 feet above the base of the overlying Summerville Formation.

Sections 2.7.1.1 through 2.7.1.3 below are based on the Report titled *Hydrogeology of the White Mesa Uranium Mill and Recommended Locations of New Perched Wells to Monitor Proposed Cells 5A and 5B*, July 11, 2018, prepared by Hydro Geo Chem, Inc. ("HGC"), a copy of which is attached to this Report as **Appendix B**.

2.7.1.1 Perched Zone Hydrogeology (Site-Specific)

Perched groundwater beneath the site occurs primarily within the Burro Canyon Formation. Where saturated thicknesses are large, perched water may extend into the overlying Dakota Sandstone. Perched groundwater at the site has a generally low quality due to high total dissolved solids ("TDS") in the range of approximately 1,100 to 7,900 milligrams per liter ("mg/L"), and is used primarily for stock watering and irrigation in the areas upgradient (north) of the site.

The quality of the perched groundwater is affected locally by elevated chloroform and nitrate, as detailed in **Appendix B**. The chloroform plume (defined by concentrations exceeding 70 micrograms per liter ("µg/L"), located up- to cross-gradient (northeast to east) of the tailings management system, likely originated from two sanitary leach field sources that accepted laboratory wastes prior to construction and operation of the Mill. The nitrate plume (defined by concentrations exceeding 10 mg/L commingles with a chloride plume (defined by concentrations exceeding 100 mg/L, and extends from upgradient of the tailings management system (in the vicinity of TWN-2 and TWN-3) to beneath a portion of the tailings management system (to MW-30 and MW-31). A former stock pond located near TWN-2, referred to as the 'historical pond', that predated Mill construction and operation, is considered a primary source to the plume. Both chloroform and nitrate plumes are under remediation by pumping. Wells MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37, and TW4-39 are chloroform pumping wells; and TWN-2, TW4-22, TW4-24, and TW4-25 are nitrate pumping wells. As discussed in **Appendix B**, even in the absence of mass removal by pumping, both plumes are expected to degrade naturally within less than 200 years.

The saturated thickness of the perched water zone generally increases to the north of the site, increasing the yield of the perched zone to wells installed north of the site. Perched water is supported within the Burro Canyon Formation by the underlying, fine-grained, and bentonitic Brushy Basin Member, considered an aquiclude. **Figure 2.7-1** is a contour map showing the approximate elevation of the contact of the Burro Canyon Formation with the Brushy Basin Member, which essentially forms the base of the perched water zone at the site. Contact elevations are based on monitoring well drilling and geophysical logs and surveyed land surface elevations. The surveyed elevations of Westwater Seep and Ruin Spring, which occur at the contact between the Burro Canyon Formation and Brushy Basin Member, are also included. As indicated, the contact generally dips to the south/southwest beneath the site.

The permeability of the Dakota Sandstone and Burro Canyon Formation at the site is generally low. No significant joints or fractures within the Dakota Sandstone or Burro Canyon Formation have been documented in any wells or borings installed across the site (Knight Piesold, 1998). Any fractures observed in cores collected from site borings are typically cemented, showing no open space. The Knight-Piésold findings are consistent with the evaluation of a 1994 drilling program by HGC and with examination by HGC of drill core samples collected during installation of MW-3A, MW-23, MW-24, MW-28, MW-30, and TW4-22 in 2005, as discussed in **Appendix B**.

Based on samples collected during installation of wells MW-16 (abandoned) and MW-17 (the locations of the various monitoring wells are indicated on **Figure 2.7-1**), porosities of the Dakota Sandstone range from 13.4% to 26%, averaging 20%, and water saturations range from 3.7% to 27.2%, averaging 13.5%. The average volumetric water content is approximately 3%. MW-17 is located cross-gradient of, and MW-16 was formerly located immediately downgradient of, the tailings management system at the site. As reported in TITAN, July 1994, the permeability of the Dakota Sandstone based on packer tests in borings installed at the site ranged from 2.71E-06 centimeters per second ("cm/s") to 9.12E-04 cm/s, with a geometric average of 3.89E-05 cm/s.

The average porosity of the Burro Canyon Formation is similar to that of the Dakota Sandstone. Based on samples collected from the Burro Canyon Formation at MW-16 (abandoned), porosity ranges from 2% to 29.1%, averaging 18.3%, and water saturations of unsaturated materials range from 0.6% to 77.2%, averaging 23.4%. TITAN, July 1994, reported that the hydraulic conductivity of the Burro Canyon Formation ranges from 1.9E-07 to 1.6E-03 cm/s, with a geometric mean of 1.1 E-05 cm/s, based on the results of 12 pump/recovery tests performed in perched monitoring wells and 30 packer tests performed in borings prior to that time. Subsequent testing by HGC of existing wells and wells installed subsequent to TITAN, 1994 yields a hydraulic conductivity range of approximately 2×10^{-8} to 0.01 cm/s

In general, as discussed in **Appendix B**, the highest permeabilities and well yields are in the portion of the site immediately northeast and east (upgradient to cross gradient) of the tailings management system. A relatively continuous, higher permeability zone (associated with poorly indurated coarser-grained materials in the general area of the chloroform plume) has been inferred to exist in this portion of the site. Analysis of drawdown data collected from this zone during long-term pumping of MW-4, MW-26 (TW4-15), and TW4-19 yielded estimates of hydraulic conductivity ranging from approximately 4×10^{-5} to 1×10^{-3} cm/s. A slug test performed at TW4-4 yielded a hydraulic conductivity of approximately 1.7×10^{-3} cm/s. The decrease in perched zone permeability south to southwest of this area (south of TW4-4), based on tests at TW4-6, TW4-26, TW4-27, TW4-29 through TW4-31, and TW4-33 and TW4-34, indicates that this higher permeability zone "pinches out".

Relatively high conductivities measured at MW-11, located on the southeastern margin of the downgradient edge of tailings Cell 3, and at MW-14, located on the downgradient edge of tailings Cell 4A, of 1.4 x 10^{-3} cm/s and 7.5 x 10^{-4} cm/s, respectively, may indicate that this higher permeability zone extends beneath the southeastern portion of the tailings management system. However, based on hydraulic tests conducted south and southwest of these wells, this zone of higher permeability does not appear to exist within the saturated zone downgradient (south southwest) of the tailings management system.

Slug tests performed at groups of wells and piezometers located northeast (upgradient) of, in the immediate vicinity of, and southwest (downgradient) of the tailings management system indicate generally lower permeabilities compared with the area of the chloroform plume. The following results are based on analysis of automatically logged slug test data using the KGS solution as discussed in **Appendix B**.

Testing of TWN-series wells installed in the northeast portion of the site as part of nitrate investigation activities yielded a hydraulic conductivity range of approximately 3.6 x 10^{-7} to 0.01 cm/s with a geometric average of approximately 6 x 10^{-5} cm/s. The value of 0.014 cm/s estimated for TWN-16 is the highest measured at the site, and the value of 3.6 x 10^{-7} cm/s estimated for TWN-7 is one of the lowest measured at the site. Testing of MW-series wells MW-23 through MW-32 installed within and at the margins of the tailings management system in 2005 (and using the higher estimate for MW-23) yielded a hydraulic conductivity range of approximately 2 x 10^{-7} to 1 x 10^{-4} cm/s with a geometric average of approximately 2 x 10^{-5} cm/s. Hydraulic tests conducted at DR-series piezometers installed as part of the southwest area investigation downgradient of the tailings management system yielded hydraulic conductivities ranging from approximately 2 x 10^{-8} to 4 x 10^{-4} cm/s with a geometric average of 9.6 x 10^{-6} cm/s. The relatively low permeabilities and shallow hydraulic gradients downgradient of the tailings management system result in average perched groundwater pore velocity estimates that are among the lowest on site (approximately 0.26 feet per year (“ft/yr”) to 0.91 ft/yr.

The extensive hydraulic testing of perched zone wells at the site indicates that perched zone permeabilities are generally low with the exception of the apparently isolated zone of higher permeability associated with the chloroform plume east to northeast (cross-gradient to upgradient) of the tailings management system. The geometric average hydraulic conductivity (less than 1 x 10^{-5} cm/s) of the DR-series piezometers which cover an area nearly half the size of the total monitored area at White Mesa (excluding MW-22), is nearly identical to the geometric average hydraulic conductivity of 1.01 x 10^{-5} cm/s reported by TITAN, July 1994, and is within the range of 5 to 10 ft/yr (approximately 5 x 10^{-6} cm/s to 1 x 10^{-5} cm/s) reported by Dames and Moore, January 1978, for the (saturated) perched zone during the initial site investigation.

The generally low permeability of the perched zone limits well yields. Although sustainable yields of as much as 4 gpm have been achieved in site wells penetrating higher transmissivity zones near unlined wildlife ponds, yields are typically low (<1/2 gpm) due to the generally low permeability of the perched zone. Even site wells that yielded as much as 4 gpm during the first few months of pumping eventually saw yields drop to about 1 gpm or less. Many of the perched monitoring wells purge dry and take several hours to more than a day to recover sufficiently for groundwater samples to be collected. As noted in **Appendix B**, during the 2011 redevelopment effort, many of the perched wells went dry during surging and bailing and required several sessions on subsequent days to remove the proper volumes of water. Sufficient productivity from the perched zone can generally be obtained only in areas where the saturated thickness is greater, which is the primary reason that the perched zone has been used on a limited basis as a water supply to the north (upgradient) of the site.

2.7.1.2 Perched Groundwater Flow

Perched groundwater flow at the site is generally to the south/southwest. **Figure 2.7-2** displays the local perched groundwater elevation contours at the Mill.

As shown in **Figure 2.7-2**, perched groundwater flow across the site is generally from northeast to southwest. This general flow pattern has been consistent based on perched water level data collected beginning with the initial site investigation described in Dames and Moore, January 1978. Perched water discharges in seeps and springs located to the west, southwest, east, and southeast of the site. Perched groundwater flow is locally influenced by groundwater withdrawal via chloroform and nitrate pumping wells, and by former recharge from three unlined wildlife ponds (as discussed in **Appendix B**).

Beneath and south of the tailings management system, in the west central portion of the site, perched water flow is south-southwest to west-southwest. Flow on the western margin of the mesa south of the tailings management system is generally southerly, approximately parallel to the mesa rim (where the Burro Canyon Formation is terminated by erosion). On the eastern side of the site perched water flow is also generally southerly to southwesterly.

Perched water flow beneath and downgradient of the millsite and tailings management system is influenced by perched water discharge points Westwater Seep, located west to west-southwest of the tailings management system, and Ruin Spring, located south-southwest of the tailings management system. As noted above, the overall southwesterly flow pattern is locally influenced by former seepage from the unlined wildlife ponds. Because of relict mounding near the northern wildlife ponds, flow direction ranges from locally westerly (west of the ponds) to locally easterly (east of the ponds).

Perched water flowing beneath the tailings management system eventually discharges to Westwater Seep, the closest discharge point, or to Ruin Spring, located approximately 9,600 feet to the south-southwest, as shown in **Figures 2.7-2 and 2.7-3**. Ruin Spring is the primary discharge point and is the only named spring appearing on United States Geological Survey ("USGS") topographic maps in the vicinity of the site. Any flow that does not discharge in seeps or springs presumably exits as underflow to the southeast of Ruin Spring, along the southwest extending lobe of White Mesa located between Ruin Spring and Corral Springs.

2.7.1.3 Perched Zone Hydrogeology (Beneath and Down-gradient of the Tailings Management System)

As of the 4th Quarter, 2017, depths to perched water range from approximately 35 feet below top of casing ("btoc") northeast of the tailings management system (at TWN-2) to approximately 115 feet btoc at the southwestern margin of tailings Cell 3. In the vicinity of the tailings management system at the site perched water was encountered at depths of approximately 63 to 115 feet btoc (**Figure 2.7-4**).

Depths to perched groundwater near tailings Cell 2 vary from approximately 63 feet btoc near the northeast (upgradient) corner of the cell to approximately 112 feet btoc at the northwest corner of the cell. Depths to water near tailings Cell 3 vary from approximately 69 feet btoc near the northeast (upgradient) corner of the cell to approximately 115 feet btoc at the southwest (downgradient) corner of the cell. Depths to water near Cells 4A and 4B vary from approximately 79 feet btoc near the northeast (upgradient) corner of Cell 4A to approximately 112 feet btoc along the western margin of Cell 4B. The average depth to water near Cell 2 is approximately 77 feet btoc; near Cell 3 approximately 92 feet btoc; and near Cells 4A and 4B approximately 102 feet btoc. Because the cells are installed a maximum of approximately 25 feet below grade, the average depth to perched water from the base of Cell 2 is approximately 52 feet; beneath Cell 3 approximately 67 feet; and beneath Cells 4A and 4B approximately 77 feet.

The saturated thicknesses of the perched zone as of the 4th Quarter, 2017 range from approximately 80 feet at MW-19 near the northern wildlife ponds to less than 5 feet in the southwest portion of the site, downgradient of the tailings management system (**Figure 2.7-5**). A saturated thickness of approximately 2 feet occurs in well MW-34 along the south dike of Cell 4B, and the perched zone has been consistently dry at MW-33 located at the southwest corner of Cell 4B, and at MW-21 located south-southwest of Cell 4B. Abandoned well MW-16, formerly located beneath Cell 4B, was also consistently dry. MW-21, MW-33 and abandoned well MW-16 are all located on a structural high in the top of Brushy Basin Member surface (**Figure 2.7-1**). As discussed in detail within **Appendix B**, perched groundwater flow and saturated thicknesses within the southwest portion of the site are influenced by this structural high.

Perched zone hydraulic gradients as of the 4th Quarter, 2017 range from a maximum of nearly 0.09 feet per foot (“ft/ft”) east of tailings Cell 2 (within the chloroform plume, between TW4-10 and TW4-11) to approximately 0.002 ft/ft in the northeast corner of the site (between TWN-19 and TWN-16). Hydraulic gradients in the southwest portion of the site are typically close to 0.01 ft/ft, but the gradient is less than 0.005 ft/ft to the west-southwest of Cell 4B, between Cell 4B and DR-8. The overall average site hydraulic gradient, between TWN-19 in the extreme northeast to Ruin Spring in the extreme southwest, is approximately 0.011 ft/ft.

As discussed in Section 7.1, hydraulic tests conducted at DR-series piezometers installed as part of the southwest area investigation downgradient of the tailings management system yielded hydraulic conductivities ranging from approximately 2×10^{-8} to 4×10^{-4} cm/s with a geometric average of 9.6×10^{-6} cm/s. The relatively low permeabilities and shallow hydraulic gradients downgradient of the tailings management system result in average perched groundwater pore velocity estimates that are among the lowest on site.

2.7.1.4 Groundwater Quality

2.7.1.4.1 Entrada/Navajo Aquifer

The Entrada and Navajo Sandstones are prolific aquifers beneath and in the vicinity of the site. Water wells at the site are screened in both of these units and, therefore, for the purposes of this discussion, they will be treated as a single aquifer. Water in the Entrada/Navajo Aquifer is under artesian pressure, rising 800 to 900 feet above the top of the Entrada's contact with the overlying Summervillle Formation; static water levels are 390 to 500 feet below ground surface.

Within the region, this aquifer is capable of yielding domestic quality water at rates of 150 to 225 gpm and, for that reason, it serves as a secondary source of water for the Mill. Additionally, two domestic water supply wells drawing from the Entrada/Navajo Aquifer are located 4.5 miles southeast of the Mill site on the Ute Mountain Ute Reservation. Although the water quality and productivity of the Navajo/Entrada aquifer are generally good, the depth of the aquifer (>1,000 feet bls) makes access difficult.

Table 2.7-1 is a tabulation of groundwater quality of the Navajo Sandstone aquifer as reported in the FES and subsequent sampling. The TDS range from 244 to 1,110 mg/l in three samples taken over a period from January 27, 1977, to May 4, 1977. High iron (0.057 mg/l) concentrations are found in the Navajo Sandstone. Because the Navajo Sandstone aquifer is isolated from the perched groundwater zone by approximately 1,000 to 1,100 feet of materials having a low average vertical permeability, sampling of the Navajo Sandstone is not required under the Mill's previous NRC Point of Compliance monitoring program or under the Mill's GWDP. However, samples were taken at two other deep aquifer wells (#2 and #5) on site (see **Figure 2.7-6** for the locations of these wells) on June 1, 1999, and June 8, 1999, respectively, and the results are included in **Table 2.7-1**.

Table 2.7- 1 Groundwater Quality in the Vicinity of the Mill

Parameter	FES, Test Well (G2R) (1/27/77 - 3/23/78[1])	Well #2 6/01/99[1]	Well #5 6/08/99[1]
Field Conductivity (µmhos/cm)	310 to 400		
Field pH	6.9 to 7.6		
Temperature (ºC)	11 to 22		
Estimated Flow m/hr (gpm)	109(20)		
pH	7.9 to 8.16		
Determination, mg/l			
TDS (@180ºC)	216 to 1110		
Redox Potential	211 to 220		
Alkalinity (as $CaCOS_3$)	180 to 224		
Hardness, total (as $CaCO_3$)	177 to 208		
Bicarbonate		226	214
Carbonate (as CO_3)	0.0	<1.0	<1.0

Parameter	FES, Test Well (G2R) (1/27/77 - 3/23/78[1])	Well #2 6/01/99[1]	Well #5 6/08/99[1]
Aluminum		0.003	0.058
Aluminum, dissolved	<0.1		
Ammonia (as N)	0.0 to 0.16	<0.05	<0.05
Antimony		<0.001	<0.001
Arsenic, total	.007 to 0.014	0.018	<0.001
Barium, total	0.0 to 0.15	0.119	0.005
Beryllium		<0.001	<0.001
Boron, total	<0.1 to 0.11		
Cadmium, total	<0.005 to 0.0	<0.001	0.018
Calcium		50.6	39.8
Calcium, dissolved	51 to 112		
Chloride	0.0 to 50	<1.0	2.3
Sodium		7.3	9.8
Sodium, dissolved	5.3 to 23		
Silver		<0.001	<0.001
Silver, dissolved	<0.002 to 0.0		
Sulfate		28.8	23.6
Sulfate, dissolved (as SO_4)	17 to 83		
Vanadium		0.003	0.003
Vanadium, dissolved	<.002 to 0.16		
Manganese		0.011	0.032
Manganese, dissolved	0.03 to 0.020		
Chromium, total	0.02 to 0.0	0.005	0.005
Copper, total	0.005 to 0.0	0.002	0.086
Fluoride		0.18	0.18
Fluoride, dissolved	0.1 to 0.22		
Iron, total	0.35 to 2.1	0.43	0.20
Iron, dissolved	0.30 to 2.3		
Lead, total	0.02 - 0.0	<0.001	0.018
Magnesium		20.4	21.3
Magnesium, dissolved	15 to 21		
Mercury, total	<.00002 to 0.0	<0.001	<0.001
Molybdenum		0.001	<0.001
Molybdenum, dissolved	0.004 to 0.010		
Nickel		<0.001	0.004
Nitrate + Nitrate as N		<0.10	<0.10
Nitrate (as N)	<.05 to 0.12		

Parameter	FES, Test Well (G2R) (1/27/77 - 3/23/78[1])	Well #2 6/01/99[1]	Well #5 6/08/99[1]
Phosphorus, total (as P)	<0.01 to 0.03		
Potassium		3.1	3.3
Potassium, dissolved	2.4 to 3.2		
Selenium		<0.001	<0.001
Selenium, dissolved	<.005 to 0.0		
Silica, dissolved (as SiO_2)	5.8 to 12		
Strontium, total (as U)	0.5 to 0.67		
Thallium		<0.001	<0.001
Uranium, total (as U)	<.002 to 0.16	0.0007	0.0042
Uranium, dissolved (as U)	<.002 to 0.031		
Zinc		0.010	0.126
Zinc, dissolved	0.007 to 0.39		
Total Organic Carbon	1.1 to 16		
Chemical Oxygen Demand	<1 to 66		
Oil and Grease	1		
Total Suspended Solids	6 to 1940	<1.0	10.4
Turbidity		5.56	19.1
Determination (pCi/l)			
Gross Alpha			<1.0
Gross Alpha ± precision	1.6±1.3 to 10.2±2.6		
Gross Beta			<2.0
Gross Beta ± precision	8±8 to 73±19		
Radium 226 ± precision			0.3±0.2
Radium 228			<1.0
Ra – 226 ± precision	0.1±.3 to 0.6±0.4		
Th – 230 ± precision	0.1±0.4 to 0.7±2.7		
Pb – 210 ± precision	0.0±4.0 to 1.0±2.0		
Po – 210 ± precision	0.0±0.3 to 0.0±0.8		

Source: Adapted from FES Table 2.25 with additional Mill sampling data. [1], Zero values (0.0) are below detection limits.

2.7.1.4.2 Perched Groundwater Zone

Perched groundwater in the Dakota/Burro Canyon Formation is used on a limited basis to the north (upgradient) of the site because it is more easily accessible, and because the saturated thickness of the perched zone generally increases to the north of the site, as discussed in **Appendix B**. The quality of the Burro Canyon perched water beneath and downgradient from the site is generally poor and extremely variable. The concentrations of TDS measured in water sampled from upgradient and downgradient wells range between approximately 1,100 to 7,900 mg/l. Sulfate concentrations measured in three upgradient wells varied between 670 and 1,740 mg/l (Titan, July 1994). The perched groundwater, therefore, is used primarily for stock watering and irrigation.

At the time of renewal of the Mill license by the NRC in March, 1997 and up until issuance of the Mill's GWDP in March 2005, the Mill implemented a groundwater detection monitoring program to ensure compliance to 10 CFR Part 40, Appendix A, in accordance with the provisions of License condition 11.3A. The detection monitoring program was in accordance with the report titled, *Points of Compliance, White Mesa Uranium Mill*, submitted by letter to the NRC dated October 5, 1994 (Titan, September 1994). Under that program, the Mill sampled monitoring wells MW-5, MW-l1, MW-12, MW-14, MW-15 and MW-17, on a quarterly basis. Samples were analyzed for chloride, potassium, nickel and uranium, and the results of such sampling were included in the Mill's Semi-Annual Effluent Monitoring Reports that were filed with the NRC up until August 2004 and with the DWMRC subsequent thereto.

Prior to 1997, commencing in 1979, the Mill monitored up to 20 constituents in up to 13 wells. That program was changed to the Points of Compliance Program in 1997 because:

- the Mill and tailings system had produced no impacts to the perched zone or deep aquifer; and
- the most dependable indicators of water quality and potential cell failure were considered to be chloride, nickel, potassium and natural uranium.

2.7.2 Surface Water

A description of the location, size, shape, and other hydrologic characteristics of water bodies in the environs of the Mill site was included in Section 2.6.2 of the 1978 ER and Section 2.6.1 of the FES. An updated discussion on surface water hydrology was also most recently included in Section 1.4 of the Reclamation Plan, Rev. 5.1B.

2.8 Climate and Meteorology

There have been no significant changes of observed meteorological conditions at the site that have occurred since the 1978 ER. Meteorological information for the site was most recently updated in Section 1.1 of the Reclamation Plan, Rev. 5.1B.
On-site meteorological monitoring at the Mill was initiated in 1997 and continues today. The diagrams included in **Appendix C** show the annual wind rose for the site for each of 2013 through 2017, which is the most recent full year of compiled meteorological data.
The updated MILDOS evaluation described in Section 5.2 is based on this most recent five-year period (2013-2017) of on-site meteorological data.

2.9 Ecology

A description of the biota in the vicinity of the Mill site, including both terrestrial and aquatic ecology, was provided in Section 2.8 of the 1978 ER and Section 2.9 of the FES. An updated description of biota (as reproduced from the 1978 ER), including the results of the NRC's environmental analysis in the 2002 EA, was also most recently included in Section 1.7 of the Reclamation Plan, Rev. 5.1B.

2.10 Background Radiological and Non-Radiological Characteristics

A discussion of natural background radiation levels and the results of measurements of concentrations of radioactive materials occurring in biota, soil, air, surface water and ground water were provided in Section 2.9 of the 1978 ER and Section 2.10 of the FES. Background radiological and non-radiological effects were also evaluated, updated and reported extensively in the recently-approved License renewal and accompanying 2007 ER.

3.0 Design of Cells 5A and 5B

3.1 Cell Design

As previously discussed in the Introduction section above, the initial environmental analyses and the License contemplated a six-cell impoundment system (see Section 3.2.4.7 of the FES). These cells are Cell 1-I (now referred to as Cell 1), Cell 1-E, which has not been constructed, existing Cells 2, 3 and 4 (comprised of two separate 40-acre cells) and Cell 5, which will also be comprised of two separate 40-acre cells (Cells 5A and 5B). Cells 5A and 5B have therefore been specifically contemplated and included in the License (see Figure 3.4 of the FES). As depicted in this figure, the size and location of the six-cell impoundment system (Cells 1, 2, 3, 4, 5 and 1-E) is consistent with the original conceptual design and licensing of the Mill.

The design features for Cells 5A and 5B are included in the *Cells 5A & 5B Design Report, White Mesa Mill, Blanding, Utah*, prepared by Geosyntec Consultants, which is included in **Appendix D**. For Cells 5A and 5B, two liner designs are being proposed in this amendment request with one option being identical to the liner design and underlying ground conditions for Cells 4A and 4B. The second option provides for three (3) 60 mil HDPE liners with geonet leak detection layers between the primary and secondary liners. The second option provides equal protection to the environment while offering efficiencies in the installation process, and also offers an additional leak detection layer. The decision on which liner design to use will be made by Energy Fuels prior to the start of cell construction. See **Appendix D** for specific liner system details and liner characteristics.

3.2 Liner Compatibility

In order to evaluate potential liner compatibility and degradation issues, an evaluation was completed by Tischler Consulting Services ("TCS") and summarized in a *Technical Memorandum* dated July 11, 2018 (see **Appendix E**). This evaluation determined that the HDPE liner material to be used in either option, as described above, is expected to be sufficient for all the components of tailings solutions and solids, under all anticipated conditions. Additional information on the compatibility of the liner system is included in Section 3.4 of the Design Report in **Appendix D**.

3.3 Modification of Restricted Area Boundary

The construction and operation of Cells 5A and 5B will require modification to the southern boundary (fence line) of the existing restricted area boundary. The proposed (revised) restricted area boundary for Cells 5A and 5B is shown on Figure 1 – Plan View of Reclamation Features in **Appendix H**.

4.0 Environmental Effects Related to Construction of Cells 5A and 5B

The environmental effects of Cells 5A and 5B construction consist of surface disturbance activities and the potential avoidance of, or data recovery programs for, cultural resources. As described in License Condition 9.7, all development will be completed in compliance with the National Historic Preservation Act (or amended) and its implementing regulations, and the Archaeological Resources Protection Act (as amended) and its implementing regulations.

As described in Section 2.4 above, an archaeological survey is being performed on the surface area that will be impacted by the construction of Cells 5A and 5B, as required by License Condition 9.7. The results of this survey will be included in **Appendix A** and summarized in a revised Report. The revised Report will include a description of any archaeological sites identified, their status and a description of proposed mitigations as appropriate.

5.0 Environmental Effects Related to Operation of Cells 5A and 5B

The environmental effects of Cells 5A and 5B operation consist of the impact, if any, on groundwater beneath the cells and the radiological effects on human beings. These evaluations are discussed in the pertinent subsections below.

5.1 Groundwater Pathway Impact

In order to evaluate the environmental considerations associated with potential hydrogeological impacts, an evaluation was completed by HGC and summarized in the report titled *Site Hydrogeology Estimation Of Groundwater Travel Times and Recommended Additional Monitoring Wells For Proposed Cells 5A and 5B White Mesa Uranium Mill Site Near Blanding, Utah,* July 11, 2018 (see **Appendix B**). This evaluation finds that the travel time for any water potentially exiting the existing tailings management system, including proposed Cells 5A and 5B, that may migrate to the perched water zone and then to the point(s) of perched zone discharge is very long, far exceeding the time period of milling operations and closure of the tailings management system when little free liquid is available for infiltration through the cell liner system.

Specifically, based on fourth quarter 2017 water levels, the estimated time for perched groundwater to travel from the western margin of the existing tailings management system to Westwater Seep along the shortest flow path is approximately 3,015 years; and the estimated time for perched groundwater to travel from the southern margin of the tailings management system to Ruin Spring along the shortest flow path is approximately 10,775 years. The time for perched groundwater to travel from the western margin of the tailings management system to DR-8, located on the mesa rim above Cottonwood Seep was estimated as approximately 15,860 years. Although, as detailed in **Appendix B**, Cottonwood Seep does not receive water from the perched water system, the travel time to the edge of the perched water system near DR-8 was estimated in case an as yet unidentified pathway should exist between the perched water system and Cottonwood Seep.

Because proposed Cells 5A and 5B would extend the tailings management system farther to the south-southwest, and thus closer to discharge point Ruin Spring, the time for perched groundwater to travel from the downgradient (southern) margin of the proposed new cells would be smaller. As discussed in **Appendix B**, using estimated fourth quarter, 2017 perched groundwater elevations at the downgradient margin of proposed Cells 5A and 5B, the estimated time for groundwater to migrate from the downgradient margin of proposed Cells 5A and 5B along the shortest flow path to Ruin Spring is approximately 8,870 years.

These travel time estimates are conservatively small with respect to any conservative solute hypothetically migrating from the base of the tailings management system to either Westwater Seep, Ruin Spring, or the mesa rim above Cottonwood Seep because 1) the estimates do not consider the travel times through the cell liners, which may be significant especially considering the state of the art liner systems within Cells 4A and 4B (which are similar to those planned for Cells 5A and 5B); 2) the estimates do not account for vadose zone travel times; and 3) the estimates assume that the solute originated from the downgradient edge of the tailings management system rather than from a location within the interior footprint of the system. In addition, most dissolved constituents within the tailings management system solutions would be retarded with respect to subsurface flow and would take longer to migrate through the vadose zone and along a perched water flow path than would a conservative solute.

Travel times through pond liners has been evaluated extensively by MWH Americas, Inc. in their report *Infiltration and Contaminant Transport Modeling Report, Mill Site, Blanding Utah, November, 2007,* (MWH, 2007) incorporated here by reference. The infiltration modeling effort revealed that the construction design for Cells 5A and 5B will meet the "Closed Cell Performance Requirements" of the GWDP at Part I.D.6. More specifically, MWH concluded that the approved reclamation plan for the cells will meet the following regulatory requirements for a period of not less than 200 years:

a) Minimize infiltration of precipitation or other surface water into the tailings, including but not limited to the radon barrier;

b) Prevent the accumulation of leachate head within the tailings waste layer that could rise above or over-top the maximum flexible membrane liner elevation internal to any disposal cell, i.e. create a "bathtub" effect; and,

c) Ensure that groundwater quality at the compliance monitoring wells does not exceed Ground Water Quality Standards or Ground Water Compliance Limits specified in Part 1.C.l and Table 2 of the GWDP.

5.2 Radiological Impact [RESERVED]

This section is reserved for discussion of the updated dose assessment associated with the proposed development of new tailings Cells 5A and 5B. Upon completion, the dose assessment will be included in **Appendix F** and summarized in a revised Report.

6.0 Effluent and Environmental Monitoring Programs

Proposed new ground water monitoring wells and changes to operational environmental monitoring programs associated with the construction and operation of Cells 5A and 5B are discussed in the pertinent subsections below.

6.1 Proposed Additional Groundwater Monitoring

In order to monitor the performance of proposed Cells 5A and 5B, and consistent with United States Environmental Protection Agency ("EPA") guidance (USEPA, 1992), it was concluded by HGC that additional wells will be needed to monitor the cell's performance at the downgradient edges of the cells. This is in addition to the many wells already incorporated into the GWDP for the facility. Accordingly, five additional wells (MW-41 through MW-45) are proposed, one on the west dike of proposed Cell 5A; one at the southwest corner of proposed Cell 5A; and three between the southwest corner of proposed Cell 5A and the southeast corner of proposed Cell 5B (see Figure 38 of **Appendix B**). Existing well MW-17 will function as the up- to cross-gradient well along the east dike of proposed Cell 5B. These installations will conservatively maintain the approximate existing spacing as defined by the wells along the downgradient edge of Cells 4A and 4B.

Cell 5A and associated groundwater monitoring wells are to be installed first. Therefore, proposed groundwater monitoring wells MW-41 through MW-44 would be installed as part of the construction of Cell 5A, and MW-45 would be installed later as part of the construction of Cell 5B. As discussed in **Appendix B**, the spacing of the proposed wells (approximately 750 ft) is conservative with regard to reliable detection of potential future impacts to groundwater that may arise from any potential future seepage from the proposed cells, and proposed wells MW-41 through MW-44 are considered adequate to monitor proposed Cell 5A even if the construction of Cell 5B is delayed indefinitely. Although five new wells at a conservative spacing are proposed, the advanced design and leak detection systems to be incorporated in the construction of the proposed cells makes it highly unlikely that any potential future seepage could bypass the leak detection systems to an extent that could impact groundwater considering that the cell design will include a triple liner and one or more leak detection systems installed between the liners. Furthermore, as detailed in **Appendix B**, the vertical heterogeneity encountered within the Dakota Sandstone and Burro Canyon Formation beneath proposed Cells 5A and 5B is expected to enhance the likelihood for timely detection of any groundwater impacts from any potential future seepage originating from the cells.

6.2 Proposed Additional Operational Environmental Monitoring

As an element of evaluating potential off-site impacts related to the construction and operation of Cells 5A and 5B, Energy Fuels commissioned a review of its operational environmental monitoring programs in order to determine what, if any, additional monitoring would be needed to accommodate the operation of Cells 5A and 5B. The review was conducted by Arcadis Canada Inc. ("ARCADIS") and summarized in the report titled *Review of Environmental Radiological Monitoring Program for the White Mesa Uranium Mill*, July 11 2018, which is included as **Appendix G** to this Report. ARCADIS concluded that the existing monitoring programs are satisfactory, with the exception that, prior to the construction and operation of Cells 5A and 5B, the current environmental monitoring program be modified as follows:

- Relocate environmental monitoring station BHV-4 to the south-southwest of the new cells, to cover the winds flowing predominantly from the north-northeast of the Mill.

The proposed new location of BHV-4 is presented in **Appendix G**.

7.0 Accidents

The following is a description of each type of radioactive materials and other accident involving proposed Cells 5A and 5B, which could potentially occur at the Mill site that could require an emergency response. The following paragraphs are excerpted from the Mill's draft Emergency Response Plan Revision 4.0, dated February 8, 2018 (the "Emergency Response Plan").

7.1 Tornado

Although this is highly unlikely, a tornado could occur at the Mill. A severe tornado could cause buildings and other structures to collapse, chemical or gas releases, major fires as well as general panic. The environmental impacts from a tornado could be the transport of tailings solids and liquids, ores or product from the Mill area into the environment. This dispersed material would contain some uranium, radium, and thorium. An increase in background radiation could result, and, if sufficient quantities are detected and isolated, they would be cleaned up. However, NRC staff have concluded in *A Regulatory Analysis on Emergency Preparedness for Fuel Cycle and Other Radioactive Materials Licensees*, S. A. McGuire, January 1988 ("NUREG-1140") that while tornadoes could release a large amount of radioactive material, they spread the material so greatly that resulting doses are very small. As a result, tornadoes are not discussed further in NUREG-1140 and are not considered to be a significant radiological risk at uranium mills.

However, to the extent that a tornado has caused or is likely to result in an ammonia leak or propane release, an SX building fire or a breach of the Mill's tailings cells, it would be classified as a Site Area Emergency or Alert, as defined in the Emergency Response Plan, depending on which one of those other accidents resulted from the tornado. All other tornadoes would be classified as On-Site Emergencies, as defined in the Emergency Response Plan. See Section 4 of the Emergency Response Plan for the significance of these classifications.

In the event of a major tornado, the procedures outlined in Appendix G to the Emergency Response Plan would be followed.

7.2 Major Earthquake

Although this is highly unlikely, an earthquake could occur at the Mill. A severe earthquake could cause buildings and other structures to collapse, chemical and/or gas releases, major fires as well as general panic. NRC staff concluded in NUREG-1140 that earthquakes were not identified as leading to significant releases of radionuclides unless they were followed by a fire.

To the extent that an earthquake has caused or is likely to result in an ammonia leak or propane release, an SX building fire or a breach of the Mill's tailings cells, it would be classified as a Site Area Emergency or Alert, as defined in the Emergency Response Plan, depending on which one of those accidents resulted from the earthquake. All other major earthquakes would be classified as On-Site Emergencies, as defined in the Emergency Response Plan. See Section 4 of the Emergency Response Plan, for the significance of those classifications.

In the event of a major earthquake the procedures outlined in Appendix G to the Emergency Response Plan would be followed.

7.3 Tailings Accidents

7.3.1 Flood Water Breaching of Retention System

In general, flood water breaching of tailings embankments presents one of the greatest dangers for the sudden release of tailings solids and impounded water. The tailings cells are designed with sufficient freeboard (at least three feet) to withstand back-to-back 100-year storm events or 40% of the probable maximum flood (PMF) followed by the 100-year storm event. The flood design is equivalent to 15 inches of rainfall. In addition, the tailings dikes were designed in accordance with NRC regulations and allow a sufficient margin of safety even in the event of an earthquake.

The possibility of floods in Westwater Creek, Corral Creek, or Cottonwood Wash causing damage to the tailings retention facility is extremely remote. This is due to the approximately 200 foot elevation difference between the streambeds of the creeks and the toe of the tailings dikes.

Flood water breaching a tailings embankment is classified as an On-Site Emergency, as defined in the Emergency Response Plan, because it is unlikely that any releases to the environment would leave the Mill property, and in the event that any contamination were to leave the property, it is unlikely that the release would be expected to require a response by an offsite response organization to protect persons offsite. See Section 4 of the Emergency Response Plan for the significance of that classification.

In the event of a Flood Water Breach of the tailings retention system, the procedures in Appendix H of the Emergency Response Plan would be followed.

7.3.2 Structural Failure of Tailings Dikes

All tailings dikes have been designed with an ample margin of safety as per NRC regulations. This has included design calculations showing dike stability even when the dike is saturated with moisture during a seismic event, the most severe failure mode. In addition, the tailings discharge system is checked at least once per shift during operation, or once per day during Mill standby.

NRC staff concluded in NUREG-1140 that tailings pond failures also release a large quantity of material. However, NRC staff concluded that rapid emergency response is not needed to avoid doses exceeding protection action guides because dose rates at a spill site are very low. NRC staff concluded that an appropriate response would be to monitor drinking water, especially for radium-226, to be sure that drinking water standards are met. Gamma monitoring of the ground would also be appropriate to determine where the tailings have been deposited. However, NRC staff concluded that ground contamination would present little immediate hazard to the public because the gamma dose rates would be low. Gamma dose rates in contact with tailings should be less than 0.1 mR/hr. A clean-up of the spilled tailings would be expected, but this could be done effectively without pre-existing emergency preparedness.

Although the discharge from a dike failure would soon cross the restricted area boundary, the flow path would be over three miles in length before leaving the Mill property. In the event of a dam failure, large operating equipment would be mobilized to construct temporary earthen dikes or berms downgradient of the failed dike. In addition, the Director, MSHA, and the State of Utah, Department of Natural Resources, Division of Dam Safety would be notified. The contamination from such an event would be cleaned up and returned to the tailings area.

A tailings dam failure is classified as an On-Site Emergency, as defined in the Emergency Response Plan, because it would be unlikely that any releases to the environment would leave the Mill property, and in the event that any contamination were to leave the property, it would be unlikely that the release would be expected to require a response by an offsite response organization to protect persons offsite. See Section 4 of the Emergency Response Plan, for the significance of that classification.

In the event of a tailings dam failure the procedures outlined in Appendix H of the Emergency Response Plan would be followed.

7.3.3 Seismic Damage to Transport System

In the event of a seismic rupture of a tailings slurry pipeline, the released slurry would be contained in the tailings cells regardless of the quantity released. The tailings retention system pipe is in the same drainage basin as the retention system. Any tailings slurry released by a pipe rupture, no matter what the cause, would flow downhill where it would be impounded inside a tailings cell.

If a break occurred, the pumping system would be shut off, personnel removed from the immediate area, and the Director notified. The break would be repaired and the affected area cleaned up in the safest and most expeditious manner. The advice and direction of the Director would be sought and heeded throughout the episode.

A seismic rupture in the tailings slurry pipeline would be classified as an On-Site Emergency, as defined in the Emergency Response Plan. See Section 4 of the Emergency Response Plan for the significance of that classification.

In the event of a rupture in the tailings slurry pipeline the procedures outlined in Appendix H of the Emergency Response Plan would be followed.

7.4 Terrorist and/or Bomb Threat

In the event that any person should receive a threat of a bomb, the procedure set out in Appendix I of the Emergency Response Plan would be followed.

Because of the unknown nature of the risk, a terrorist/bomb threat would be classified as an Alert, as defined in the Emergency Response Plan. See Section 4 of the Emergency Response Plan for the significance of that classification.

In the event of a terrorist/bomb threat, the procedures in Appendix I of the Emergency Response Plan would be followed.

8.0 Cost and Benefits

There have been no significant changes to the costs associated with the Mill since the License renewal in 2018. While there will a change to the currently disturbed area as a result of the Cells 5A and 5B construction, these additional cells were contemplated, described and assessed, as a critical component of the initial FES and attendant licensing of the facility. As indicated in Section 3 of the 2007 ER accompanying the renewal application, the Mill has operated in accordance with applicable regulatory standards and ALARA goals since its inception, and updated MILDOS modeling indicates that the Mill is capable of continuing to operate well within those standards and goals. There have been no significant demographic changes that have impacted the ability of the Mill to operate in a manner that will result in no significant impacts to public health, safety or the environment. It is expected that continued Mill operations will continue to draw primarily upon the existing work force in the area with little impact on social services.

The Mill is the only licensed, operating conventional uranium mill in the United States and is one of the largest private employers in San Juan County, Utah. The benefits of the Mill will continue to be the provision of well-paying jobs to workers in San Juan County and the support of the tax base in that County. Moreover, as the only operating uranium mill on the western slope of the Rocky Mountains, the Mill is relied upon by the large number of independent uranium miners in San Juan County and the Colorado Plateau as the only feasible uranium mill for their uranium ores. The need for continued licensing of the Mill is crucial for such miners and for the uranium industry in the United States as a whole.

In sum, the costs associated with the operation of the Mill have not changed significantly, but the benefits have become more evident over time as the number of uranium mills has dwindled and the demand for uranium milling services from local miners and the industry as a whole has increased.

9.0 Decommissioning, Reclamation and Long Term Impacts

The Mill currently has an approved Reclamation Plan for Cells 1, 2, 3, 4A and 4B. This is Revision 5.1B of the Reclamation Plan dated February 2018 that was approved by the DWMRC on February 16, 2018. In addition, the financial surety arrangements, as well as the provisions in the Mill's GWDP that relate to final reclamation of the site, are described in detail in Section 8 of the February 2007 License Renewal Application. The current surety for the Mill, including surety for the reclamation of Cells 1, 2, 3, 4A and 4B, is based on the application of approved provisions of Reclamation Plan, Revision 5.1B.

The long term impacts, including decommissioning, decontamination, and reclamation impacts associated with activities conducted pursuant to the License have been considered in detail by the NRC and UDEQ in previous analyses, including the FES, the 2007 EA (UDEQ, 2007) and the recently-approved Reclamation Plan, Revision 5.1B. The construction of Cells 5A and 5B will not result in any changes to operations at the Mill that would impact decommissioning, decontamination or reclamation aspects associated with Mill activities, or the previous analyses of such aspects. As described in a letter dated June 15, 2018, from Stantec Consulting Services Inc. (see **Appendix H**), Cells 5A and 5B will be reclaimed in a similar fashion to Cells 4A and 4B with the final reclamation cover being the same as the final reclamation cover for these cells.

At this time, Energy Fuels does not anticipate the construction of Cells 5A and 5B immediately upon the Director’s approval of the License and GWDP amendments; however, authorization is being sought in advance to allow the Mill to respond to expected improvements in uranium market conditions. As a result, as there are no immediate reclamation or financial surety implications associated with the authorization of Cells 5A and 5B, Energy Fuels has prepared an addendum (as Attachment F) to Reclamation Plan, Revision 5.1C (see **Appendix H** of this Report), to extend the currently approved provisions of the Reclamation Plan to Cells 5A and 5B. This addendum should be considered part of the Reclamation Plan and the redline pages considered replacement pages to the Reclamation Plan. Prior to commencement of construction of Cell 5A or 5B, these changes may be incorporated into a re-stated Reclamation Plan, and the financial surety will be adjusted accordingly at that time.

10.0 Alternatives

The action under consideration is the construction of two already contemplated tailings cells (Cell 5A and 5B) in order to accommodate continued operation of the Mill. The alternatives available to the Director are to:

- amend the License to include the construction of Cells 5A and 5B with its existing terms and conditions;

- amend the License to include the construction of Cells 5A and 5B with such additional conditions as are considered necessary or appropriate to protect public health, safety and the environment; or

- deny the addition of Cells 5A and 5B construction into the License.

As demonstrated in this Report, the environmental impacts associated with construction and operation of Cells 5A and 5B do not warrant either limiting the Mill's future operations or denying the construction approval request. As there are no significant public health, safety or environmental impacts associated with the construction of Cells 5A and 5B, Energy Fuels asserts that alternatives with equal or greater impacts need not be evaluated, and alternative a) is the appropriate alternative for selection.

10.1 Issuance of Amendment for Cells 5A and 5B

The Mill is the only licensed, operating uranium mill in the United States and the only operational uranium mill on the western slope of the Rocky Mountains. As a result, the Mill is the only currently available opportunity for production of uranium from conventionally mined ore in San Juan County and in the four corners area of the United States, including mines owned by Energy Fuels and others in Colorado, Arizona, New Mexico and Utah. The Mill therefore provides a benefit to the regional community and to the uranium industry as a whole in the United States. The construction of Cells 5A and 5B as proposed would allow the Mill to continue to provide these benefits for many more years and as contemplated in the original licensing effort.

As was demonstrated in Section 3 of the 2008 ER in support of construction of tailings Cell 4B, the Mill's equipment, facilities and procedures are adequate to minimize impacts to public health, safety and the environment. More importantly, UDEQ has already approved the construction of Cells 4A and 4B. Depending on the liner design used for Cells 5A and 5B, the liner system will be identical and/or equivalent to Cells 4A and 4B with regard to its robust and state-of-the-art protective design features. Also, the Mill has operated since its inception in compliance with all applicable regulatory standards and ALARA goals and is capable of continuing to operate in compliance with such standards and goals.

In addition to the License, the Mill has been issued the renewed GWDP in 2018, which provides additional protection for public health and the environment, including a rigorous groundwater monitoring program to monitor and assess the performance of tailings cells associated with the facility. The Mill has demonstrate that it is capable of continuing to operate in a manner that satisfies all regulatory standards and ALARA goals under the existing terms and conditions of the License and GWDP. This amendment application has assessed and proposed additional monitoring necessary to accommodate newly constructed Cells 5A and 5B. Based upon these factors and considerations, Energy Fuels asserts that there is no need to add any additional conditions to the License in order to protect public health, safety or the environment as a result of the construction of Cells 5A and 5B.

10.2 No Action Alternative

A "no action" alternative would result in the amendment request being denied and the immediately available processing opportunities for mined uranium ore being limited in the short term, potentially impacting independent uranium miners in the area and lessening the United States' capability to respond to the need for uranium for nuclear power generation.

Denying the request for construction of Cells 5A and 5B will limit the ability of the Mill to respond to increased mining activity that would result from expected improvements in market conditions, in the near term, and eliminate its ability to operate over the longer term. In addition, the construction of Cells 5A and 5B will provide the opportunity for regular employment in an economically depressed area of the United States. A large percentage of the workers at the Mill are Native American, and this employment opportunity has significant direct impact in the local Native American community. In addition to the direct hiring of employees at the Mill, local miners and other western United States mining companies require access to an operating uranium mill. The inability of these mining entities to gain access to local milling services will prevent the mining industry from responding to any improvements in uranium market conditions. Thus, secondary local economies will not enjoy the benefit of renewed mining income, and national demand for uranium will continue to be reliant primarily on foreign supplies of uranium for nuclear fuel. In order to respond to any improvements in uranium market conditions, conventional mining companies will be forced to license and construct new uranium milling facilities to engage in conventional ore processing, directly in opposition to the objective of non-proliferation of new uranium mill tailings disposal facilities embodied by 10 CFR Part 40 Appendix A, Criterion 2.

As has been demonstrated by the forgoing assessments, the impacts associated with the construction and operation of Cells 5A and 5B are well within the realm of impacts anticipated in the FES, the EAs performed by NRC in 1985 (NRC, 1985) and 1997 (NRC, 1997) and by the State of Utah in 2018 (Utah, 2018) in connection with previous License renewals, and UDEQ's approval of Cells 5A and 5B construction will satisfy applicable criteria in R313-22-33 and R313-24. Further, the siting and use of Cells 5A and 5B have already been approved and are part of the License (see the discussion in the Introduction above). As a result, Energy Fuels asserts that the Director should have no basis for denying the proposed action.

10.3 Alternatives Considered But Eliminated

10.3.1 Consideration of Alternative Sites

The Mill is already sited and in existence and has been operating for over 35 years. It is not feasible to consider moving the Mill to an alternative site or to construct additional tailing cells at a different location. Even if that were possible, it has been demonstrated in Section 3 of the 2007 ER that it is sited in a good hydrogeologic setting and is otherwise well sited for its operations, including tailings cells contemplated at the time of the Mill's original licensing. This is evident from the fact that the Mill has operated since its inception in compliance with applicable regulatory standards and ALARA goals. See also Appendices H and I of the 1978 ER, which address alternative tailings disposal systems and locations.

If the construction of Cells 5A and 5B is not approved as an element of continued milling operations, there can be no assurance that, as an alternative, an equally well-suited site for milling and tailings cell construction, that complies with the applicable siting requirements of 10 CFR Part 40 Appendix A, can be identified and obtained. Even if a suitable alternative site were to be identified and obtained, licensing and construction of a new mill and tailings cells could not be accomplished in a time frame that would ensure production could commence in a period of suitable market conditions. Furthermore, as the existing Mill tailings would have to be decommissioned in place, creation of a new mill site would result in unnecessary proliferation of mill tailings disposal facilities in contravention of 10 CFR Part 40 Appendix A, Criterion 2.

10.3.2 Consideration of Alternative Engineering Methods

The existing Mill facilities, equipment, procedures and training of personnel have resulted in the Mill operating since inception in compliance with all applicable regulatory standards and ALARA goals. Current modeling demonstrates that the Mill is capable of continuing to operate under the existing terms and conditions of the License in a manner that will continue to comply with such standards and goals. Furthermore, the Mill's GWDP institutes additional protections and engineering controls, including the requirement that any new construction of tailings cells must meet current best available technology standards. Therefore, there is no need to consider alternative engineering methods. The existing equipment and facilities, together with the existing terms and conditions of the License and the GWDP are sufficient to ensure that all applicable requirements will continue to be satisfied. More specifically, the proposed design of Cells 5A and 5B is essentially the same as the design of Cells 4A and 4B, which incorporates Best Available Technology and which has been approved by the Executive Secretary.

10.4 Cumulative Effects

There are no past, present, or reasonably foreseeable future actions which could result in cumulative impacts that have not been contemplated and previously approved under the existing License and the design of Cells 5A and 5B.

As stated throughout this License Amendment request, the construction of Cells 5A and 5B will result in no activity with potential, significant, incremental impacts to public health, safety or the environment over and above the actions contemplated in the FES and the 1985, 1997, and 2007 EAs. The activities contemplated with regard to ore processing and disposal of tailings remain unchanged from those previously authorized under the License.

10.5 Comparison of the Predicted Environmental Impacts

There have been no observed significant impacts which were not previously quantified and addressed to public health, safety or the environment resulting from the proposed construction of Cells 5A and 5B. As there will be no significant changes in Mill operations if the License is amended to accommodate construction of Cells 5A and 5B, possible impacts to public health, safety or the environment will not exceed those predicted in the original License application and periodic renewals.

10.6 Updates & Changes to Factors That May Cause Reconsideration of Alternatives

As discussed in Section 8 above, Costs and Benefits, there have been no changes to factors that may cause reconsideration of alternatives. There have been no significant changes in the costs associated with operation of the Mill (including its impoundments), and the benefits associated with continued operation and construction of already contemplated tailing cells have become more evident over time as the number of uranium mills has dwindled. In addition, the demand for uranium milling service capacity from local miners and the industry as a whole has increased in alternatives to the services provided by the Mill and its impoundments have been identified since the License renewal in 2018.

11.0 Environmental Approvals and Consultations

The Mill has the following licenses and permits in place which provide the regulatory framework for Mill operations and environmental, health and safety procedures.

- State of Utah, Renewal of Radioactive Material License ("RML") No. UT 1900479, Amendment 8, Effective February 16, 2018;
- State of Utah, Renewal of GWDP No. UGW370004; Effective January 19, 2018; and
- State of Utah, Division of Air Quality, Approval Order ("AO") No. DAQE-AN0112050018-11, Effective March 2, 2011.

In addition to the RML and GWDP amendments, which are supported through this Report and associated amendment requests, Energy Fuels will be submitting an application to the State of Utah, Division of Air Quality, for approval of modification of an existing source pursuant to the requirements of 40 CFR Part 61 – National Emission Standards for Hazardous Air Pollutants, Subpart A, Section 61.07.

12.0 References

Arcadis Canada Inc. July 11, 2018. *Review of Environmental Radiological Monitoring Program for the White Mesa Uranium Mill*.

Dames & Moore. January 30, 1978. *Environmental Report, White Mesa Uranium Project San Juan County, Utah.*

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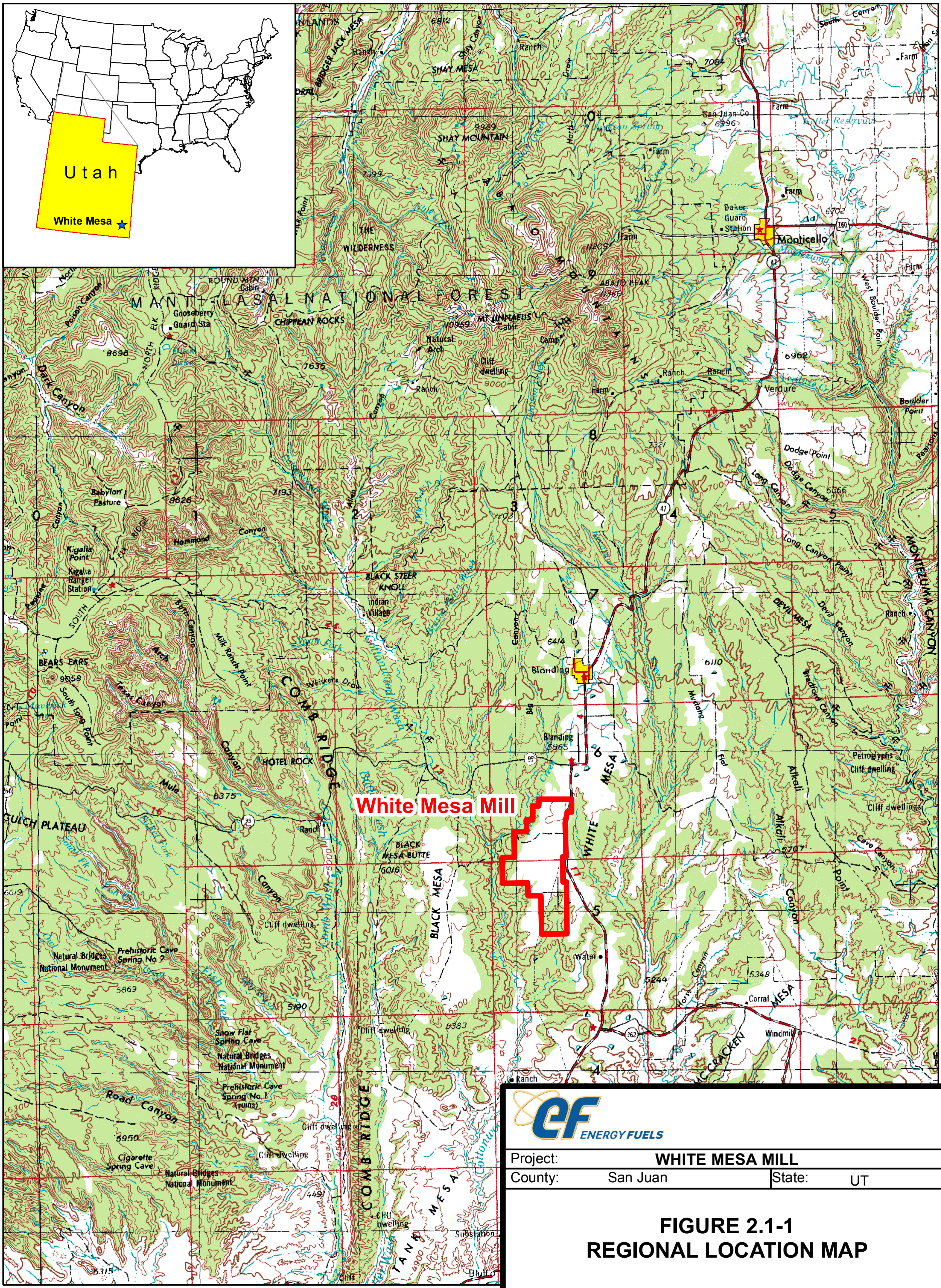
FIGURES



Scale 1 " = 5 miles A portion of USGS Map No NJ12-9 Cortez, CO-UT

ENERGY FUELS

Project:	WHITE MESA MILL		
County:	San Juan	State:	UT

FIGURE 2.1-1
REGIONAL LOCATION MAP

Date: Jun 2018	Design:	Drafted By: D. Kapostasy

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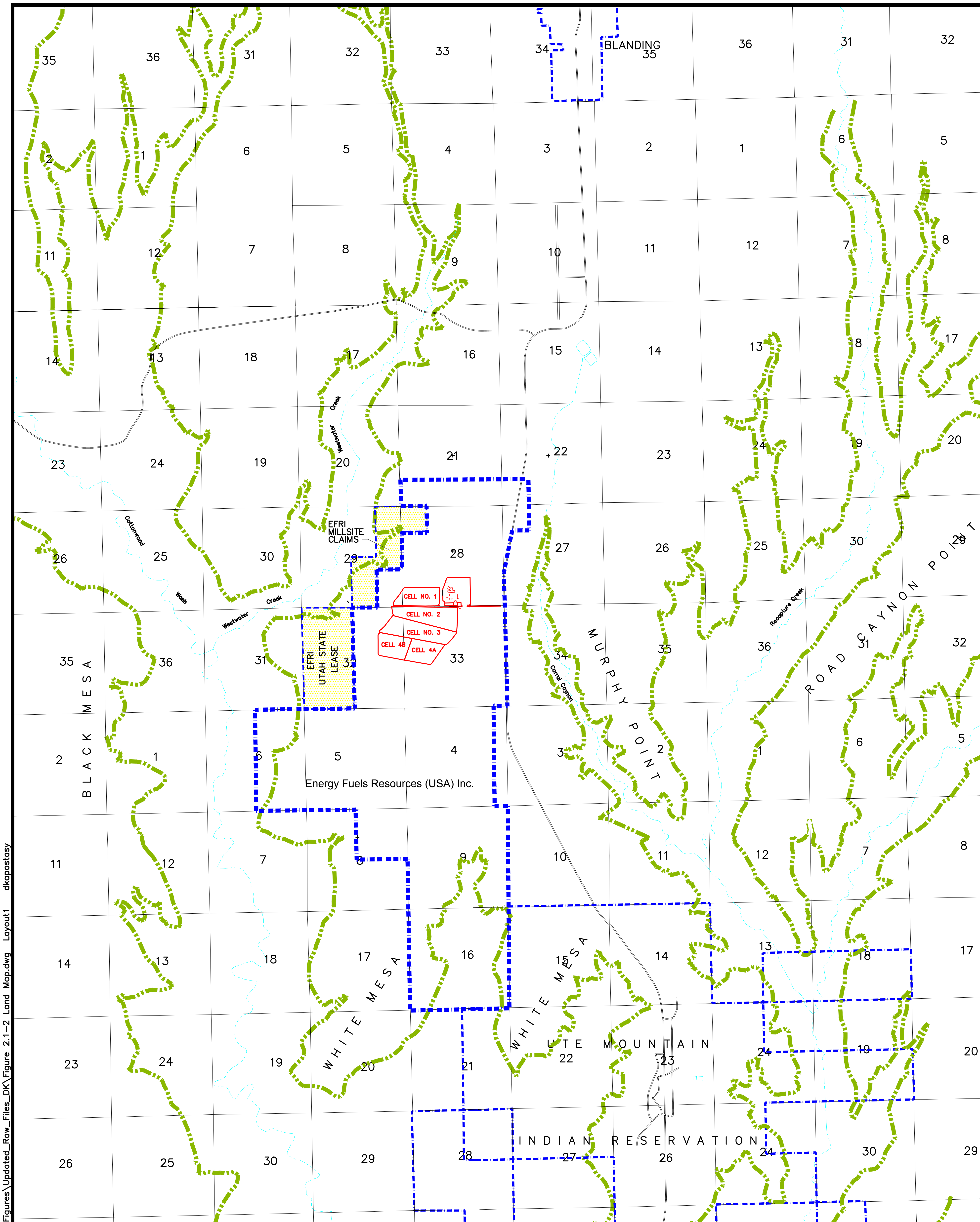

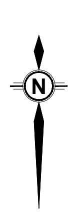

2,500' 0 2,500' 5,000'

SCALE: 1" = 5,000'

UT83-SF

ENERGY FUELS

REVISIONS	
Date	By
07-11	GM

Project: White Mesa Mill

County: San Juan State: UT

Location:

LAND MAP
FIGURE 2.1-2

Author: Date: May 1999 Drafted By: RAH

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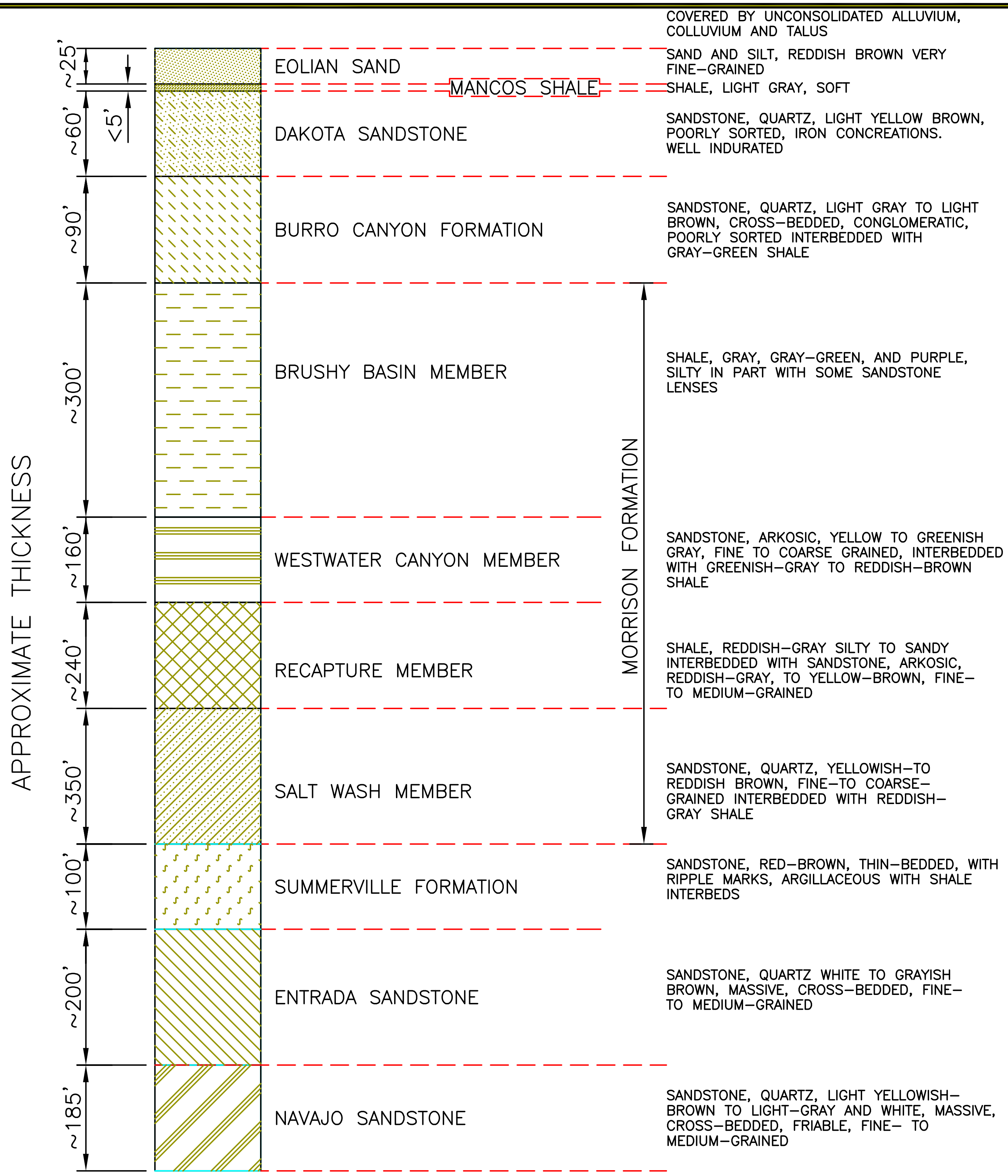


Taken from Stratigraphic Section near Water Well #3

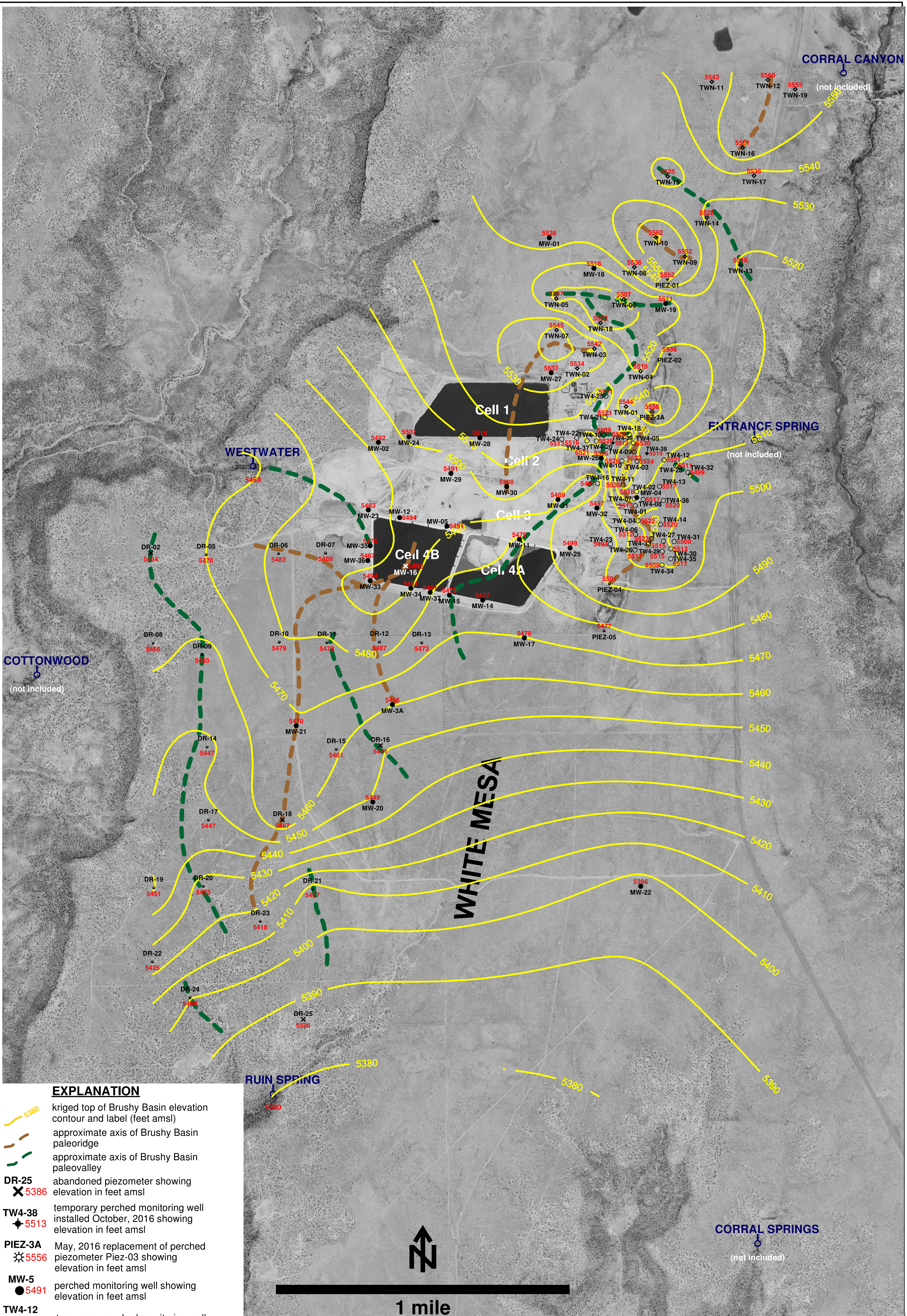
ENERGY FUELS

Project: WHITE MESA MILL

REVISIONS		County:	State: UT
Date	By	Location:	

Figure 2.5-1
Generalized Stratigraphy of White Mesa Mill

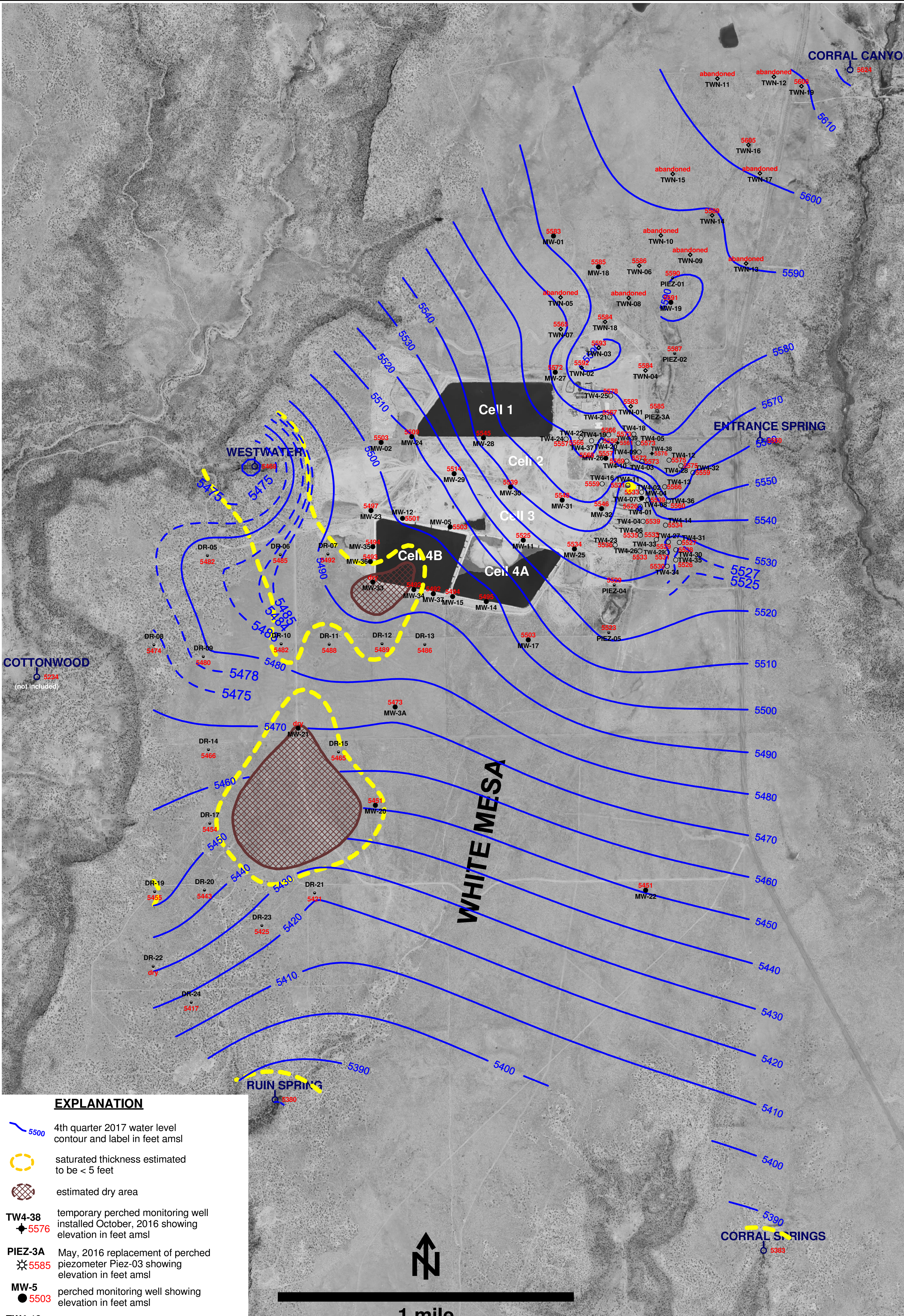
Scale: N/A | Date: Aug 2009
Author: HRR | Drafted By: D.Sledd



HYDRO GEO CHEM, INC.

KRIGED TOP OF BRUSHY BASIN
WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	6/19/2018	H:/718000/hydrpt2018/cell5a5b/Ubbel1217ER.srf	2.7-1



EXPLANATION

5500 — 4th quarter 2017 water level contour and label in feet amsl

saturated thickness estimated to be < 5 feet

estimated dry area

TW4-38 5576 — temporary perched monitoring well installed October, 2016 showing elevation in feet amsl

PIEZ-3A 5585 — May, 2016 replacement of perched piezometer Piez-03 showing elevation in feet amsl

MW-5 5503 — perched monitoring well showing elevation in feet amsl

TW4-12 5575 — temporary perched monitoring well showing elevation in feet amsl

TWN-7 5565 — temporary perched nitrate monitoring well showing elevation in feet amsl

PIEZ-1 5590 — perched piezometer showing elevation in feet amsl

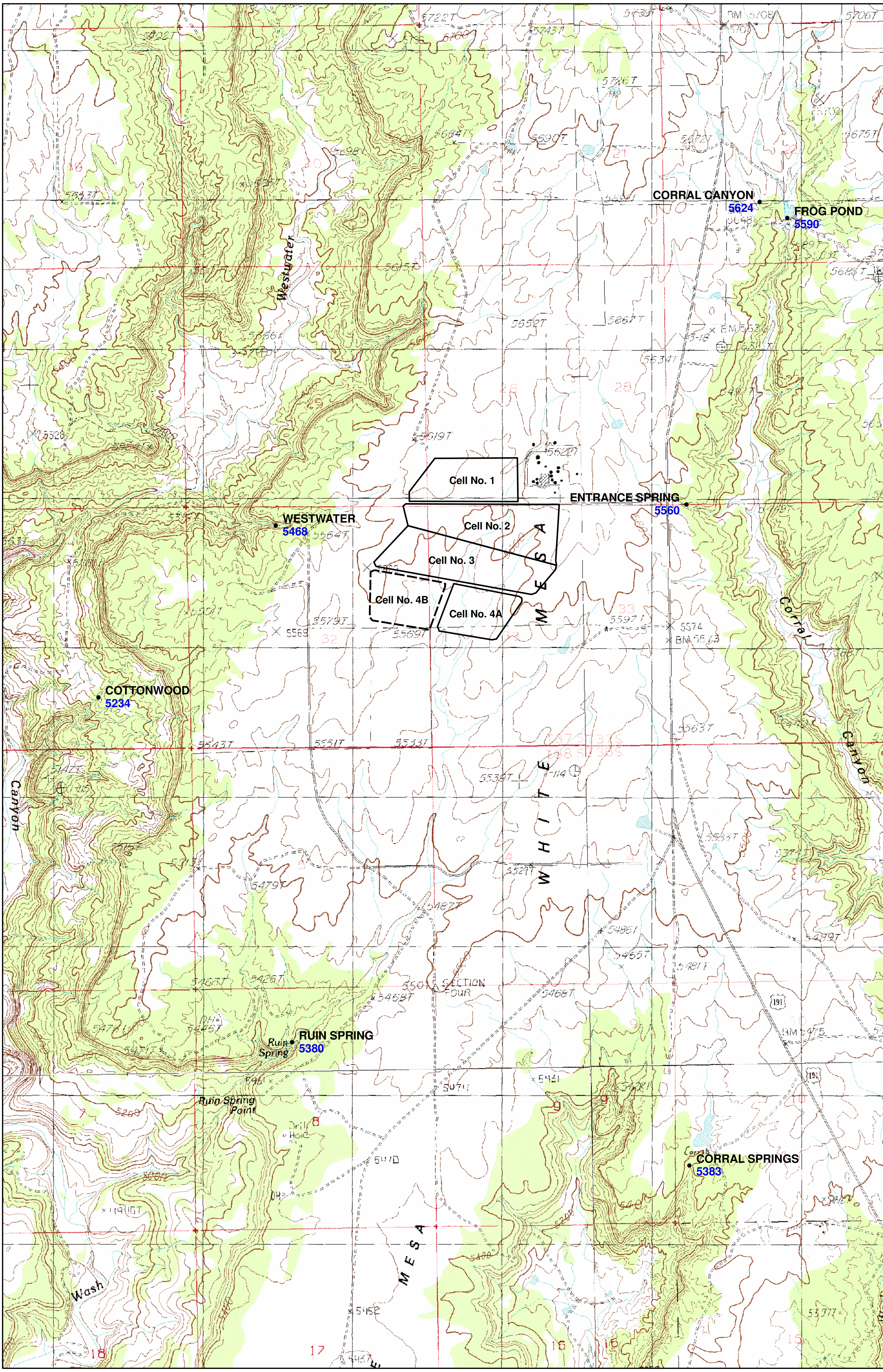
RUIN SPRING 5380 — seep or spring showing elevation in feet amsl

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

KRIGED 4th QUARTER, 2017 WATER LEVELS WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	6/19/2018	H:/718000/hydrpt2018/ cell5a5bUwl1217_detER.srf	2.7-2



0.5 0.25 0 0.5 1
Mile

● **WESTWATER** **Seep or Spring**
5468 **Elevation (feet) above mean sea level**

NORTH

HYDRO GEO CHEM, INC.

SEEPS AND SPRINGS
ON USGS TOPOGRAPHIC BASE
WHITE MESA

Approved	Date	Author	Date	File Name	Figure
SJS	09/17/10	DRS	07/16/10	7180002G	2.7-3

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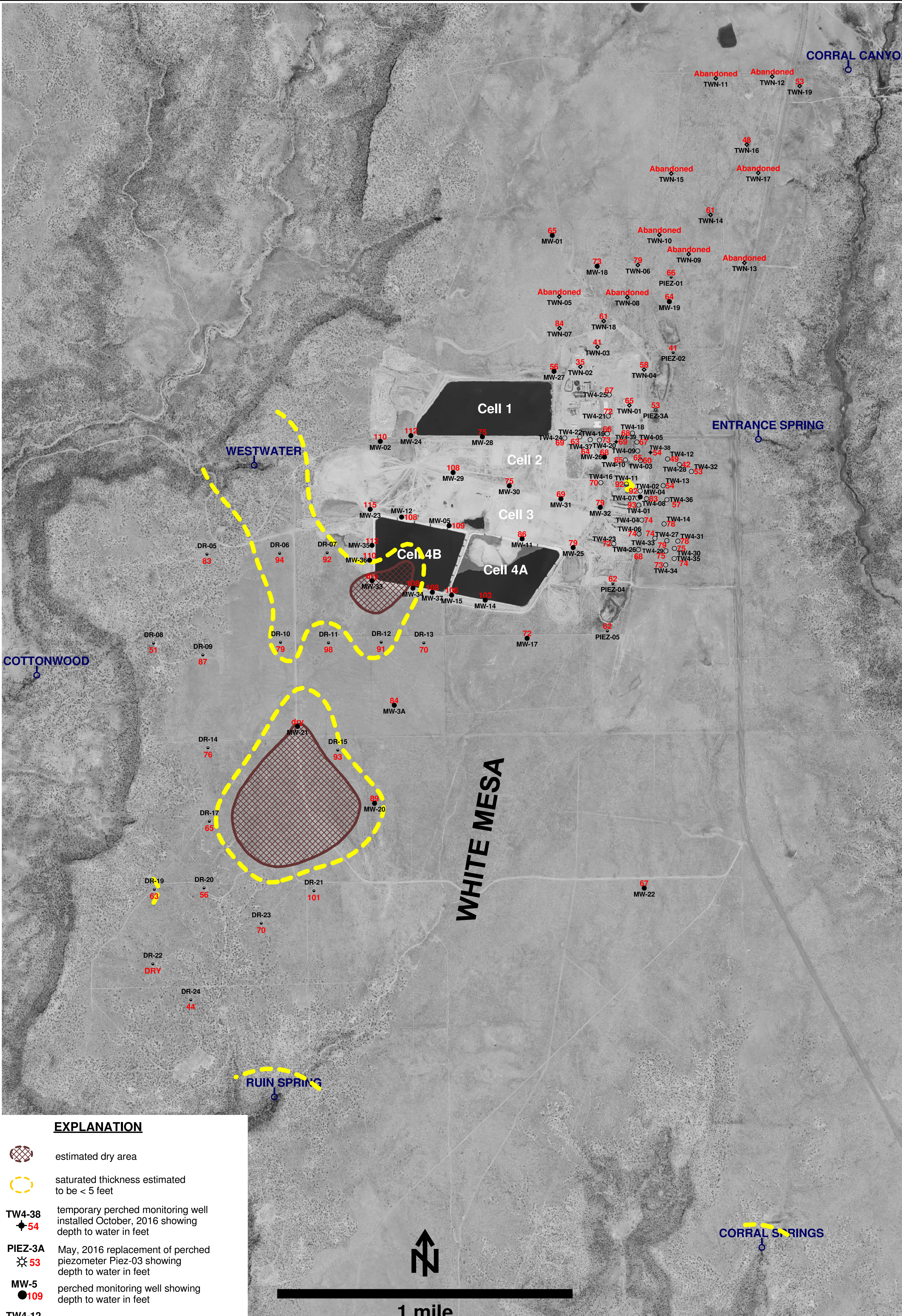


EXPLANATION

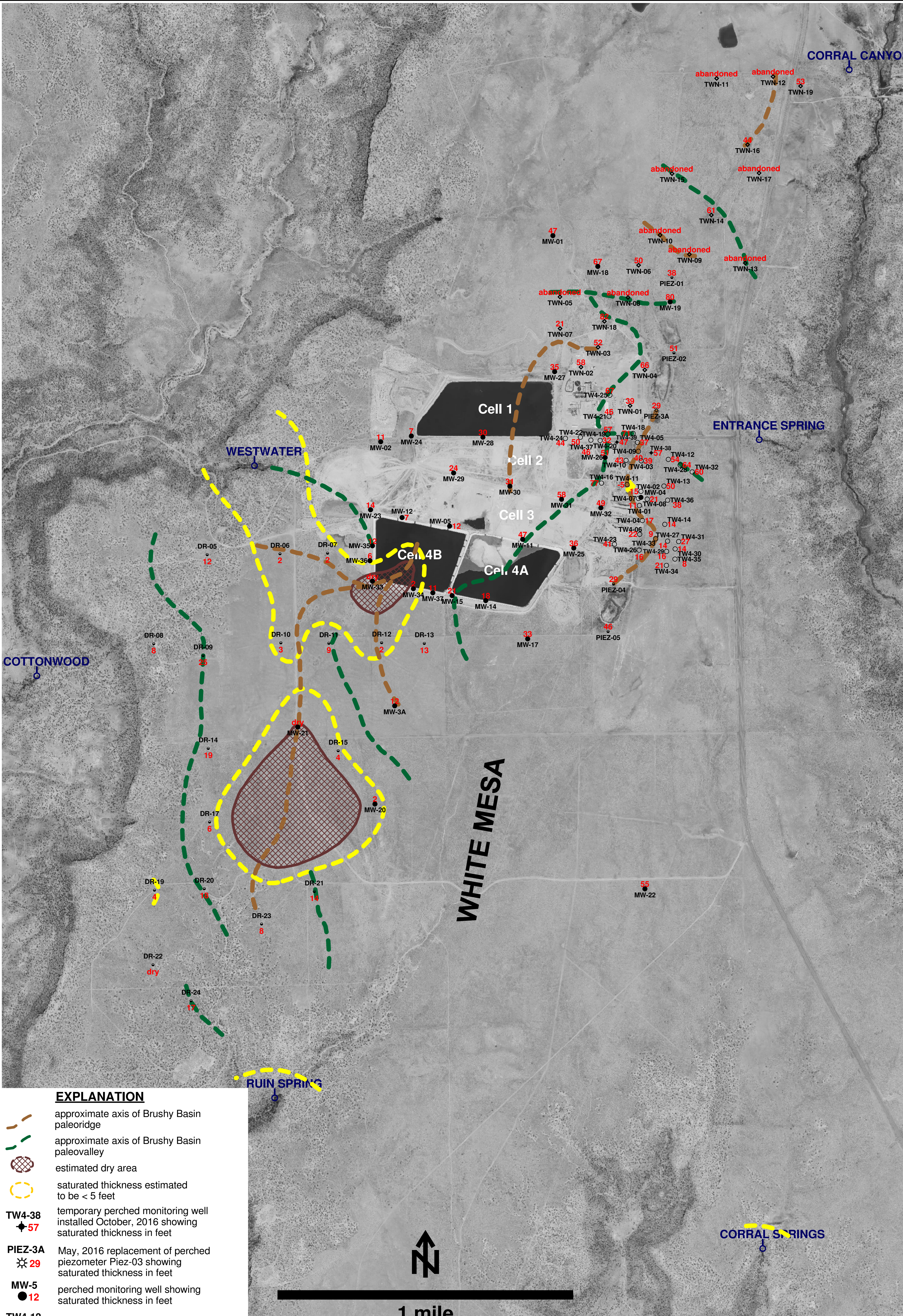
- estimated dry area
- saturated thickness estimated to be < 5 feet
- TW4-38 54 — temporary perched monitoring well installed October, 2016 showing depth to water in feet
- PIEZ-3A 53 — May, 2016 replacement of perched piezometer Piez-03 showing depth to water in feet
- MW-5 109 — perched monitoring well showing depth to water in feet
- TW4-12 49 — temporary perched monitoring well showing depth to water in feet
- TWN-7 84 — temporary perched nitrate monitoring well showing depth to water n feet
- PIEZ-1 66 — perched piezometer showing depth to water in feet
- RUIN SPRING — seep or spring

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

4th QUARTER, 2017 DEPTHS TO WATER WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	6/19/2018	H:/718000/hydrpt2018/cell5a5b/Udtw1217ER.srf	2.7-4



EXPLANATION

- approximate axis of Brushy Basin paleoridge
- approximate axis of Brushy Basin paleovalley
- estimated dry area
- saturated thickness estimated to be < 5 feet
- TW4-38 57 — temporary perched monitoring well installed October, 2016 showing saturated thickness in feet
- PIEZ-3A 29 — May, 2016 replacement of perched piezometer Piez-03 showing saturated thickness in feet
- MW-5 12 — perched monitoring well showing saturated thickness in feet
- TW4-12 54 — temporary perched monitoring well showing saturated thickness in feet
- TWN-7 21 — temporary perched nitrate monitoring well showing saturated thickness in feet
- PIEZ-1 38 — perched piezometer showing saturated thickness in feet
- RUIN SPRING — seep or spring

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

4th QUARTER, 2017 PERCHED ZONE SATURATED THICKNESSES AND BRUSHY BASIN PALEORIDGES AND PALEOVALLEYS WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
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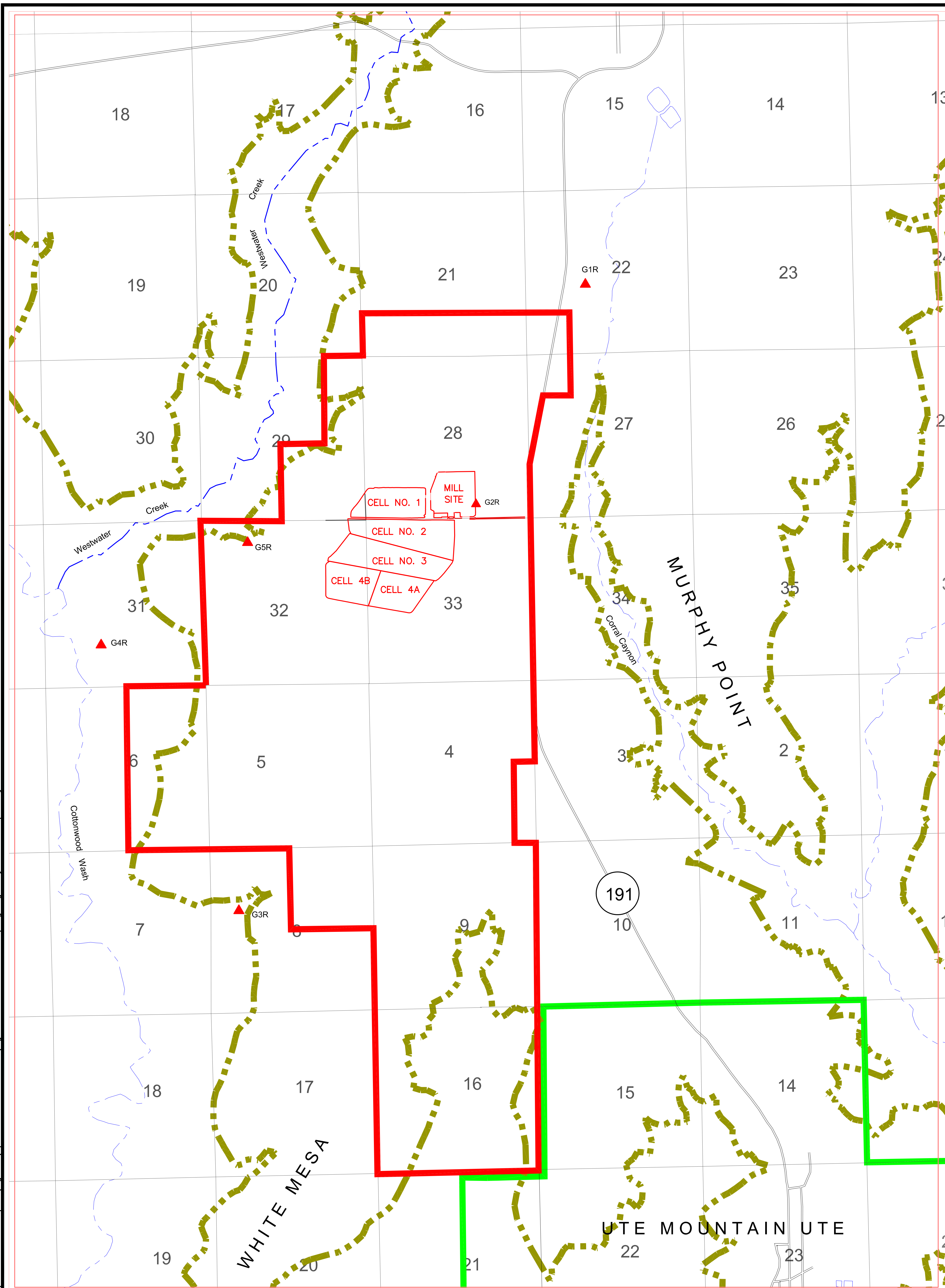

PROPERTY BOUNDARY

RESERVATION BOUNDARY

CANYON RIM

G4R GROUNDWATER (WELL OR SPRING) SAMPLING LOCATION

5 WATER SUPPLY WELL

1,500' 0 1,500' 3,000'

SCALE: 1" = 3,000'

UT83-SF

ENERGY FUELS

REVISIONS		Project: White Mesa Mill	
Date	By	County: San Juan	State: UT
09-11	GM	Location:	

GROUNDWATER (WELL OR SPRING) SAMPLING STATIONS IN THE WHITE MESA VICINITY
FIGURE 2.7-6

Author: bm | Date: Aug 2009 | Drafted By: D.Sledd

S:\Environmental\UT\WhiteMesaMill\Cell 5A and 5B\Environmental Report\Figures\Updated_Raw_Files_DK\Fig.2.7-6_GroundWaterSampling.dwg Layout1 dkapostasy

APPENDIX A

[RESERVED]

APPENDIX B

HYDROGEOLOGY OF THE WHITE MESA URANIUM MILL AND RECOMMENDED LOCATIONS OF NEW PERCHED WELLS TO MONITOR PROPOSED CELLS 5A AND 5B

HYDROGEOLOGY OF THE WHITE MESA URANIUM MILL AND RECOMMENDED LOCATIONS OF NEW PERCHED WELLS TO MONITOR PROPOSED CELLS 5A AND 5B

July 11, 2018

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Project Number 7180000.00-02.0

HYDRO GEO CHEM, INC.
Environmental Science & Technology

HYDROGEOLOGY OF THE WHITE MESA URANIUM MILL AND RECOMMENDED LOCATIONS OF NEW PERCHED WELLS TO MONITOR PROPOSED CELLS 5A AND 5B

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July 11, 2018

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FIGURES (Continued)

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APPENDICES

1. INTRODUCTION

This report is prepared to support the addition of proposed new cells 5A and 5B to the existing tailings management system at the White Mesa Uranium Mill (the Mill or the site) located near Blanding, Utah. The proposed locations of these new cells are provided in Figure 1A. Cell 5A and associated new perched groundwater monitoring wells are to be installed first as will be discussed in Section 7.

In addition to making recommendations as to the locations of new perched groundwater wells to monitor proposed cells 5A and 5B (discussed in Section 7), this report provides an update to the June 6, 2014 report *Hydrogeology of the White Mesa Uranium Mill, Blanding Utah* (the 2014 hydrogeologic report; HGC [2014b]).

The present report, which incorporates all the elements of the 2014 hydrogeologic report, also considers the additional hydrogeologic data collected at the site from the first quarter of 2014 through the fourth quarter of 2017. Calculations provided in the 2014 hydrogeologic report are updated based on the more recent data. Some of the additional data and updated calculations include:

1. Quarterly perched water level and analytical (chloroform and nitrate concentration) data;
2. Lithologic data collected from wells TW4-35 through TW4-39;
3. Hydraulic test data collected from wells TW4-35 through TW4-39;
4. Rates of perched groundwater movement and conservative solute travel times, in particular within the southwest portion of the site (downgradient of the tailings management system);
5. Perched water balance calculations in the southwest portion of the site;
6. Pyrite occurrence;
7. Changes in chloroform and nitrate plumes; and
8. Chloroform and nitrate degradation rates.

2. BACKGROUND AND OVERVIEW

Figure 1A is a site map showing general site features and the locations of perched groundwater wells and piezometers (as of the fourth quarter of 2017), springs, and lithologic cross-sections. Figure 1B shows fourth quarter, 2017 kriged perched groundwater elevation contours and the kriged fourth quarter 2017 boundaries of the chloroform and nitrate plumes at the site.

Although not shown in Figures 1A and 1B, three additional MW-series groundwater monitoring wells (MW-38, MW-39, and MW-40) were installed in the southeastern portion of the site (between MW-17 and MW-22) during the first quarter of 2018 (HGC, 2018c). These wells are located far cross-gradient of the tailings management system. Also during the first quarter of 2018, two new chloroform wells (TW4-40 and TW4-41) were installed as discussed in HGC (2018b). TW4-40 was installed approximately 200 feet south of TW4-26 and TW4-41 was installed immediately north-northeast of TW4-4. Because of the recent installation and development of these five wells, water level and chemical data are not yet likely to be representative and are not discussed in this report. However, the preliminary water level data collected from these wells indicates that incorporation of this data will have minimal impact on groundwater flow patterns and hydraulic gradients at the site.

Hydrogeologic investigation of the site has been ongoing since the initial investigation in 1977-1978 (Dames and Moore, 1978). Major hydrogeologic and groundwater investigations include Dames and Moore (1978); UMETCO (1993); UMETCO (1994); TITAN (1994); International Uranium (USA) Corporation (IUSA) and Hydro Geo Chem, Inc. (HGC) [2000]; IUSA and HGC (2001); HGC (2004); HGC (2007); INTERA (2007a); INTERA (2007b); INTERA (2008); Hurst and Solomon (2008); INTERA (2009); HGC (2010g); INTERA (2012a); INTERA (2012b); HGC (2012b); HGC (2012c); HGC (2014a); and HGC (2014b).

Investigations to date and more than 37 years of perched groundwater monitoring indicate that operation of the tailings management system (cells 1 through 4B in Figures 1A and 1B) has not impacted perched groundwater. The lack of impact is detailed in Hurst and Solomon (2008) and various INTERA documents (INTERA, 2007a; INTERA 2007b; INTERA, 2008; INTERA, 2010; INTERA, 2012a; INTERA 2012b; INTERA, 2013a; INTERA, 2013b; INTERA, 2014a; INTERA, 2014b; INTERA, 2014c; INTERA, 2015; INTERA, 2016; and INTERA, 2017).

Perched groundwater was impacted by operation of a temporary laboratory facility that was located at the site prior to and during the construction of the Mill, and from septic drain fields that were used for laboratory and sanitary wastes prior to operation of the Mill's tailings management system circa 1980 (HGC, 2007; HGC, 2018a). Laboratory wastes prior to 1980 were first disposed to the abandoned scale house leach field, and later to the former office leach field. Disposal of laboratory wastes to the abandoned scale house and former office leach fields is considered the source of the chloroform plume (defined by concentrations greater than 70 micrograms per liter [µg/L]) located upgradient to cross-gradient (northeast to east) of the tailings management system (Figure 1B). The eastern portion of the chloroform plume likely originated from the abandoned scale house leach field (located immediately north-northwest of TW4-18 [Figure 1B]), and the western portion from the former office leach field (located in the immediate vicinity of TW4-19 [Figure 1B]).

Perched groundwater has also been impacted by nitrate (INTERA, 2009). The nitrate plume (Figure 1B), defined by concentrations greater than 10 milligrams per liter (mg/L), contains elevated chloride (exceeding 100 mg/L) and extends from upgradient (northeast) of the tailings management system to a portion of the area beneath the tailings management system as described in the Nitrate Corrective Action Plan (nitrate CAP)[HGC, 2012a]. The precise source(s) of the nitrate plume are not well defined. However, the footprint of a former agricultural/stock watering pond referred to as the 'historical pond' is located beneath the upgradient portion of the nitrate plume and extends to the north of the plume (Figure 1B). This pond was active from the early part of the 20th century until the area was re-graded as part of Mill construction circa 1980 (HGC, 2012a). This pond is considered one of the likely historical sources of nitrate and chloride to the nitrate plume. Ammonium sulfate handling in the vicinity of the ammonium sulfate crystal tanks (southeast of TWN-2 [Figures 1A and 1B]) is considered the only potential Mill contribution of nitrate to the nitrate plume and has been addressed through implementation of Phase 1 of the nitrate CAP [HGC (2012a) and EFRI (2013)].

Both the chloroform and nitrate plumes are under remediation by pumping and are discussed in more detail in Section 3.

Appendix A contains copies of lithologic logs from site perched monitoring wells and piezometers. Appendix B contains copies of perched well construction schematics. Appendix C contains logs of borings installed by INTERA as part of the nitrate investigation that supported the nitrate CAP. Logs of soil borings installed per Phase I of the nitrate CAP are provided in EFRI (2013).

2.1 Overview of Site Hydrogeology

TITAN (1994) provides a detailed description of site hydrogeology based on information available at that time. A brief summary of site hydrogeology that is based in part on TITAN (1994) and updated with information from the literature and more recent site investigations is provided below.

2.1.1 Geology/Stratigraphy

The White Mesa Uranium Mill is located within the Blanding Basin (the Basin) of the Colorado Plateau physiographic province. Bedrock units exposed in the Basin include Upper Jurassic through Cretaceous sedimentary rocks (Figure 2, from Doelling, 2004). The general succession, in ascending order, is the Upper Jurassic Morrison Formation, the Lower Cretaceous Burro Canyon Formation, and the Upper Cretaceous Dakota Sandstone and Mancos Shale. Most exposures of the Morrison Formation consist of the Brushy Basin Member. Typical of large portions of the Colorado Plateau province, the rocks within the Basin are relatively undeformed.

The Mill has an average elevation of approximately 5,600 feet above mean sea level (ft amsl) and is underlain by unconsolidated alluvium and indurated sedimentary rocks. Indurated rocks include those exposed within the Basin (described above), and consist primarily of sandstone and shale. The indurated rocks are relatively flat lying with dips generally less than 3º. The alluvial materials consist primarily of aeolian silts and fine-grained aeolian sands with a thickness varying from a few feet to as much as 25 to 30 feet across the site. The alluvium is underlain by the Dakota Sandstone and Burro Canyon Formation, and where present, the Mancos Shale. The Dakota and Burro Canyon are sandstones having a total thickness ranging from approximately 55 to 140 feet, and, because of their similarity, are typically not distinguished in lithologic logs at the site. Beneath the Burro Canyon Formation lies the Morrison Formation, consisting, in descending order, of the Brushy Basin Member, the Westwater Canyon Member, the Recapture Member, and the Salt Wash Member. The Brushy Basin and Recapture Members of the Morrison Formation, classified as shales, are very fine-grained, have a very low permeability, and are considered aquicludes. The Brushy Basin Member is primarily composed of bentonitic mudstones, siltstones, and claystones. The Westwater Canyon and Salt Wash Members also have a low average vertical permeability due to the presence of interbedded shales.

Beneath the Morrison Formation lie the Summerville Formation, an argillaceous sandstone with interbedded shales, and the Entrada Sandstone. Beneath the Entrada lies the Navajo Sandstone. The Navajo and Entrada Sandstones constitute the primary aquifer in the vicinity of the site. The Entrada and Navajo Sandstones are separated from the Burro Canyon Formation by approximately 1,000 to 1,100 feet of materials having a low average vertical permeability. Groundwater within this system is under artesian pressure in the vicinity of the site, is of generally good quality, and is used as a secondary source of water at the site. Stratigraphic relationships beneath the site are summarized in Figure 3 (adapted from TITAN, 1994 and based on the lithology of water supply well WW-3, located just northwest of TWN-2 [Figure 1A]).

The Upper Jurassic Morrison Formation is the youngest Jurassic unit in the Basin. In many places an unconformity separates the Morrison Formation from underlying Middle Jurassic strata. The Morrison was deposited in a variety of depositional environments, ranging from aeolian to fluvial and lacustrine. Much of the Morrison is composed of fluvial sandstone and mudstone that have sources to the west and southwest of the Basin (Peterson and Turner-Peterson, 1987). The upper Brushy Basin Member (a bentonitic shale), was deposited in a combination of lacustrine and marginal lacustrine environments (Turner and Fishman, 1991).

The contact between the Morrison Formation and overlying strata has been subject to discussion. In the southeastern part of the Basin, the Lower Cretaceous Burro Canyon Formation overlies the Morrison Formation. The contact between the Burro Canyon Formation and the Morrison Formation has been interpreted as a disconformity (Young, 1960); however, Tschudy *et al.*, (1984) indicated that the Burro Canyon Formation may be a continuation of deposition of the Morrison Formation. More recent studies by Aubrey (1992) also suggest interfingering between the Morrison Formation and overlying units.

Kirby (2008) indicates that the contact between the Morrison Formation and the Burro Canyon Formation (between the Brushy Basin Member of the Morrison and the Burro Canyon Formation) near Blanding, Utah is disconformable with "local erosional relief of several feet". Data collected from perched borings at the site that penetrate the Brushy Basin Member are consistent with a disconformable, erosional contact in agreement with Kirby (2008).

2.1.2 Hydrogeologic Setting

The site and vicinity has a dry to arid continental climate, with an average annual precipitation of approximately 13.3 inches, and an average annual lake evaporation rate of approximately 47.6 inches. Recharge to major aquifers (such as the Entrada/Navajo) occurs primarily along the mountain fronts (for example, the Henry, Abajo, and La Sal Mountains), and along the flanks of folds such as Comb Ridge Monocline.

Although the water quality and productivity of the Navajo/Entrada aquifer are generally good, the depth (approximately 1,200 feet below land surface [ft bls]) makes access difficult. The

Navajo/Entrada aquifer is capable of yielding significant quantities of water to wells (hundreds of gallons per minute [gpm]). Water in WW-series supply wells completed across these units at the site rises approximately 800 feet above the base of the overlying Summerville Formation (TITAN, 1994).

2.1.3 Perched Water Zone

Perched groundwater occurs within the Dakota Sandstone and Burro Canyon Formation beneath the site and is used on a limited basis to the north (upgradient) of the site because it is more easily accessible than the Navajo/Entrada aquifer. Perched groundwater originates mainly from precipitation and local recharge sources such as unlined reservoirs (Kirby, 2008) and is supported within the Burro Canyon Formation by the underlying aquiclude (Brushy Basin Member of the Morrison Formation).

Water quality of the Dakota Sandstone and Burro Canyon Formation is generally poor due to high total dissolved solids (TDS) in the range of approximately 1,100 to 7,900 milligrams per liter (mg/L), and is used primarily for stock watering and irrigation. The saturated thickness of the perched water zone generally increases to the north of the site, increasing the yield of the perched zone to wells installed north of the site. The generally low permeability of the perched zone limits well yields. Although sustainable yields of as much as 4 gallons per minute (gpm) have been achieved in site wells penetrating higher transmissivity zones near unlined wildlife ponds, yields are typically low ($<^1/_2$ gpm) due to the generally low permeability of the perched zone. Even site wells that yielded as much as 4 gpm during the first few months of pumping eventually saw yields drop to about 1 gpm or less. Many of the perched monitoring wells purge dry and take several hours to more than a day to recover sufficiently for groundwater samples to be collected. During redevelopment (HGC, 2011b) many of the perched wells went dry during surging and bailing and required several sessions on subsequent days to remove the proper volumes of water.

Although perched groundwater extends into the overlying Dakota Sandstone within areas having greater saturated thicknesses, perched groundwater at the site is hosted primarily by the Burro Canyon Formation, which consists of a relatively hard to hard, fine- to medium-grained sandstone containing siltstone, shale and conglomeratic materials. As discussed above, the Burro Canyon Formation is separated from the underlying regional Navajo/Entrada aquifer by approximately 1,000 to 1,100 feet of Morrison Formation and Summerville Formation materials having a low average vertical permeability. As discussed above, the Brushy Basin Member of the Morrison Formation (a bentonitic shale), lying immediately beneath the Burro Canyon

Formation, forms the base of the perched water zone at the site. Figure 4 is a photograph of the contact between the Burro Canyon Formation and the underlying Brushy Basin Member taken from a location along Highway 95 north of the Mill. This photograph illustrates the transition from the cliff-forming sandstone of the Burro Canyon Formation to the slope-forming Brushy Basin Member.

Figure 5 is a perched groundwater elevation contour map generated from fourth quarter, 2017 data. Historic water level maps based on data from 1990, 1994 and 2002 are provided in Appendix D. Note that maps shown in Appendix D are based only on water levels from perched zone wells and do not include seep and spring elevations.

As shown in Figure 5 and Appendix D, perched water flow across the site is generally from northeast to southwest. This general flow pattern has been consistent based on perched water level data collected beginning with the initial site investigation described in Dames and Moore (1978). Perched water discharges in seeps and springs located to the west, southwest, east, and southeast of the site.

Beneath and south of the tailings management system, in the west central portion of the site, perched water flow is south-southwest to west-southwest. Flow on the western margin of the mesa south of the tailings management system is generally southerly, approximately parallel to the mesa rim (where the Burro Canyon Formation is terminated by erosion). On the eastern side of the site perched water flow is also generally southerly to southwesterly.

Perched water flow beneath and downgradient of the millsite and tailings management system is influenced by perched water discharge points Westwater Seep, located west to west-southwest of the tailings management system, and Ruin Spring, located southwest of the tailings management system. The overall southwesterly flow pattern is locally influenced by former seepage from the unlined wildlife ponds. Because of relict mounding near the northern wildlife ponds, flow direction ranges from locally westerly (west of the ponds) to locally easterly (east of the ponds).

In general, perched groundwater elevations have not changed significantly at most of the site monitoring wells since installation, except in the vicinity of the three unlined wildlife ponds and fifteen pumping wells (shown in Figures 1A and 1B). For example, relatively large increases in water levels occurred between 1994 and 2002 at MW-4 and MW-19, located in the east and northeast portions of the site, as discussed in HGC (2007). These water level increases in the northeastern and eastern portions of the site were the result of seepage from the northern wildlife ponds. Piezometers PIEZ-1 through PIEZ-5, shown in Figure 5, were installed in 2001 to investigate these changes. The mounding associated with the wildlife ponds and the general increase in water levels in the northeastern portion of the site resulted in a local steepening of groundwater gradients near the ponds.

Since the first quarter of 2012, after water delivery to the two northern wildlife ponds ceased, the perched groundwater mound associated with these ponds (the northern mound) began to diminish. In addition, reduced water delivery to the southern wildlife pond caused the associated perched groundwater mound (the southern mound) to diminish. Since the first quarter of 2012, water levels have declined within the northern mound by nearly 21 feet (at PIEZ-2), and within the southern mound by more than 18 feet (at PIEZ-5). The decay of the groundwater mounds associated with the wildlife ponds has caused reductions in hydraulic gradients over those portions of the site that experienced prior increases resulting from former water delivery to the ponds.

Although use of these ponds specifically as wildlife ponds began in the early 1990s, the northernmost pond contained water as least as early as 1984 (based on aerial photography). The 1985 editions of United States Geological Survey (USGS) topographic maps covering the western (Black Mesa Butte map) and eastern (Blanding South map) portions of the Mill property show the Mill buildings but none of the cells within the future tailings management system. The northern wildlife pond is shown as water-bearing, but the historical pond, which shows up on pre-1978 aerial photography, is not shown. The absence of the historical pond is consistent with the elimination of that pond during regrading as part of Mill construction circa 1979. The features shown on these maps suggest that they are representative of the time period between approximately 1979 and the year the maps were published, 1985. Therefore, based on the features shown on these USGS topographic maps, the northern wildlife pond could have been water bearing as early as about 1979.

In addition a perched groundwater mound extending beneath the future millsite was likely present at the time of the initial site investigation. Dames and Moore (1978) indicated that the depth to water beneath the future millsite was a relatively shallow 56 ft bls, while depths to water beneath the future tailings management system were generally greater than 90 ft bls. Dames and Moore (1978) also indicated that the hydraulic gradient beneath the future millsite was a relatively large 0.03 feet per foot (ft/ft), while the hydraulic gradient beneath the future tailings management system was a more typical 0.01 ft/ft. The relatively shallow depth to water and relatively steep hydraulic gradient beneath the future millsite are consistent with a perched groundwater mound originating from a source upgradient to the north (historical pond) or northeast (northernmost wildlife pond).

In addition to the impacts of wildlife and historical pond seepage on site water levels, pumping of chloroform wells MW-4, TW4-4, TW4-19, TW4-20, and MW-26, and nitrate wells TW4-22, TW4-24, TW4-25, and TWN-2 has depressed the perched water table locally and contributed to reduced average hydraulic gradients to the south and southwest of these wells. Pumping is designed to remove chloroform and nitrate associated with the chloroform and nitrate plumes shown on Figure 1B.

Hydraulic testing of perched zone wells yields a hydraulic conductivity range of approximately 2 x 10^{-8} to 0.01 centimeters per second (cm/s) as discussed in HGC (2012b). Hydraulic conductivity estimates obtained from perched wells installed and tested subsequent to HGC (2012b) also fall within this range (HGC, 2013a; HGC, 2013b; HGC, 2014c; HGC, 2015; and HGC, 2016). Hydraulic conductivity estimates are summarized in Tables 1 through 4. Table 1 provides estimates of hydraulic conductivity from slug test data analyzed using the KGS and Bouwer-Rice solutions available in AQTESOLVE (HydroSOLVE, 2000). Table 2 summarizes recovery and slug test data analyzed using the Moench solutions in WHIP (HGC, 1988) and AQTESOLVE. The estimates provided in Tables 1 and 2 are based on HGC (2002); HGC (2005); HGC (2010c); HGC (2010d); HGC (2010e); HGC (2010f); HGC (2011a); HGC (2011c); HGC (2013a); HGC (2013b); HGC (2014c); HGC (2015); and HGC (2016). Table 3 summarizes analyses of test data collected during long-term pumping within the chloroform plume area using the Theis solutions available in AQTESOLVE (HGC, 2004). Table 4 (from TITAN, 1994) summarizes hydraulic conductivity estimates based on testing prior to 1994.

In general, the highest perched zone permeabilities and well yields are in the area of the site immediately northeast and east (upgradient to cross gradient) of the tailings management system. A relatively continuous, higher permeability zone associated with the chloroform plume and consisting of poorly indurated (poorly cemented) coarser-grained materials has been inferred to exist in this portion of the site (HGC, 2007; HGC, 2018a). Because their existence requires both coarse grain size and poor cementation, such relatively continuous, higher permeability zones are expected to be relatively rare at the site.

Perched zone permeabilities downgradient (southwest) of the tailings management system are generally low. The low permeabilities and relatively shallow hydraulic gradients downgradient of the tailings management system result in average perched groundwater pore velocity estimates that are among the lowest on site.

2.1.4 Seeps and Springs in Relation to Perched Zone Hydrogeology

Hydro Geo Chem (2010g) discusses the relationships between the perched water zone and seeps and springs at the margins of White Mesa. The relationships between seeps and springs and site geology/stratigraphy are provided in Figure E.1 and Figure E.2 of Appendix E. Key findings of HGC (2010g) include the following:

1. Incorporating the seep and spring elevations in perched water elevation contour maps produces little change with regard to perched water flow directions except in the area west of the tailings management system and near Entrance Spring. West of the tailings management system, incorporation of Westwater Seep creates a more westerly hydraulic gradient. Westwater Seep appears to be downgradient of the western portion of the tailings management system (Figure 5); and Ruin Spring is downgradient of the eastern portion of the tailings management system (Figure 5). Westwater Seep is the closest apparent discharge point west of the tailings management system and Ruin Spring is the closest discharge point south-southwest of the tailings management system. Including the Entrance Spring elevation on the east side of the site creates a more easterly gradient in the perched water contours, and places Entrance Spring more directly downgradient of the northern wildlife ponds. Seeps and springs on the east side of the mesa are either cross-gradient of the tailings management system or are separated from the tailings management system by a groundwater divide.

2. Ruin Spring and Westwater Seep are interpreted to occur at the contact between the Burro Canyon Formation and the Brushy Basin Member. Corral Canyon Seep, Entrance Spring, and Corral Springs are interpreted to occur at elevations within the Burro Canyon Formation at their respective locations but above the contact with the Brushy Basin Member. All seeps and springs (except Cottonwood Seep which is located within the Morrison Formation near the Brushy Basin Member/Westwater Canyon Member contact) are associated with conglomeratic portions of the Burro Canyon Formation. Provided they are poorly indurated (poorly cemented) the more conglomeratic portions of the Burro Canyon Formation are likely to have higher permeabilities and the ability to transmit water more readily than finer-grained portions. This behavior is consistent with on-site drilling and hydraulic test data that associates higher permeability with the poorly indurated coarser-grained horizons detected east and northeast of the tailings management system that are associated with the chloroform plume).

3. Cottonwood Seep is located more than 1,500 feet west of the mesa rim in an area where the Dakota Sandstone and Burro Canyon Formation (which hosts the perched water system) are absent due to erosion. Cottonwood Seep occurs near a transition from slope-forming to bench-forming morphology (indicating a change in lithology). Cottonwood Seep (and 2^{nd} Seep located immediately to the north [annotated photograph provided in Figure 6]) are interpreted to originate from coarser-grained materials within the lower portion of the Brushy Basin Member (or upper portion of the Westwater Canyon Member) and are therefore not (directly) connected to the perched water system at the site.

4. Only Ruin Spring appears to receive a predominant and relatively consistent proportion of its flow from perched groundwater. Ruin Spring originates from conglomeratic Burro Canyon Formation sandstone where it contacts the underlying Brushy Basin Member, at an elevation above the alluvium in the associated drainage. Westwater Seep, which also originates at the contact between the Burro Canyon Formation and the Brushy Basin Member, likely receives a significant contribution from perched water. All seeps and springs other than Ruin Spring (and 2^{nd} Seep just north of Cottonwood Seep) are located within alluvium occupying the basal portions of small drainages and canyons. The relative contribution of flow to these features from bedrock and from alluvium is indeterminate.

5. All seeps and springs are reported to have enhanced flow during wet periods. For seeps and springs associated with alluvium, this behavior is consistent with an alluvial contribution to flow. Enhanced flow during wet periods at Ruin Spring, which originates from bedrock above the level of the alluvium, likely results from direct recharge of Burro Canyon Formation and Dakota Sandstone outcropping near the mesa margin in the vicinity of Ruin Spring. This recharge would be expected to temporarily increase the flow at Ruin Spring (as well as other seeps and springs where associated bedrock is directly recharged) after precipitation events.

6. The assumption that the seep or spring elevation is representative of the perched water elevation is likely to be correct only in cases where the feature receives most or all of its flow from perched water and where the supply is relatively continuous (for example at Ruin Spring). The perched water elevation at the location of a seep or spring that receives a significant proportion of water from a source other than perched water may be different from the elevation of the seep or spring. The elevations of seeps that are dry for at least part of the year will not be representative of the perched water elevation when dry. Some uncertainty therefore results from including these seeps and springs in the contouring of perched water levels. However, even if such springs are sometimes dry, the presence of cottonwoods suggests that perched groundwater is close to the surface at these locations.

Although there are uncertainties associated with incorporation of seep and spring elevations into maps depicting perched water elevations or maps depicting the Burro Canyon Formation/Brushy Basin Member contact elevations, post-2010 perched water elevation maps incorporate seep and spring elevations other than Cottonwood Seep, and post-2010 contact elevation maps incorporate Westwater Seep and Ruin Spring elevations.

As discussed above, Cottonwood Seep was interpreted in HGC (2010g) to be associated with coarser-grained materials within the lower portion of the Brushy Basin Member. The justification for this interpretation is based primarily on 1) the rate of flow at Cottonwood Seep, which is typically estimated to range between approximately 1 and 10 gpm (consistent with Dames and Moore, 1978), 2) the need for relatively permeable materials to transmit this rate of flow, and 3) the change in morphology near Cottonwood Seep indicating a change in lithology. The change in morphology from slope-former to bench-former just east of Cottonwood Seep can be seen in the topographic map included in Appendix E (Figure E.1) and the annotated photograph provided in Figure 6.

The upper portion of the Brushy Basin Member, which hydraulically isolates the perched zone from underlying materials, is composed primarily of bentonitic mudstone, claystone, and shale. The rate of flow at Cottonwood Seep is inconsistent with the materials found within the upper portion of the Brushy Basin Member but is consistent with coarser-grained materials expected either within the lower portion of the Brushy Basin Member or within the upper portion of the underlying Westwater Canyon (sandstone) Member. The relationship between Cottonwood Seep and lithology is shown on the geologic map provided in Appendix E (Figure E.2) and Figure 6.

As shown in Figures 6 and E.1, Cottonwood Seep is located approximately 230 feet below the base of the perched zone defined by the contact between the cliff-forming Burro Canyon Formation and the underlying slope-forming Brushy Basin Member. The change in morphology from slope-former to bench-former occurs within the lower portion of the Brushy Basin Member (or the upper portion of the Westwater Canyon Member), between the termination of the perched zone at the mesa rim and Cottonwood Seep. The bench-like area hosting Cottonwood Seep begins at the change in morphology east of Cottonwood Seep and terminates west of Cottonwood Seep where a cliff-forming sandstone, interpreted to be within the Westwater Canyon Member, is exposed. The contact between the Westwater Canyon Member and the Brushy Basin Member is interpreted to be located between this sandstone outcrop and the change in morphology from slope-former to bench-former. This places Cottonwood Seep at the transition between the Brushy Basin Member and the underlying Westwater Canyon Member. This is consistent with the stratigraphy provided in Figure 3 which places the contact between the Brushy Basin Member and the Westwater Canyon Member at elevations between approximately 5,220 and 5,230 ft amsl in this portion of the site, within 5 to 15 feet of the elevation of Cottonwood Seep (5,234 ft amsl).

Details of the coarse-grained nature of the lower portion of the Brushy Basin Member are consistent with Shawe (2005) as will be discussed in Section 3.1.1.

2.1.5 Tailings Management System

The existing tailings management system includes cells 1 through 4B (Figure 1A). Details of the construction of cells 2 though 4A are provided in UMETCO (1993). Mill tailings are disposed in lined cells excavated below grade into the upper Dakota Sandstone. Cells 2 and 3 are underlain by a synthetic liner placed over compacted bedding material. The bedding material serves as a drain layer. The drain layer and a sand drain on the downstream embankment are connected to a leak detection lateral. Slime drains were installed above the liner in each cell within the area having the lowest topographic elevation.

Cell 4A and cell 4B have a geoclay liner overlain by geotextile and a double synthetic liner. The leak detection systems lie between the two synthetic liners.

Although the cells are equipped with leak detection systems, and monitoring activities have not detected impacts to the perched aquifer from tailings disposal (as discussed in Section 2), the Mill installed additional perched monitoring wells between existing wells on the downgradient margin of the tailings management system and between existing cells to function as an 'early warning system' for any potential impacts to perched water. These additional wells, MW-23 through MW-25, and MW-27 through MW-31, were installed and tested in 2005 (HGC 2005). At this time, temporary wells TW4-15 and TW4-17, located at the eastern edge of the cell complex and installed in 2002 (HGC, 2002), were converted to permanent status and renamed MW-26 and MW-32, respectively. Subsequently, upon installation of cell 4B, MW-33 through MW-37 were added to the west and south (downgradient) edges of the cell.

3. DETAILED SITE HYDROGEOLOGY

A detailed description of site hydrogeology is provided in the following Sections.

3.1 Stratigraphy and Formation Characteristics

The site stratigraphy is summarized in Figure 3. Details of formations underlying the site that are stratigraphically above the Westwater Canyon Member of the Morrison Formation are provided in the following Sections.

3.1.1 Brushy Basin Member

As discussed in Sections 2.1.1 and 2.1.3, the upper portion of the Brushy Basin Member is composed of bentonitic mudstone, claystone, and shale, which hydraulically support the perched groundwater zone and isolate it from underlying materials.

The upper portion of the Brushy Basin Member is described by Shawe (2005) as "principally mudstone; it contains only minor amounts of sandstone, conglomeratic sandstone, and conglomerate as discontinuous lenses". Shawe (2005) describes the lower portion of the Brushy Basin as coarser-grained, having "mudstone layers which contain, near their base, lenses lithologically similar to sandstone of the Salt Wash Member, and near their top, conglomeratic sandstone lenses".

With regard to the vicinity of Cottonwood Seep (discussed in Section 2.1.4), the expectation of coarser-grained materials is consistent with its location near the transition from the lower coarser-grained portion of the Brushy Basin Member into the underlying Westwater Canyon Member. As discussed in Craig *et al.* (1955), and Flesch (1974), the Westwater Canyon Member intertongues with the Brushy Basin Member. Craig *et al.* (1955) state "The Westwater Canyon Member forms the lower portion of the upper part of the Morrison in northeastern Arizona, northwestern New Mexico, and places in southeastern Utah and southwestern Colorado near the Four Corners, and it intertongues and intergrades northward into the Brushy Basin Member".

3.1.2 Burro Canyon Formation/Dakota Sandstone

Although the Dakota Sandstone and Burro Canyon Formations are often described as a single unit due to their similarity, previous investigators at the site have distinguished between them. The Dakota Sandstone is a relatively hard to hard, generally fine-to-medium grained sandstone cemented by kaolinite clays. The Dakota Sandstone locally contains discontinuous interbeds of siltstone, shale, and conglomeratic materials. Porosity is primarily intergranular. The underlying Burro Canyon Formation is the primary host of the perched groundwater at the site. The Burro Canyon Formation is similar to the Dakota Sandstone but is generally more poorly sorted, contains more conglomeratic materials, and becomes argillaceous near its contact with the underlying Brushy Basin Member (TITAN, 1994). The permeabilities of the Dakota Sandstone and Burro Canyon Formations at the site are generally low. Porosities and water contents measured in samples of Dakota Sandstone and Burro Canyon Formation collected from borings MW-16 and MW-17 are described in Sections 3.1.2.1 and 3.1.2.2 below. Porosity estimates from these borings agree with measurements reported by MWH (MWH, 2010) for archived samples collected from borings MW-23 and MW-30.

No significant joints or fractures within the Dakota Sandstone or Burro Canyon Formation have been documented in any wells or borings installed across the site (Knight-Piésold, 1998). Any fractures observed in cores collected from site borings are typically cemented, showing no open space. The Knight-Piésold findings are consistent with the evaluation of a 1994 drilling program provided in HGC (2001a) and with examination of drill core samples collected during installation of MW-3A, MW-23, MW-24, MW-28, MW-30, and TW4-22 in 2005 (HGC, 2005).

3.1.2.1 Dakota Sandstone

The Dakota Sandstone, named by Meek and Hayden (1862) for exposures in northeastern Nebraska, rests disconformably upon the Burro Canyon Formation where present. A three-fold lithologic sequence occurs in many localities, and consists of a basal conglomeratic sandstone with an underlying disconformity, a middle unit of carbonaceous shale and coal, and an upper unit of evenly-bedded sandstone which intertongues with the overlying Mancos Shale. These strata have been described as deposits of transitional environments which accompanied the westward transgressing Mancos Sea (Young, 1973).

The basal conglomerate represents floodplain braided channel deposits which extend into the adjacent paludal environment. The carbonaceous shales are partly marshy but most formed in lagoon ponds, tidal flats and tidal channels of the lagoonal environment just seaward of the marsh belt. The evenly-bedded sandstone was formed at the shoreline as a mainland or barrier beach deposit of the littoral marine environment. Faunal evidence summarized by O'Sullivan *et al.*, (1972) indicates that the lower part of the Dakota Sandstone is of Early Cretaceous age and the upper part is of Late Cretaceous age.

Based on samples collected during installation of wells MW-16 (abandoned) and MW-17, located beneath and immediately downgradient of the tailings management system at the site

(Figures 1A and 1B), porosities of the Dakota Sandstone range from 13.4% to 26%, and average 20% (Table 5) which is nearly the same as the average porosity of 19% reported by MWH (MWH, 2010) for archived sandstone samples collected from MW-23 and MW-30.

Water saturations from MW-16 and MW-17 range from 3.7% to 27.2%, averaging 13.5%, and the average volumetric water content is approximately 3% (Table 5). The permeability of the Dakota Sandstone based on packer tests in borings installed at the site ranges from 2.71 x 10^{-6} cm/s to 9.12 x 10^{-4} cm/s, with a geometric average of 3.89 x 10^{-5} cm/s (TITAN, 1994).

3.1.2.2 Burro Canyon Formation

The Burro Canyon Formation, as defined by Stokes and Phoenix (1948) at its type locality near Slick Rock, Colorado, consists of alternating conglomerate, sandstone, shale, limestone and chert ranging in thickness from 150 to 260 feet. In the Blanding Basin, the Burro Canyon Formation consists of deposits of alluvial and floodplain materials up to about 100 feet thick, consisting of medium to coarse grained sandstone, conglomerate, pebbly sandstone, and claystone. Persistent, widely traceable, conglomeratic sandstones, interpreted as deposits of a braided channel sub-environment, occur within the formation. Sandwiched between these sandstones are variegated mudstone units containing sandstone and siltstone lenses, the products of interchannel and meandering channel subenvironments. Fossils collected from the Burro Canyon Formation at various localities include freshwater invertebrates, dinosaur bones and plants. Although not truly diagnostic, they suggest an Early Cretaceous (Aptian) age.

The average porosity of the Burro Canyon Formation is similar to that of the Dakota Sandstone. Based on samples collected from the Burro Canyon Formation at MW-16 (abandoned, located beneath cell 4B as shown in Figure 1A), porosity ranges from 2% to 29.1%, averaging 18.3%, similar to the average porosity of 19% reported by MWH (MWH, 2010) for archived sandstone samples collected from MW-23 and MW-30. Water saturations of unsaturated materials collected from MW-16 range from 0.6% to 77.2%, and average 23.4% (Table 5).

TITAN (1994), reported that the hydraulic conductivity of the Burro Canyon Formation ranges from 1.9 x 10^{-7} to 1.6 x 10^{-3} cm/s, with a geometric mean of 1.01 x 10^{-5} cm/s, based on the results of 12 pumping/recovery tests performed in monitoring wells and 30 packer tests performed in borings prior to 1994 (Table 4). As discussed in Section 2, subsequent testing of wells by HGC yields a hydraulic conductivity range of approximately 2 x 10^{-8} to 0.01 cm/s (HGC, 2012b). Hydraulic conductivity estimates obtained from perched wells installed and tested subsequent to HGC (2012b) also fall within this range (HGC, 2013a; HGC, 2013b; HGC, 2014c; HGC, 2015; and HGC, 2016).

In general (as discussed in Section 2.1.3), the highest permeabilities and well yields are in the portion of the site immediately northeast and east (upgradient to cross gradient) of the tailings management system. A relatively continuous, higher permeability zone (associated with poorly indurated coarser-grained materials in the general area of the chloroform plume) has been inferred to exist in this portion of the site (HGC, 2007). As discussed in HGC (2004), analysis of drawdown data collected from this zone during long-term pumping of MW-4, MW-26 (TW4-15), and TW4-19 (Figures 1A and 1B) yielded estimates of hydraulic conductivity ranging from approximately 4 x 10^{-5} to 1 x 10^{-3} cm/s (Table 3). A slug test performed at TW4-4 yielded a hydraulic conductivity of approximately 1.7 x 10^{-3} cm/s (Table 1). The decrease in perched zone permeability south to southwest of this area (south of TW4-4), based on tests at TW4-6, TW4-26, TW4-27, TW4-29 through TW4-31, and TW4-33 and TW4-34 (Table 1), indicates that this higher permeability zone "pinches out", consistent with the interpretation provided in HGC (2007).

Relatively high conductivities measured at MW-11, located on the southeastern margin of the downgradient edge of cell 3, and at MW-14, located on the downgradient edge of cell 4A, of 1.4 x 10^{-3} cm/s and 7.5 x 10^{-4} cm/s, respectively (UMETCO, 1993 and Table 4), may indicate that this higher permeability zone extends beneath the southeastern portion of the tailings management system. However, based on hydraulic tests conducted south and southwest of these wells, this zone of higher permeability does not appear to exist within the saturated zone downgradient (south-southwest) of the tailings management system.

Slug tests performed at groups of wells and piezometers located northeast (upgradient) of, in the immediate vicinity of, and southwest (downgradient) of the tailings management system indicate generally lower permeabilities compared with the area of the chloroform plume. The following results are based on analysis of automatically logged slug test data using the KGS solution available in AQTESOLVE (HydroSOLVE, 2000).

Testing of TWN-series wells installed in the northeast portion of the site as part of nitrate investigation activities (HGC, 2009) yielded a hydraulic conductivity range of approximately 3.6 x 10^{-7} to 0.01 cm/s with a geometric average of approximately 6 x 10^{-5} cm/s. The value of 0.014 cm/s estimated for TWN-16 is the highest measured at the site, and the value of 3.6 x 10^{-7} cm/s estimated for TWN-7 is one of the lowest measured at the site. Testing of MW-series wells MW-23 through MW-32 (HGC, 2005) installed within and at the margins of the tailings management system in 2005 (and using the higher estimate for MW-23) yielded a hydraulic conductivity range of approximately 2 x 10^{-7} to 1 x 10^{-4} cm/s with a geometric average of approximately 2 x 10^{-5} cm/s. Hydraulic tests conducted at DR-series piezometers installed as part of the southwest area investigation (HGC 2012b) downgradient of the tailings management system yielded hydraulic conductivities ranging from approximately 2 x 10^{-8} to 4 x 10^{-4} cm/s with a geometric average of 9.6 x 10^{-6} cm/s. The relatively low permeabilities and shallow hydraulic gradients downgradient of the tailings management system result in average perched groundwater pore velocity estimates that are among the lowest on site (approximately 0.26 feet per year (ft/yr) to 0.91 ft/yr based on calculations presented in HGC, 2012b).

The extensive hydraulic testing of perched zone wells at the site indicates that perched zone permeabilities are generally low with the exception of the apparently isolated zone of higher permeability associated with the chloroform plume east to northeast (cross-gradient to upgradient) of the tailings management system. The geometric average hydraulic conductivity (less than 1 x 10^{-5} cm/s) of the DR-series piezometers which cover an area nearly half the size of the total monitored area at White Mesa (excluding MW-22), is nearly identical to the geometric average hydraulic conductivity of 1.01 x 10^{-5} cm/s reported by TITAN (1994), and is within the range of 5 to 10 feet per year (ft/yr) [approximately 5 x 10^{-6} cm/s to 1 x 10^{-5} cm/s] reported by Dames and Moore (1978) for the (saturated) perched zone during the initial site investigation.

3.1.3 Mancos Shale

Conformably overlying the Dakota Sandstone is the Upper Cretaceous Mancos Shale. The Mancos Shale was deposited in the Western Interior Cretaceous seaway (Figure 7) and is primarily composed of uniform, dark-gray mudstone, shale, and siltstone. It was deposited in nearshore and offshore neritic subenvironments of the Late Cretaceous Sea during its overall southwestern transgression and subsequent northeastward regression.

The Mancos Shale was named by Cross and Purington (1899) from exposures near Mancos, Colorado. Outcrops of the Upper Cretaceous Mancos Shale occur as hills and slopes generally near or directly beneath overlying Quaternary pediment remnants across portions of the Blanding Basin. Mancos Shale is absent in most of the Blanding Basin (due to erosion) where rocks of the Dakota Sandstone and Burro Canyon Formation are either exposed or mantled by thin unconsolidated deposits.

The Mancos Shale in the Blanding Basin consists of marine shale and interbeds of thin (less than 2 feet thick) sandstone and siltstone beds. Various pelecypod fossils are common in Mancos Shale outcrop areas (Huff and Lesure, 1965; Haynes *et al*., 1972). Total thickness is estimated at 30 to 40 feet, but is generally negligible to 20 feet, a small erosional remnant of its original thickness of approximately 2,000 feet. The Mancos Shale was deposited during transgression and highstand of the Cretaceous Interior Seaway during the Late Cretaceous (Elder and Kirkland, 1994). Where present, the Mancos Shale may act as an important impermeable layer reducing the amount of potential infiltration and recharge to the underlying Dakota-Burro Canyon perched aquifer (Avery, 1986; Goodknight and Smith, 1996).

The Mancos Shale belongs to the group of thick marine organic muds (or black shales) generally considered to be deposited in geosynclinal areas. Bentonitic volcanic ash layers are abundant in the Mancos Shale (Shawe, 1968). An abundance of pyrite in the layers may indicate that iron was an important constituent of the ash, possibly being liberated by devitrification of glass and redeposited with the diagenetic development of pyrite. Hydrogen sulfide was abundant in the organic rich sediments accumulating at the bottom of the Mancos Sea, if it was a typical sapropelic marine environment, as seems likely, and may have been especially abundant in the volcanic ash (Fenner, 1933).

Trapped sea water that is buried in the mud of the Mancos Shale likely had a high content of organic material consistent with the abundance of diagenetic pyrite. Chemical reduction resulting from hydrogen sulfide generated in carbon-rich sediments is characteristic of stagnant sea bottoms.

In the Early Tertiary, the original clay and silt deposited in the Mancos Shale became compacted to about a third to a tenth of its original water saturated volume by the time it was buried to a depth of about 10,000 feet (Shawe, 1976). Pore water throughout the Colorado Plateau, driven from compacting mud, moved largely upward into younger sediments (Yoder, 1955), but much water must have moved into the lower more porous strata because of local conditions of rock structure (Hedberg, 1936), because of the relatively high water density, and because of abnormally high fluid pressures. Expulsion of water likely occurred throughout the deposition of the Mancos Shale in the Late Cretaceous and during deposition of younger sediments in the Early Tertiary. Therefore expulsion occurred during a period of many millions of years and at depths ranging from near- surface to nearly maximum depths of burial.

Faulting occurred in many places on the Colorado Plateau, including the Blanding Basin during the Late Cretaceous and Early Tertiary when the Mancos was undergoing deep burial by younger strata. Faulting provided numerous avenues allowing water movement into underlying porous strata. It seems likely therefore that the Dakota Sandstone at the base of the Mancos Shale, and the dominantly sandy underlying Burro Canyon Formation, contained pore water which was expelled from the Mancos and was under abnormally high fluid pressures (Shawe, 1976).

Compaction of bedding around pyrite crystals shows the early development of part of the diagenetic pyrite, and indicates that pore fluids were being squeezed out of the Mancos Shale during the period of diagenesis. As pore fluids became trapped in the Mancos Shale following deposition of sediment in the Late Cretaceous, they immediately began to react with black opaque minerals, with magnetite deposited with the abundant ash fall material and possibly with volcanic glass and other iron-bearing material to form pyrite. Faulting that occurred on the Colorado Plateau in the Late Cretaceous and Early Tertiary facilitated movement of the Mancos pore water into underlying beds, causing removal of hematite coating on sand grains, destruction of detrital black opaque minerals, and growth of iron sulfide minerals (Shawe, 1976).

3.1.4 Pyrite Occurrence in the Dakota Sandstone and Burro Canyon Formation

As discussed above, downward movement of the Mancos Shale pore water into underlying beds of the Dakota Sandstone and Burro Canyon Formations caused removal of hematite coatings on sand grains, destruction of detrital black opaque minerals, and the growth of iron sulfide minerals. Shawe (1976) classifies the Dakota Sandstone and Burro Canyon Formations as "altered-facies" rocks primarily as a result of the invasion of pore waters expelled from the overlying Mancos Shale during compaction. Shawe states that "altered facies rocks that developed by solution attack are notable for their almost complete loss of black opaque minerals and gain of significant pyrite." Shawe further states that "altered-facies rocks contain only sparse black opaque minerals but appreciable pyrite" and that "alteration caused destruction of most detrital back opaque minerals, precipitation of substantial pyrite, and recrystallization of carbonate minerals that took up much of the iron liberated from the solution of black opaque minerals."

According to Shawe (1976), "altered-facies sandstone is light gray or, where weathered, also light buff to light brown. It contains only a small amount of black opaque heavy minerals and may or may not contain carbonaceous material. The light buff to light brown colors are imparted by limonite formed from oxidation of pyrite in weathered rock."

Furthermore Shawe (1976) states "In weathered rocks as observed in thin sections pyrite has been replaced by 'limonite', but preservation of original pyrite crystal forms and lack of abundant limonite 'wash' or dustlike limonite suggest that the forms of most limonite are indicative of the original forms of pyrite before oxidation. Pyrite (or limonite) in sandstone occurs as isolated interstitial patches as much as 2 millimeters (mm) in diameter enclosing many detrital grains, or as cubes 1 mm across and smaller that are mainly interstitial but that also partially replace detrital grains." Also "limonite pseudomorphs after marcasite have been recognized in vugs in altered-facies sandstone of the Burro Canyon Formation." Shawe (1976) also notes that pyrite is more common below the water table and iron oxides (likely formed by oxidation of pyrite) are more common in the vadose zone. These observations are consistent with the occurrence of and oxidation of pyrite in the formations hosting the perched water at the site as will be discussed in Section 4.

3.2 Contact Descriptions

Lithologic contacts between the Brushy Basin Member of the Morrison Formation, and between the Dakota Sandstone and the overlying soils and/or the Mancos Shale, are described in Sections 3.2.1 and 3.2.2. Cross-sections through soils based on soil borings installed per Phase I of the nitrate CAP are presented and discussed in Section 3.2.3.

3.2.1 Brushy Basin Member/Burro Canyon Formation Contact Elevations

Figure 8 is a contour map of the Burro Canyon Formation/Brushy Basin Member contact generated from perched well, piezometer, DR-series boring data and the locations and elevations of Westwater Seep and Ruin Spring. Figure 8 was generated based on data indicating that only Westwater Seep and Ruin Spring are located at the contact between the Burro Canyon Formation and the Brushy Basin Member (HGC, 2012b). Other seeps and springs (except Cottonwood Seep) shown on Figure 8 occur within generally conglomeratic horizons of the Burro Canyon Formation but at elevations above the contact with the underlying Brushy basin Member.

As discussed in HGC (2012b) examination of the area near Cottonwood Seep in July 2010 and re-examination in October 2011 revealed no evidence for a hydraulic connection with the perched zone. The absence of any visible seeps or anomalous vegetation in the Brushy Basin Member east and northeast of Cottonwood Seep is consistent with dry conditions in the upper portion of the Brushy Basin Member.

Figure 8 shows that the erosional Brushy Basin/Burro Canyon contact surface dips generally to the south-southwest and is very irregular in the northeast portion of the site. A paleoridge in the Brushy Basin erosional paleosurface extends from beneath cell 4B to the southwest near abandoned boring DR-18. To the east of this paleoridge, a paleovalley extends from south of cell 4A to the northeast, extending into the vicinity of the northern wildlife ponds. A paleovalley subparallel to the cell 4B paleoridge is also present on the west side of the paleoridge, between the paleoridge and the western mesa margin.

The approximate axes of these and other paleoridges and paleovalleys in the southwest portion of the site are indicated on Figure 8. These features are especially important in this portion of the site due to the generally small saturated thicknesses and the consequently relatively large impacts these features are expected to have on perched water flow in this area.

Other notable features include a paleoridge surrounded by paleovalleys that trend northwest – southeast (rather than northeast – southwest) in the area northeast of the millsite, a paleovalley extending from the area of cell 4B to Westwater Seep, and paleovalleys converging on Ruin Spring.

3.2.2 Mancos Shale/Dakota Contact Elevations

Figures 9 through 11 are elevation contour maps of the top of bedrock (top of the Dakota Sandstone or Mancos Shale [where present]), the top of the Dakota Sandstone, and the top of bedrock showing Mancos thickness. The thickness of the Mancos Shale shown in Figure 11 is based on the difference between the top of bedrock and top of Dakota Sandstone surfaces, and is clipped in areas where erosion is expected to have removed the Mancos. Based on these maps, the top of Dakota and top of bedrock surfaces dip generally to the south-southwest consistent with the general dip of the top of Brushy Basin surface. In the northeast portion of the site these surfaces are generally less irregular than the top of the Brushy Basin surface.

Notable features include a structural high in the top of Dakota and top of bedrock surfaces near cell 4B, and a north-south trending structural high in the top of bedrock surface east to northeast of the tailings management system. The latter feature is primarily the result of a ridge-like remnant of the Mancos Shale that reaches thicknesses greater than 30 feet along the axis of the feature.

Structural highs near cell 4B are present in the top of Brushy Basin surface (Figure 8), the top of bedrock (Figure 9), and the top of Dakota (Figure 10) surface. These features are ridge-like in all three surfaces but the paleoridge in the top of Brushy Basin is not coincident with the paleoridge in the top of bedrock and top of Dakota surfaces except in the vicinity of cell 4B. The primary axis of the paleoridge in the Brushy Basin surface extends from MW-33 at the southwest corner of cell 4B through DR-10, MW-21 and DR-18. The axis of the paleoridge in the top of bedrock surface extends from MW-35 through DR-11, DR-15, and DR-21. The axis of the paleoridge in the top of Dakota surface appears to extend from the vicinity of MW-24 (at the southwest corner of cell 1) through MW-33, DR-11, and possibly DR-15 (but is less well-defined near DR-15).

3.2.3 Soils Above The Dakota and /or Mancos

Figure 12 depicts the locations of soil borings installed near the ammonium sulfate crystal tanks as per Phase I of the nitrate CAP (HGC, 2012a). Borings were installed to depths of refusal using a drive-point rig as described in EFRI (2013). The depth of refusal is assumed to represent competent bedrock. Figure 13 depicts soils cross-sections developed from these borings.

Unconsolidated soils consist primarily of silts with interbedded sands and clays. Weathered Mancos Shale was encountered in many of the borings. Detailed logs of all soil borings are provided in EFRI (2013).

Soils present above the Mancos Shale in this portion of the site are dominated by the same fine-grained materials typical of other portions of the site. Soil types encountered in borings installed by INTERA (Appendix C) are generally consistent with those found in the vicinity of the ammonium sulfate crystal tanks and other portions of the site.

3.3 Perched Water Elevations, Saturated Thicknesses, and Depths to Water

As discussed in Section 2.1.3, Figure 5 is a contour map of perched water elevations generated from fourth quarter, 2017 water level data. Figure 5 contains perched well and piezometer water level data, and the elevations of all seeps and springs except Cottonwood Seep (for which there is no evidence to establish a connection to the perched water system and which is located near the Brushy Basin Member/Westwater Canyon Member contact, indicating that its elevation is not representative of the perched potentiometric surface). Fill-in contours between the 10-foot elevation contours are provided over portions of the site, including the area immediately west-southwest of the tailings management system to allow detail in an area having relatively flat hydraulic gradients.

Figure 5 was generated assuming that each seep or spring (except Cottonwood Seep) is a known discharge point for perched groundwater and that the elevation of the seep or spring is representative of the perched water elevation at that location (HGC, 2010g). As discussed in Section 2.1.4, because of the presence of cottonwoods, perched groundwater elevations near seeps/springs that are dry for portions of the year are likely to be near the surface.

Figure 14 shows the saturated thicknesses of the perched zone based on fourth quarter, 2017 water level data. Saturated thicknesses range from approximately 80 feet at MW-19 near the northern wildlife ponds to less than 5 feet in the southwest portion of the site, downgradient of the tailings management system. A saturated thickness of approximately 2 feet occurs in well MW-34 along the south dike of cell 4B, and the perched zone has been consistently dry at MW-33 located at the southwest corner of cell 4B, and at MW-21 located south-southwest of cell 4B. Abandoned well MW-16 (formerly located beneath cell 4B as shown in Figure 1A) was also consistently dry. MW-21, MW-33 and abandoned well MW-16 are all located on a structural high in the top of Brushy Basin Member surface (Figure 8).

Figure 15 shows depths to perched water as of the fourth quarter of 2017. Depths to perched water range from approximately 35 feet below top of casing (btoc) northeast of the tailings management system (at TWN-2, within the footprint of the historical pond) to approximately 115 feet btoc at the southwestern margin of cell 3. Prior to cessation of water delivery to the northern wildlife ponds the shallowest depths to water were encountered in piezometers and wells near these ponds.

3.4 Interpretation of Cross-Sections

Lithologic and soils cross-sections prepared for various portions of the site are discussed in the following Sections. In general, the lithologies encountered in the borings used to construct the cross-sections are consistent with the literature and with past investigations at the site (prior to TITAN, 1994).

3.4.1 Central and Northeast Areas

Figures 16A, 16B and 17 are lithologic cross-sections in the central to northeast portions of the site, as shown on Figure 1A. Figure 16A is a northeast-southwest oriented cross-section (NE-SW) extending from abandoned well MW-3 to TWN-12. Figure 16B is a parallel cross section (NE2-SW2) extending from TWN-18 to TWN-19. Figure 17 is a northwest-southeast cross-section (NW-SE) extending from TWN-7 to abandoned piezometer Piez-3. Figures 16A, 16B, and 17 indicate site features located near the cross-sections.

These cross-sections indicate that the top of Brushy Basin surface is irregular in the northeast portion of the site and that, as discussed in Sections 3.1.2.1 and 3.1.2.2, the Burro Canyon Formation and Dakota Sandstone contain shale/claystone and conglomerate interbeds of varying thickness and continuity. Where poorly indurated (poorly cemented), coarser sand and conglomeratic horizons are expected to be relatively permeable; shale/claystone horizons are expected to be at least partial barriers to perched groundwater flow, and where present in the vadose zone, to represent at least partial barriers to downward percolation of recharge. That local saturated conditions have not been encountered above shale/claystone horizons during drilling within the Dakota Sandstone and Burro Canyon Formations suggests that recharge rates over most of the site are generally low, except near unlined ponds or surface depressions, or other areas having enhanced recharge due to their locations within drainages or due to relatively flat, slowly drainable topography.

Figures 16A, 16B and 17 show that the perched water table surface remains relatively elevated in the vicinities of the northern wildlife ponds and the historical pond. TWN-2 (Figure 1B) is located within the footprint of the historical pond. As will be discussed in Section 3.5.2, the persistently high water level at TWN-2 likely results from low permeability and possibly enhanced recharge in the vicinity of TWN-2 due to graded areas of the millsite having relatively flat topography and relatively slow runoff.

3.4.2 Southwest Area

Figures 18 and 19 are cross-sections showing the hydrogeology of the perched zone in the area southwest of the tailings management system located as shown in Figure 1A. Figure 18 provides west-east cross-sections (W-E and W2-E2) across the area immediately west and southwest of cell 4B. Figure 19 is a south-north cross-section (S-N) from the south dike of cell 4B to Ruin Spring. Cross-sections W-E and S-N are oriented approximately parallel to perched water flow and W2-E2 is oriented roughly perpendicular to perched water flow. Except for abandoned DR-series borings, water levels in the cross sections are based on fourth quarter, 2017 data. Water levels for abandoned DR-series borings are from the second quarter, 2011. Water levels for DR-series piezometers have not changed significantly between the third quarter of 2011 and the fourth quarter of 2017 (as shown in Figure 20) suggesting that second quarter, 2011 water levels for abandoned DR-series borings are likely representative of current conditions.

As shown in Figure 14, cross-sections W-E and W2-E2 in Figure 18, and cross section S-N in figure 19, the saturated thickness of the perched zone in the southwest area of the site varies from negligible to more than 20 feet. The variable saturated thickness has implications regarding the flow of perched water to known discharge points Westwater Seep and Ruin Spring. Perched water moving downgradient from the vicinity of the tailings management system westward toward abandoned boring DR-2 must pass through a region of low saturated thickness occupied by DR-6 and DR-7 (Figures 5, 14 and 18). By Darcy's Law, downgradient areas affected by groundwater discharge points such as Westwater Seep and Ruin Spring that have larger saturated thicknesses must receive local recharge from precipitation because the water supplied by lateral perched flow is inadequate to maintain the large saturated thicknesses in these areas.

Two areas of relatively large saturated thickness that are downgradient of areas of small saturated thickness are of particular interest: the area near DR-2 (abandoned) and DR-5 located west of the area near DR-6 and DR-7 as shown in Figure 18 (cross-section W-E), and the area near DR-25 located south of the area near MW-20 as shown in Figure 19 (cross-section S-N). Each of the above areas of larger saturated thickness is downgradient of the corresponding area of small saturated thickness, and each downgradient area of larger saturated thickness is affected by a perched water sink or discharge point. The primary known perched groundwater discharge point or sink downgradient of DR-2 (abandoned) and DR-5 are Westwater Seep to the northeast and the paleovalley leading south to Ruin Spring (Figures 8 and 14). The primary discharge point near abandoned boring DR-25 is Ruin Spring. Lateral flow from areas of larger saturated thickness that may exist to the east of cross-section S-N may supply the water needed to maintain the relatively large saturated thickness near DR-25. However, the reported temporary increases in flow from Ruin Spring (and Westwater Seep) after precipitation events (HGC, 2010g) are problematic unless flow is temporarily enhanced by local recharge.

As discussed in HGC (2010g), enhanced local recharge is likely near the mesa margins where weathered Dakota Sandstone and Burro Canyon Formation are exposed by erosion (Figure E.2, Appendix E). Lithologic Logs at DR-2 and DR-5 (Appendix A) show only a few feet of unconsolidated material above the Dakota Sandstone and visual inspection of the mesa near DR-2 (abandoned) and DR-5 shows that weathered Dakota is often exposed (consistent with the geology presented in Dames and Moore (1978). Due to the thin veneer of alluvium overlying the Dakota Sandstone, and thin or absent Mancos Shale, recharge near DR-2 and DR-5 (cross-section W-E, Figure 18) will be facilitated. Similarly, in the area near abandoned boring DR-25 and Ruin Spring, recharge will be facilitated by the topography, the thinness or absence of the Mancos Shale, and the surface exposure of the Dakota Sandstone and Burro Canyon Formation between DR-25 and Ruin Spring (cross-section S-N, Figure 19).

3.5 Perched Water Occurrence and Flow

Description of the occurrence and flow of perched water at the site focuses on three general areas: 1) the nitrate investigation area, 2) the vicinity of the chloroform plume, and 3) areas beneath and downgradient of the tailings management system, as per Sections 3.5.2, 3.5.3, and 3.5.4 respectively.

3.5.1 Overview

As discussed in Section 2.1.3, perched groundwater at the site occurs primarily within the Burro Canyon Formation as well as the overlying Dakota sandstone where saturated thicknesses are greater. Perched water flow is generally from northeast to southwest across the site. Flow onto the site occurs as underflow from areas northeast of the millsite where perched zone saturated thicknesses are generally greater. Flow exits the Mill property in seeps and springs to the east, west, southwest and southeast. Any flow that does not discharge in seeps or springs presumably exits as underflow to the southeast of Ruin Spring, along the southwest extending lobe of White Mesa located between Ruin Spring and Corral Springs (Figure 1B).

3.5.1.1 General Site Flow Pattern

Fourth quarter 2017 perched water elevations (Figure 5) show the typical west-southwesterly to south-southwesterly flow pattern at the site. The historic water level contour maps in Appendix D demonstrate the persistence of the generally southwesterly perched flow pattern. As noted previously, the Appendix D maps do not incorporate seep and spring elevations.

As discussed in Section 2.1.3, beneath and downgradient of the tailings management system, on the west side of the site, perched water flow is south-southwest to west-southwest. On the eastern side of the site perched water flow is generally southerly to south-southwesterly. Perched zone hydraulic gradients currently range from a maximum of nearly 0.09 feet per foot (ft/ft) east of cell 2 (within the chloroform plume, between TW4-10 and TW4-11) to approximately 0.002 ft/ft in the northeast corner of the site (between TWN-19 and TWN-16). Hydraulic gradients in the southwest portion of the site are typically close to 0.01 ft/ft, but the gradient is less than 0.005 ft/ft to the west-southwest of cell 4B, between cell 4B and DR-8. The overall average site hydraulic gradient, between TWN-19 in the extreme northeast to Ruin Spring in the extreme southwest, is approximately 0.011 ft/ft.

Perched groundwater discharges in springs and seeps along the mesa margins. These features are located along Westwater Creek Canyon and Cottonwood Canyon to the west and southwest of the site, and along Corral Canyon to the east of the site, where the Burro Canyon Formation is exposed. Based on the data presented in Figure 5, the discharge points located most directly downgradient of the tailings management system are Westwater Seep and Ruin Spring. Westwater Seep is located approximately 2,200 feet west, and Ruin Spring is located approximately 9,400 feet south-southwest, of the existing tailings management system (Figure 1B).

Dry areas beneath cell 4B and southwest of cell 4B (south of MW-21) affect perched water flow and are defined in Figure 5 by areas where the kriged contact between the Burro Canyon Formation and the Brushy Basin Member is higher in elevation than the kriged perched groundwater elevation. The dry areas shown in Figure 5 encompass abandoned dry well MW-16, dry well MW-21, dry well MW-33, and abandoned dry boring DR-18. The areas defined by the heavy yellow dashed contour lines have saturated thicknesses estimated to be less than 5 feet. As shown in Figure 5 and southwest area cross-sections (Figures 18 and 19), a large portion of the perched zone west and southwest (downgradient) of the tailings management system has a saturated thickness less than 5 feet. This zone has been persistent based on measurements since the third quarter of 2011. An apparent perched water divide exists in the vicinity of DR-2 (abandoned, Figure 1A) and DR-5 (Figure 5). Perched water north of this apparent divide is expected to flow primarily northeast toward Westwater Seep and perched water south of this apparent divide is expected to flow primarily south toward Ruin Spring (as will be discussed in Section 3.5.4).

Figure 14 shows the axes of paleoridges and paleovalleys in the Brushy Basin Member erosional paleosurface and posted fourth quarter, 2017 saturated thicknesses. As indicated, paleoridges in the southwest area of the site are associated with dry areas and with areas of low saturated thicknesses; paleovalleys are associated with areas of higher saturated thicknesses. Westwater Seep and Ruin Spring are located in paleovalleys. The average saturated thickness based on measurements at MW-35, DR-7, and DR-6, which are the points closest to a line between the southwest portion of cell 3 and Westwater Seep, is approximately 5 feet. The average saturated thickness based on measurements at MW-37, DR-13, MW-3A, MW-20, and DR-21, which lay close to a line between the southeast portion of cell 4B and Ruin Spring, is approximately 10 feet.

Perched groundwater mounding associated with the wildlife ponds locally changes the generally southwesterly perched water flow patterns. For example, northeast of the Mill site, relict mounding associated with the northern wildlife ponds results in locally northerly flow near PIEZ-1. Mounding also causes the hydraulic gradient to be more westerly west of the ponds and more easterly east of the ponds. The impact of the mounding associated with the northern ponds, to which water has not been delivered since March 2012, continues to diminish as the mound decays due to reduced recharge. Similarly, the impact of mounding associated with the southern wildlife pond is diminishing due to reduced recharge. As discussed in Section 2.1.3, since the first quarter of 2012, water levels have declined within the northern mound by as much as 21 feet (at PIEZ-2), and within the southern mound by as much as 18 feet (at PIEZ-5).

3.5.1.2 Influence of Pumping and Wildlife Pond Seepage on Flow and Dissolved Constituent Concentrations

Figures 1A and 1B show the locations of chloroform and nitrate pumping wells at the site. MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37, and TW4-39 are chloroform pumping wells; and TWN-2, TW4-22, TW4-24, and TW4-25 are nitrate pumping wells. Figure 21 is a map showing kriged fourth quarter 2017 perched water levels, the extents of the nitrate and chloroform plumes at the site, and inferred perched water flow paths. Figure 22 is a detail map showing the locations of perched wells, fourth quarter, 2017 kriged water levels, and inferred capture zones associated with pumping wells.

As discussed in Section 2 (although not shown on Figures 1A or 1B), two additional chloroform wells, TW4-40 and TW4-41, were installed during February, 2018 (HGC, 2018b). TW4-40 was installed approximately 200 feet south of TW4-26 and TW4-41 was installed immediately north-northeast of TW4-4. TW4-41 was designed as a pumping well to augment chloroform mass removal in the southern portion of the plume.

As described in HGC (2012a) the nitrate pumping system, which became operational in the first quarter of 2013, is designed to (eventually) establish hydraulic capture of the nitrate plume upgradient (north of) TW4-22 and TW4-24. MW-30 and MW-31, located at the downgradient edge of the plume, are not pumped in order to minimize the potential for downgradient chloroform migration. As described in HGC (2007) and HGC (2018b), the chloroform pumping system, which became operational in 2003 with the pumping of MW-4, TW4-19, and MW-26 (TW4-15), and later enhanced by the addition of TW4-20 in 2005; TW4-4 in 2010; TW4-1, TW4-2, TW4-11, TW4-21, and TW4-37 in 2015; and TW4-39 in 2016, is designed primarily to reduce mass in upgradient portions of the plume where saturated thicknesses, concentrations, and well productivities are higher. Mass reduction is thereby maximized, the source of chloroform to downgradient areas cut off, and natural attenuation facilitated.

Local depression of the perched water table occurs near chloroform pumping wells MW-4, MW-26, TW4-1, TW4-2, TW4-11, TW4-19, TW4-20, TW4-21, and TW4-39 (Figure 22). Pumping of chloroform wells MW-4 and TW4-19 began in 2003 (HGC, 2004). Well-defined cones of depression are evident near all chloroform pumping wells except TW4-4, which began pumping in the first quarter of 2010, and TW4-37, which began pumping during 2015. Although operation of chloroform pumping well TW4-4 has depressed the water table in the vicinity of TW4-4, a well-defined cone of depression is not clearly evident. The lack of a well-defined cone of depression near TW4-4 likely results from 1) variable permeability conditions in the vicinity of TW4-4, and 2) persistent relatively low water levels at adjacent well TW4-14, as will be discussed in Section 3.5.3. The lack of a well-defined cone of depression near TW4-37 is likely due to its close proximity to chloroform and nitrate pumping wells TW4-20 and TW4-22.

Local depression of the perched water table also occurs near nitrate pumping wells TW4-22, TW4-24, and TW4-25 (Figure 22), which are operated to reduce nitrate mass in the perched groundwater as per the nitrate CAP (HGC, 2012a). TWN-2 is also a nitrate pumping well but the cone of depression associated with this well is apparently masked by its location on the edge of a perched groundwater mound. Cones of depression may still be in the process of development in the vicinities of nitrate pumping wells which were brought on-line in the first quarter of 2013. Relatively slow development of capture zones is expected due to generally low permeability within the nitrate plume.

The hydraulic effects of the chloroform and nitrate pumping systems overlap. Figure 22 shows the inferred capture of both chloroform and nitrate pumping systems as of the fourth quarter, 2017. Capture zones are calculated by hand based on the kriged water level contours following the rules for flow nets. From each pumping well, stream tubes that bound the capture zone are reverse-tracked, and perpendicularity is maintained between each stream tube and the intersected kriged water level contours.

Recharge from the wildlife ponds has impacted perched water elevations and flow directions at the site by creating perched groundwater mounds as discussed in Section 3.5.1. Furthermore, the March 2012 cessation of water delivery to the northern ponds, which are generally upgradient of the nitrate and chloroform plumes at the site, has resulted in changing conditions that were expected to impact constituent concentrations and migration rates within the plumes. Specifically, past recharge from the ponds has helped limit many constituent concentrations within the plumes by dilution while the associated groundwater mounding has increased hydraulic gradients and contributed to plume migration. Since use of the northern ponds was discontinued in March 2012, increases in constituent concentrations in many wells, and decreases in hydraulic gradients within the plumes, are attributable to reduced recharge and the decay of the associated groundwater mound.

The impacts associated with cessation of water delivery to the northern wildlife ponds were expected to propagate downgradient (south and southwest) over time. Wells close to the ponds were generally expected to be impacted sooner than wells farther downgradient of the ponds. Therefore, constituent concentrations were generally expected to increase in downgradient wells close to the ponds before increases were detected in wells farther downgradient of the ponds. Although such increases were anticipated to result from reduced dilution, the magnitude and timing of the increases have been difficult to predict due to the complex permeability distribution at the site and factors such as pumping and the rate of decay of the perched groundwater mound. The potential exists for some wells completed in higher permeability materials to be impacted sooner than some wells completed in lower permeability materials even though the latter may be closer to the ponds. Localized increases in concentrations of constituents such as chloroform and nitrate within and near the chloroform plume, and of nitrate and chloride within and near the nitrate plume, may occur even when these plumes are under control. Ongoing mechanisms that can be expected to increase constituent concentrations locally as a result of reduced wildlife pond recharge include but are not limited to:

1. Reduced dilution - the mixing of low constituent concentration pond recharge into existing perched groundwater will be reduced over time.
2. Reduced saturated thicknesses – dewatering of any higher permeability layers receiving primarily low constituent concentration pond water will result in wells intercepting these layers receiving a smaller proportion of the low constituent concentration water.

The combined impact of the above two mechanisms was considered to be especially likely at chloroform and nitrate pumping wells and non-pumped wells adjacent to the pumped wells. The expected overall impact was generally higher constituent concentrations in chloroform and nitrate wells over time until mass reduction resulting from pumping and natural attenuation eventually reduced concentrations. Short-term changes in concentrations at pumping wells and wells adjacent to pumping wells are also expected to result from changes in pumping conditions.

3.5.2 Nitrate Investigation Area

The extent of the nitrate plume addressed by the nitrate CAP (HGC, 2012a) and referred to as the 'nitrate plume' (defined by nitrate as nitrogen concentrations exceeding 10 mg/L) is shown in Figure 21. Figure 21 also displays kriged fourth quarter, 2017 perched water level contours and inferred flow paths and shows the extent of the chloroform plume which overlaps the nitrate plume in the vicinity of TW4-22. Nitrate exceeding 10 mg/L also occurs to the southeast of the plume in relatively isolated pockets (near TW4-10, TW4-12, TW4-18, and TW4-27). As discussed in HGC (2014a), this southeastern nitrate is attributed to sanitary leach field discharge associated with the chloroform plume and potentially with former cattle ranching operations at the site. Nitrate exceeding 10 mg/L at far down gradient location MW-20 is also potentially associated with former cattle ranching operations. The potential for cattle to contribute nitrate to soil is discussed in McFarland *et al* (2006). Elevated nitrate in soil can then act as a source to groundwater.

Perched groundwater flow within the area of the nitrate plume varies from southwest to west-southwest. The generally southwesterly gradient typical of the majority of the site is influenced by past recharge from the northern wildlife ponds, and elevated water levels in the vicinities of wells TWN-2 and TWN-3. TWN-2 is within the footprint of the historical pond and TWN-3 is immediately east of the footprint of the pond, as shown in Figure 1B. Recharge from the northern wildlife ponds, located immediately northeast of the nitrate plume, caused a shift in gradient in the northern portion of the plume from southwesterly to west-southwesterly (compare Appendix D 1990 and 1994 water level maps with Figure 21). The persistently elevated water level at TWN-2, which has functioned as a nitrate pumping well since the first quarter of 2013, likely results from low permeability and possibly enhanced recharge in the vicinity of TWN-2 due to graded areas of the millsite having relatively flat topography and relatively slow runoff.

Cones of depression associated with nitrate pumping wells TW4-22, TW4-24, TW4-25, and TWN-2, have been developing since initiation of pumping during the first quarter of 2013. Hydraulic capture associated with these wells is developing slowly due to low permeability conditions. That sufficient capture will eventually develop is indicated by calculations presented in HGC (2017) showing that nitrate pumping exceeds pre-pumping flow through the nitrate plume by a factor of approximately 2.1.

Water level patterns near nitrate pumping wells are expected to be influenced by the presence of, and the decay of, the groundwater mound associated with the northern wildlife ponds, and by the persistently low water level elevation at TWN-7. Chloroform and nitrate pumping wells interact. The long term interaction between nitrate and chloroform pumping systems continues to evolve.

Criteria regarding control and potential migration of the nitrate plume are detailed in the nitrate CAP (HGC, 2012a). As stated in the CAP, MW-5, MW-11, MW-30, and MW-31 are located downgradient of TW4-22 and TW4-24. MW-30 and MW-31 are within the nitrate plume near its downgradient edge and MW-5 and MW-11 are outside and downgradient of the plume. Per the CAP, hydraulic control based on concentration data is considered successful if the concentrations of nitrate in MW-30 and MW-31 remain stable or decline, and concentrations of nitrate in downgradient wells MW-5 and MW-11 do not exceed the 10 mg/L standard. Based on these criteria, the nitrate plume is under control.

The plume has not migrated downgradient to MW-5 or MW-11 because nitrate has not been detected at MW-11 and has been detected at concentrations less than 1 mg/L at MW-5. Nitrate concentrations in both MW-30 and MW-31 at the downgradient edge of the plume have been relatively stable, demonstrating that plume migration is minimal or absent (HGC, 2017).

As discussed in Section 2, elevated chloride (exceeding 100 mg/L) commingles with the nitrate plume. Chloride has been stable to increasing at MW-30 and is increasing at MW-31, consistent with ongoing downgradient migration (HGC, 2017). The apparent increases in chloride and stable nitrate at MW-30 and MW-31 suggest a natural attenuation process that is affecting nitrate but not chloride. A likely process that would degrade nitrate but leave chloride unaffected is reduction of nitrate by pyrite. The likelihood of this process in the perched zone is discussed in HGC (2012c) and HGC (2017). Estimated natural nitrate degradation rates range from approximately 172 pounds per year (lb/yr) to 200 lb/yr as discussed in HGC (2017). Based on these rates, less than 200 years would be required to remediate the nitrate plume, even in the absence of any direct mass removal by pumping.

Understanding of perched water level behavior in the area northeast of the millsite was enhanced by the installation of TWN-series wells northeast of the nitrate plume in 2009. Prior to the installation of these wells, upgradient information was limited to that provided by MW-1, MW-18, MW-19, PIEZ-1, and PIEZ-2. As shown in Figure 1B, nitrate wells TWN-5, TWN-8, TWN-9, TWN-10, TWN-11, TWN-12, TWN-13, TWN-15, and TWN-17 have been abandoned as per the nitrate CAP.

In general, water level data provided by these TWN-series wells and existing wells and piezometers in the northeast portion of the Mill property indicated that perched water flow is to the southwest. Data from many of these wells helped to better define the extent of the perched groundwater mound resulting from former recharge at the northern wildlife ponds. Figure 23 is a water level contour map from the fourth quarter, 2011 constructed prior to both TWN well abandonment and cessation of water delivery to the wildlife ponds. Comparing Figure 23 with Figure 5 demonstrates the substantial reductions in the perched groundwater mounds associated with the wildlife ponds between the fourth quarters of 2011 and 2017.

3.5.3 Vicinity of Chloroform Plume

As noted in Section 3.5.1.2, the footprint of the chloroform plume is shown in Figure 21. The plume boundary is defined by the Groundwater Corrective Action Limit (GCAL) of 70 μg/L. Water level and concentration data presented in this Section are from EFRI (2018b) or HGC (2018a) unless otherwise indicated.

Perched groundwater flow within the area of the chloroform plume has been generally southerly to southwesterly. The chloroform plume resulted from disposal of laboratory wastes to the abandoned scale house and former office sanitary leach fields. The abandoned scale house leach field is the likely source of the southeastern portion of the plume and the former office leach field is the likely source of the northwestern portion of the plume (HGC, 2007). Both of these sources received laboratory wastes prior to operation of the tailings management system (circa 1980), and in the case of the abandoned scale house leachfield, prior to construction of the Mill. Laboratory wastes prior to 1980 were first disposed to the abandoned scale house leach field and later to the former office leach field. Laboratory wastes have been disposed to the tailings management system since it became operational circa 1980.

The abandoned scale house leach field was located immediately north-northwest of well TW4-18 (Figure 1B). Historic perched water flow in this area was generally to the south (Appendix D). Chloroform disposed in the abandoned scale house leach field migrated primarily southerly to the vicinity of well MW-4 where it was detected in 1999. Hydraulic gradients and flow directions in this area were impacted by pre-2012 recharge from the northern wildlife ponds located north of MW-4.

The former office leach field is located in the immediate vicinity of well TW4-19 (a chloroform pumping well) and immediately northeast of cell 2 (and chloroform pumping well TW4-20) [Figure 1B]. Perched water flow in this area was historically southwest (Appendix D), and hydraulic gradients were enhanced by pre-2012 recharge from the northern wildlife ponds (located to the northeast).

Once chloroform pumping began in 2003 the flow regime, formerly dominated by wildlife pond recharge in the vicinity of the chloroform plume, began to change locally under the influence of the pumping. Reduced wildlife pond recharge since the first quarter of 2012 and the initiation of nitrate pumping in the first quarter of 2013 have also impacted the flow regime.

Well defined cones of depression are evident in the vicinity of all chloroform pumping wells except TW4-4, which began pumping in the first quarter of 2010, and TW4-37, which began pumping during 2015. The lack of a well-defined cone of depression near TW4-37 is likely due to its close proximity to chloroform pumping well TW4-20 and nitrate pumping well TW4-22. The lack of a well-defined cone of depression near TW4-4 likely has causes other than proximity of other pumping wells, although operation of chloroform pumping well TW4-4 has depressed the water table in the vicinity of TW4-4.

As discussed in Section 3.5.1.2 variable permeability conditions likely contribute to the lack of a well-defined cone of depression near chloroform pumping well TW4-4. Changes in water levels at wells immediately south of TW4-4 resulting from TW4-4 pumping are expected to be muted because TW4-4 is located at a transition from relatively high to relatively low permeability conditions south (downgradient) of TW4-4. The permeability of the perched zone at TW4-6, TW4-26, and TW4-29 is approximately two orders of magnitude lower than at TW4-4 (Table 1). Any drawdown of water levels at wells immediately south of TW4-4 resulting from TW4-4 pumping is also difficult to determine because of the general increase in water levels that occurred in this area due to past recharge from the wildlife ponds.

Water levels at TW4-4 and TW4-6 increased by nearly 2.7 and 2.9 feet, respectively, between the fourth quarter of 2007 and the fourth quarter of 2009 (just prior to the start of TW4-4 pumping) at rates of approximately 1.2 feet/year and 1.3 feet/year, respectively. However, the increase in water level at TW4-6 was reduced after the start of pumping at TW4-4 (first quarter of 2010) to approximately 0.5 feet/year suggesting that TW4-6 is within the hydraulic influence of TW4-4 (Figure 24).

Since the fourth quarter of 2013, water levels in all wells currently within the chloroform plume south of TW4-4 (TW4-6, TW4-29, and TW4-33) have been trending generally downward. This downward trend is attributable to both the cessation of water delivery to the wildlife ponds and pumping. Generally increasing water levels are now confined to some of the wells marginal to the chloroform plume such as TW4-14, TW4-27, TW4-30, and TW4-31.

These spatially variable water level trends likely result from pumping conditions, the permeability distribution, and distance from the wildlife ponds. Wells that are relatively hydraulically isolated (due to completion in lower permeability materials or due to intervening lower permeability materials) and that are more distant from pumping wells and the wildlife ponds, are expected to respond more slowly to pumping and reduced recharge than wells that are less hydraulically isolated and are closer to pumping wells and the wildlife ponds. Wells that are more hydraulically isolated will also respond more slowly to changes in pumping.

The ongoing lack of a well-defined cone of depression at TW4-4 is also influenced by the persistent, relatively low water level at non-pumping well TW4-14, located east of TW4-4 and TW4-6. For the fourth quarter of 2017, the water level at TW4-14 (approximately 5534.3 ft amsl) is less than 1 foot lower than the water level at TW4-6 (approximately 5534.5 ft amsl) and nearly 5 feet lower than the water level at TW4-4 (approximately 5539.1 ft amsl), even though TW4-4 is pumping. In general, water level differences among these wells are diminishing.

The static water levels at wells TW4-14 and downgradient well TW4-27 (installed south of TW4-14 in the fourth quarter of 2011) were similar (within 1 to 2 feet) until the third quarter of 2014; both appeared anomalously low. TW4-27 was positioned at a location considered likely to detect any chloroform present and/or to bound the chloroform plume to the southeast and east (respectively) of TW4-4 and TW4-6. As will be discussed below, groundwater data collected since installation indicates that TW4-27 does indeed bound the chloroform plume to the southeast and east of TW4-4 and TW4-6 (respectively); however chloroform exceeding 70 µg/L has been detected at more recently installed temporary perched wells TW4-29 (located south of TW4-27) and TW4-33 (located between TW4-4 and TW4-29).

Prior to the installation of TW4-27, the persistently low water level at TW4-14 was considered anomalous because it appeared to be downgradient of all three wells TW4-4, TW4-6, and TW4-26, yet chloroform had not been detected at TW4-14. Chloroform had apparently migrated from TW4-4 to TW4-6 and from TW4-6 to TW4-26. This suggested that TW4-26 was actually downgradient of TW4-6, and TW4-6 was actually downgradient of TW4-4, regardless of the flow direction implied by the low water level at TW4-14. The water level at TW4-26 (5533.4 feet amsl) is, however, lower than water levels at adjacent wells TW4-6 (5534.5 feet amsl), and TW4-23 (5535.7 feet amsl).

Hydraulic tests indicate that the permeability at TW4-27 is an order of magnitude lower than at TW4-6 and three orders of magnitude lower than at TW4-4 (Table 1). Past similarity of water levels at TW4-14 and TW4-27, and the low permeability estimate at TW4-27, suggested that both wells were completed in materials having lower permeability than nearby wells. The low permeability condition likely reduced the rate of long-term water level increase at TW4-14 and TW4-27 compared to nearby wells, yielding water levels that appeared anomalously low. This behavior is consistent with hydraulic test data collected from more recently installed wells TW4-29, TW4-30, TW4-31, TW4-33, TW4-34 and TW4-35, which indicate that the permeability of these wells is one to two orders of magnitude higher than the permeability of TW4-27 (Table 1). Hydraulic tests also indicate that the permeability at TW4-36 is slightly higher than but comparable to the low permeability at TW4-27, suggesting that TW4-36, TW4-14 and TW4-27 are completed in a continuous low permeability zone.

The fourth quarter, 2017 water level at TW4-27 (approximately 5528.9 ft. amsl) is more than 5 feet lower than the water level at TW4-14 (5534.3 ft. amsl). Increases in water level differences between TW4-14 and TW4-27 since 2013 are attributable to more rapid increases in water levels at TW4-14 compared to TW4-27. This behavior likely results primarily from: the relative positions of the wells; past water delivery to the northern wildlife ponds; and the permeability distribution. Past seepage from the ponds caused propagation of water level increases in all directions including downgradient to the south. The relative hydraulic isolation of TW4-14 and TW4-27 delayed responses at these locations to such an extent that they are still responding to the past seepage. Water levels at these wells are still lower than in surrounding higher permeability materials even though water levels in surrounding materials are now generally decreasing due to reduced wildlife pond seepage and pumping. As a result, water levels at TW4-14 and TW4-27 are still increasing. Compared to TW4-27, the rate of increase is higher at TW4-14 due to factors that include: closer proximity to the northern pond seepage source; a smaller thickness of low permeability materials separating TW4-14 from surrounding higher permeability materials; and hydraulic gradients between TW4-14 and surrounding higher permeability materials that on average have been larger. Slowing of the rates of water level increase at TW4-14 (since 2015) and TW4-27 (since early 2014) is attributable to reduced hydraulic gradients as TW4-14 and TW4-27 water levels 'catch up' with water levels in surrounding higher permeability materials.

In addition, water levels in this area may also be affected by reduced recharge at the southern wildlife pond and the consequent decay of the associated groundwater mound. The decay of the southern mound is likely to contribute to the reduction in hydraulic gradients between the low permeability materials penetrated by TW4-14 and TW4-27 and the surrounding higher permeability materials. TW4-27 is closer to the southern wildlife pond than TW4-14. Any reduction in hydraulic gradients attributable to the southern pond is expected to impact TW4-27 sooner and to a greater extent than TW4-14, consistent with the lower rate of increase in water levels at TW4-27, and the earlier reduction in the rate of increase (since early 2014) as discussed above.

The low permeability at TW4-14 and TW4-27 is expected to retard the transport of chloroform to these wells (compared to nearby wells). TW4-14 and TW4-27 remain outside the plume with fourth quarter, 2017 chloroform concentrations of approximately 6.1 µg/L and 5.9 µg/L, respectively.

Chloroform exceeding 70 µg/L detected at TW4-29 and TW4-33 since their installation in 2013 indicated that, in addition to migrating south from TW4-4 to TW4-6 and TW4-26, chloroform also migrated along a relatively narrow path to the southeast from the vicinity of TW4-4 to TW4-33 then TW4-29. Such migration was in a direction nearly cross-gradient with respect to the direction of groundwater flow implied by the historic groundwater elevations in this area, which, until relatively recently, placed TW4-14 almost directly downgradient of TW4-4. Such migration was historically possible because the water levels at TW4-29 have been lower than the water levels at TW4-4 (and TW4-6). The permeability and historic water level distributions are generally consistent with the apparent nearly cross-gradient migration of chloroform from TW4-4 around the low permeability zone defined by TW4-36, TW4-14, and TW4-27.

During the fourth quarter of 2017 chloroform at TW4-30 (located east and downgradient of TW4-29) was detected at approximately 13.4 µg/L, and was not detected at wells TW4-31 (located east of TW4-27), TW4-34 (located south and cross-gradient of TW4-29), nor TW4-35 (located southeast and generally cross- to downgradient of TW4-29).

Data from wells within and adjacent to the southern portion of the chloroform plume indicate that:

1. Chloroform exceeding 70 µg/L at TW4-29 is bounded by concentrations below 70 µg/L at wells TW4-23, TW4-27, TW4-30, TW4-34, and TW4-35. TW4-30 is downgradient of TW4-29; TW4-23 is generally cross- to upgradient of TW4-29; and TW4-27, TW4-34 and TW4-35 are generally cross- to downgradient of TW4-29.
2. Chloroform concentrations at TW4-33 that are lower than concentrations at TW4-29, and the likelihood that a pathway exists from TW4-4 to TW4-33 to TW4-29, suggest that concentrations in the vicinity of TW4-33 were likely higher prior to initiation of TW4-4 pumping, and that lower concentrations currently detected at TW4-33 are due to its closer proximity to TW4-4.
3. Chloroform concentrations at TW4-26 exceeded 70 µg/L for the first time during the second quarter of 2017. Chloroform at TW4-26 is bounded by non-detectable concentrations at TW4-23 (located up- to cross-gradient of TW4-26), and at TW4-34 (located downgradient of TW4-26). Chloroform at TW4-26 is bounded far to the south-southwest (cross-gradient) by MW-17 (non-detect) and far to the south (cross- to downgradient) by MW-22 (non-detect) but is not bounded directly to the south by any nearby wells.
4. As discussed above, a new chloroform well (TW4-40) was installed during February, 2018 in an attempt to bound the plume immediately to the south of TW4-26, and a new pumping well, TW4-41, was installed near TW4-4 to improve chloroform mass removal within the southern portion of the plume (HGC, 2018b).

Eventually, TW4-4 pumping (enhanced by pumping at TW4-41) is likely to reduce chloroform at both TW4-33 and TW4-29 by cutting off the source. The decrease at TW4-33 is expected to be faster than at TW4-29 because TW4-33 is in closer proximity to TW4-4 pumping. Such behavior is expected by analogy with the temporary decreases in chloroform concentrations that occurred at TW4-6 and TW4-26 once TW4-4 pumping began (discussed above). Since installation in 2013, however, concentrations at TW4-33 appear to be relatively stable; since the third quarter of 2014, concentrations at TW4-29 appear to be generally increasing.

Relatively stable chloroform at TW4-33 and generally increasing concentrations at TW4-29 suggest that chloroform migration has been arrested at TW4-33 by TW4-4 pumping and that increasing chloroform at downgradient well TW4-29 results from a remnant of the plume that continues to migrate downgradient (toward TW4-30, which bounds the plume to the east). The influence of TW4-4 pumping at the distal end of the plume is consistent with generally decreasing water levels at both TW4-29 and TW4-33.

Decreasing water level trends at these wells are also consistent with reduced wildlife pond seepage. The decay of the groundwater mound associated with the southern wildlife pond, which is 3 to 4 times closer to the southern extremity of the chloroform plume than the northern ponds, is likely to have an impact on water levels within and adjacent to this portion of the plume.

Similarly, decreasing water level trends (since about the fourth quarter of 2013) at TW4-6 and TW4-26, and increased concentrations (since the first quarter of 2014 and the third quarter of 2016, respectively) are consistent with reduced wildlife pond seepage, in particular, reduced seepage from the southern wildlife pond. As the groundwater mound associated with the southern pond decays, groundwater flow directions in the southern extremity of the plume are likely to become more southerly (rather than southeasterly), and plume migration is likely to turn more to the south. An increasingly southerly direction of plume migration is consistent with increasing concentrations at TW4-26. Continued decay of the southern mound is expected to result in eventual restoration of the typical site southwesterly flow pattern within this portion of the plume.

Detectable chloroform concentrations at TW4-14 (since the fourth quarter of 2014) and TW4-27 (since the third quarter of 2015) suggest ongoing, but slow, downgradient migration of chloroform from the distal end of the plume (defined by TW4-29 and TW4-33) into the low permeability materials penetrated by TW4-14 and TW4-27.

Although chloroform at the southeastern extremity of the plume may temporarily continue to migrate to the southeast, the southeastern extremity of the plume is approximately 1,200 feet from the closest (eastern) property boundary (Figure 1B). Site water level data suggest that the plume is unlikely to reach the eastern property boundary as perched water flow along the boundary to the east of the southeastern extremity of the plume appears to be generally south-southwesterly and sub-parallel to the boundary (Figure 1B; Figure 21; HGC, 2014a). The southern property boundary on the east side of the site is more than three miles to the south of the plume and the nearest downgradient discharge point (Ruin Spring) is nearly two miles to the south-southwest of the plume. Because of the large distance to the southern property boundary, chloroform mass removal by pumping, and natural attenuation of chloroform, it is unlikely that chloroform within the southern or southeastern extremities of the plume will ever reach the southern property boundary at concentrations exceeding the GCAL.

As discussed in HGC (2018a), reduced dilution from reduced wildlife pond recharge caused average chloroform concentrations and calculated residual masses within the plume to increase after 2012; however both average concentrations and calculated residual masses have been trending downward since 2015. In addition, the more than doubling of the number of chloroform pumping wells since 2014 has increased mass removal rates and has helped to maintain a relatively large proportion of the plume mass under hydraulic capture (nearly 90%). Furthermore, as will be discussed in Section 4.4.3, first-order chloroform biodegradation rate calculations presented in HGC (2007) and HGC (2018a) indicate that less than 200 years would be required to remediate the plume, even in the absence of any direct mass removal by pumping.

3.5.4 Beneath and Downgradient of the Tailings Management System

As discussed in Section 2, more than 37 years of groundwater monitoring beneath and downgradient of the tailings management system indicates that the system has not impacted groundwater. In the event that potential seepage from the tailings management system should impact groundwater at a future date, the likely pathways to known discharge points Westwater Seep and Ruin Spring are calculated in Section 3.5.4.1. Perched zone water balances within the areas near DR-2 (abandoned) and DR-5, and flow within the vicinities of Westwater Seep and Ruin Spring are calculated in Sections 3.5.4.2 and 3.5.4.3.

3.5.4.1 Overview

Figure 25 is a perched water level contour map showing inferred pathlines from various locations on the west or south (downgradient) dikes of tailings management system cells toward known discharge points Westwater Seep and Ruin Spring. These pathlines show the primary expected directions of perched water flow. As indicated, perched water passing beneath the west dike of cell 4B has the potential to travel to either of known discharge points Westwater Seep or to Ruin Spring because of an apparent groundwater divide in the vicinity of DR-2 (abandoned; Figure 1A) and DR-5. Perched water north of this apparent divide is expected to flow primarily northeast to Westwater Seep and perched water south of this apparent divide is expected to flow primarily south toward Ruin Spring. The presence of this apparent divide is consistent with enhanced recharge over this portion of the mesa.

The path to Ruin Spring from the area south of the apparent groundwater divide is sub-parallel to the western rim of the mesa. The path is generally along a paleovalley between the mesa rim and the dry portion of the Brushy Basin Member paleoridge defined by MW-21 and abandoned boring DR-18. Perched water passing beneath the south dike of cell 4B is expected to travel south-southwest to Ruin Spring, to the east of the dry paleoridge defined by MW-21 and abandoned boring DR-18.

As discussed previously, the data suggest that perched water flow in the southwest portion of the site is influenced by paleotopography to a greater extent than in other areas of the site due to the prevalence of relatively small saturated thicknesses.

As discussed in Section 2.1.4, there is no evidence to hydraulically connect Cottonwood Seep to the perched water system; therefore no inferred flow pathway depicted in Figure 25 leads to Cottonwood Seep. Section 3.6.3 posits a potential pathway that may hypothetically exist between the perched zone near DR-8 and Cottonwood Seep for purposes of travel time calculations, and to allow for the possibility that an as yet unidentified pathway may exist.

3.5.4.2 Water Balance Near DR-2 and DR-5

Enhanced recharge south/southwest of Westwater Seep near DR-2 (abandoned; Figure 1A) and DR-5 is likely needed to maintain the relatively large saturated thicknesses there, considering the slow rate of perched water flow into this area via the zone of small saturated thickness and the presence of known discharge point Westwater Seep to the northeast and the paleovalley leading south to Ruin Spring (acting as a sink).

Because the water columns in most piezometers penetrating the area of low saturated thicknesses were inadequate for hydraulic testing, only one estimate of hydraulic conductivity was obtained, at DR-10. As shown in Table 1, the KGS method hydraulic conductivity estimates at DR-10 (located within the area of low saturated thickness) were one to two orders of magnitude lower than at DR-5 and DR-9, located west of the area of low saturated thickness. Assuming the estimate at DR-10 is representative of the area of low saturated thickness, the transmissivity (the product of hydraulic conductivity and saturated thickness) of the area of low saturated thickness is two to three orders of magnitude lower than for the area of larger saturated thickness to the west (near DR-2 [abandoned], DR-5, and DR-9). Figures 5 and 25 show that the hydraulic gradient in this area is relatively flat; the gradient does not change significantly across the area of low saturated thickness, but flattens to the west (downgradient) of the area.

Water flows westward from the area of the tailings management system through the area of low saturated thickness between DR-6 and DR-10 (Figure 25). The fourth quarter, 2017 saturated thicknesses at DR-6 and DR-10 are approximately 1.7 feet and 2.5 feet, respectively, averaging 2.1 feet. Using Darcy's Law, and assuming a hydraulic conductivity of 3×10^{-6} cm/s (0.0084 feet per day [ft/day], based on the KGS estimate provided for DR-10 in Table 1), an average hydraulic gradient of approximately 0.0056 ft/ft, an average saturated thickness of approximately 2.1 ft, and a width of approximately 1,600 feet (the approximate distance between DR-6 and DR-10), the rate of perched water flow westward through the area of low saturated thickness is approximately 0.16 cubic feet per day (ft^3/day) or 0.00082 gpm.

Water flows out of the area of larger saturated thickness (near DR-2 [abandoned] and DR-5) to the northeast toward known discharge point Westwater Seep and to the south through the paleovalley leading towards known discharge point Ruin Spring. The rate of flow out of this area northeast to Westwater Seep is expected to be smaller than the discharge rate at Westwater Seep which also receives water from the east and northeast. The discharge rate at Westwater Seep is too small for a reliable estimate. However, the rate of flow south through the paleovalley leading towards Ruin Spring can be calculated using the geometric average hydraulic conductivity of 0.0089 ft/day (based on KGS estimates for DR-8 [October, 2012 estimate], DR-9, and DR-10 in Table 1), an approximate hydraulic gradient of 0.0083 ft/ft (between DR-9 and DR-14), an average saturated thickness of approximately 12 ft, and a width of approximately 2,250 ft (between DR-8 and DR-10), as 2.0 ft^3/day, or approximately 0.01 gpm, an order of magnitude larger than the calculated flow into the area. The difference between calculated inflow and outflow is approximately 0.009 gpm.

These calculations indicate that an additional water source is needed to maintain the relatively large saturated thicknesses west of the area of low saturated thickness between DR-6 and DR-10; otherwise Westwater Seep and the paleovalley to the south would drain the area of larger saturated thickness more quickly than water was supplied. The most likely source of additional water is infiltration of precipitation enhanced by the direct exposure of weathered Dakota Sandstone and Burro Canyon Formation, and the thinness or absence of any overlying low permeability materials such as the Mancos Shale. Assuming uniform recharge over the portion of the mesa west of Westwater Seep and north of DR-8 and DR-9 (an area of approximately 175 acres, or 7.6×10^6 square feet [ft^2]), the calculated difference of 0.009 gpm implies a conservatively low recharge rate of approximately 0.001 inches per year (in/yr). Most of the recharge likely occurs near the mesa rim where the Dakota Sandstone and Burro Canyon Formation are exposed (Figure E.1 and Figure E.2, Appendix E). Such recharge is expected to be enhanced within drainages where they cross weathered Dakota Sandstone and Burro Canyon Formation.

Furthermore, these calculations indicate that perched water flow in the portion of the site south of Westwater Seep is inadequate as a primary supply to Cottonwood Seep. Perched water flow from the area of the tailings management system through the area of low saturated thickness towards Cottonwood Seep would have to be more than three orders of magnitude higher than calculated above to provide a supply of between approximately 1 and 10 gpm. The required flow would have to be even larger considering that some of the incoming flow is diverted to known discharge point Westwater Seep and to the paleovalley that leads south to known discharge point Ruin Spring. Even if this calculation were performed using the geometric average of the KGS hydraulic conductivity estimates for all tested DR-series piezometers (approximately 1 x 10^{-5} cm/s or 0.028 ft/day) rather than the estimate for DR-10 (3 x 10^{-6} cm/s or 0.0084 ft/day), the calculated rate of flow through the area of low saturated thickness would be approximately 0.0031 gpm, which is still approximately three orders of magnitude lower than the estimated discharge rate of Cottonwood Seep. The inadequacy of the perched zone as the primary supply to Cottonwood Seep indicates that the primary source or sources of Cottonwood Seep lie elsewhere.

3.5.4.3 Water Balance Near Ruin Spring and Westwater Seep

Figure 26 is a map showing inferred perched groundwater pathlines in the immediate vicinities of Ruin Spring and Westwater Seep. These pathlines were used to estimate expected flow rates to these features based on Darcy's Law using local hydraulic gradients, saturated thicknesses, and hydraulic conductivity estimates. Saturated thicknesses posted on Figure 26 were calculated as the difference between kriged fourth quarter, 2017 water level and top of Brushy Basin Member surfaces.

The water level contours plotted on Figure 26 do not demonstrate the increase in hydraulic gradient that would generally be expected when groundwater approaches a discharge point such as Ruin spring (or an extraction well). However, the increase in hydraulic gradient is evident if an additional data point, DR-25 (Figure 1A), is considered. Boring DR-25 was abandoned during 2011; however, as shown in Figure 20, water levels at DR-series piezometers have been stable. Therefore, the water level at abandoned boring DR-25 at the present time would likely be about the same as the second quarter, 2011 water level that was included in Figure 19. As shown in Figure 19 the water table (and hydraulic gradient) show the expected steepening approaching Ruin Spring.

The area of the perched zone providing flow to Ruin Spring was estimated by assuming the flow is approximately divided between Ruin Spring to the west and Corral Springs to the east. This division coincides approximately with a groundwater divide that extends southwest from the southern wildlife pond toward Ruin Spring, approximately parallel to the southeasternmost flow path depicted on Figure 21. Using the geometric average hydraulic conductivity based on estimates at DR-21, DR-23, and DR-24 (2.2 x 10^{-5} cm/s or 0.062 ft/day based on KGS analysis of automatically logged slug test data [Table 6]), which are closest to Ruin Spring, an average hydraulic gradient of approximately 0.01 ft/ft, and an average saturated thickness of approximately 17.5 feet over a width of approximately 7,700 feet (along the 5420 foot elevation contour), yields a rate of perched flow of approximately 84 ft^3/day or 0.44 gpm.

The calculated value of 0.44 gpm is slightly less than the estimated average flow for Ruin Spring of approximately 0.5 gpm. Assuming that the difference between the calculated perched water flow and the estimated flow at Ruin Spring (0.06 gpm or 12 ft^3/day) is due to local recharge over the area of Figure 26 covered by the inferred flow paths (approximately 420 acres or 18.3 x 10^6 ft^2), then the local recharge rate needed to make up the difference is approximately 6.6 x 10^{-7} ft/day or 0.0029 in/yr. If the average flow for Ruin Spring were as high as 1 gpm, then approximately 0.56 gpm, or 0.026 in/yr of local recharge would be needed to make up the difference. Both estimates of local recharge are relatively small and within a range that is reasonable considering the topography and surface lithology of this portion of the site.

Perched groundwater flow to Westwater Seep was similarly estimated. Hydraulic conductivities used in the calculations are summarized in Table 6. Hydraulic conductivity estimates at DR-5, DR-8, DR-9, DR-10, and DR-11 are based on automatically logged slug test data analyzed using the KGS solution method; estimates at MW-12, MW-14, and MW-15 are based on pumping test analyses reported in TITAN (1994) [Table 4]. Estimates from DR-2, DR-16, and DR-17 are not available as hydraulic tests could not be performed because these borings were abandoned after surveying and water level collection based on the criteria presented in HGC (2012b). Tests also could not be performed at DR-6 nor DR-7 due to an insufficient water column.

Using a geometric average hydraulic conductivity of 9.8 x 10^{-6} cm/s (0.027 ft/day), an average hydraulic gradient of 0.013 ft/ft, and an average saturated thickness of 4.8 feet over a width of approximately 3,300 feet, yields a rate of perched flow of approximately 5.6 ft^3/day or 0.029 gpm. If the geometric average of the hydraulic conductivities estimated at the four closest wells (MW-23, MW-24, MW-35, and DR-5) is substituted (1.8 x 10^{-5} cm/s [0.05 ft/day]), the calculated rate of perched flow is 10.3 ft^3/day or 0.054 gpm. In calculating the latter average, the highest estimate from the MW-24 test was used. Because the flow to Westwater Seep is too small to be reliably measured (as discussed in Section 3.7), either result is considered reasonable.

3.6 Perched Water Migration Rates and Travel Times

Perched groundwater pore velocities and travel times along selected pathlines shown in Figure 27 were calculated using Darcy's Law. The calculated pore velocities and travel times are representative of the movement of a conservative solute assuming no hydrodynamic dispersion. Hydraulic conductivity estimates used for pathlines 1, 2A, and 2B are summarized in Table 7, and for pathlines 3 through 6 in Table 8. Pore velocity estimates are summarized in Table 9.

3.6.1 Nitrate Investigation Area

Perched groundwater pore velocities and travel times were calculated along Path 1 (Figure 27) located within the nitrate plume. Path 1 is approximately 1,425 feet long. Under current conditions, a particle migrating along Path 1 would be captured by nitrate pumping well TW4-24 (near the center of the plume).

The average hydraulic conductivity along Path 1 is assumed to be the geometric average of the conductivities of wells located within and immediately upgradient and downgradient of the nitrate plume (wells TWN-2, TWN-3, TWN-18, TW4-21, TW4-22, TW4-24, TW4-37, MW-11, MW-27, MW-30, and MW-31) as estimated by analyzing automatically logged slug test data using the KGS solution (Table 7). Using a geometric average conductivity of 1.27 x 10^{-4} cm/s (0.36 ft/day), a hydraulic gradient of 0.023 ft/ft, and a porosity of 0.18, the estimated average pore velocity along Path 1 is approximately 17 ft/yr. This implies that, under current conditions, approximately 84 years would be required to traverse Path 1.

Historic hydraulic gradients within the area of the nitrate plume were likely much larger than 0.023 ft/ft during the time prior to Mill construction when the historical pond was active (Figure 1B). The depth to water at TWN-2, located within the former footprint of the historical pond (Figure 1B), was approximately 16 feet bls prior to its conversion to a nitrate pumping well. The relatively small depth to water is interpreted to result from the relatively low perched zone permeability at TWN-2 (approximately 1.5 x 10^{-5} cm/s) and slightly elevated recharge by precipitation resulting from the relatively flat topography in that portion of the site. When the historical pond was active and ponded water was present in the vicinity of TWN-2, depths to water were likely negligible as the associated groundwater mound likely reached an elevation just beneath the pond bottom.

Historic water level maps (Appendix D) show that water levels in the vicinities of MW-30 and MW-31, located along the downgradient margin of cell 2, and at the downgradient margin of the nitrate plume, were approximately 5,520 feet amsl. Assuming that the perched water level beneath the historical pond was close to the pond bottom (approximately 5,625 feet amsl), the perched water level at the downgradient edge of cell 2 was approximately 5,520 feet amsl, and the distance between the southern edge of the historical pond and the downgradient edge of cell 2 was approximately 2,200 feet, the historic hydraulic gradient is calculated as approximately

0.048 ft/ft. This estimate is more than four times the overall average site hydraulic gradient of approximately 0.011 ft/ft (calculated between TWN-19 and Ruin Spring).

Using the geometric average hydraulic conductivity of 0.36 ft/day (as discussed above), the estimated historic hydraulic gradient of 0.048 ft/ft, and a porosity of 0.18, the estimated historic pore velocity downgradient of the historical pond is approximately 35 ft/yr, implying that nitrate originating from the historical pond could have migrated to the downgradient edge of cell 2 within 63 years. Assuming the historical pond was active circa 1920, that nitrate was conservative, and ignoring hydrodynamic dispersion, nitrate originating from the historical pond could have reached the vicinities of MW-30 and MW-31 by 1983.

3.6.2 Vicinity of Chloroform Plume

Perched groundwater pore velocities and travel times along Paths 2A and 2B (Figure 27), located within the vicinity of the chloroform plume, were calculated. Path 2A is approximately 1,045 feet long and path 2B is approximately 1,190 feet long. Under current conditions, a particle migrating along Path 2A would be captured by chloroform pumping well MW-26, and. a particle migrating along Path 2B would be captured by chloroform pumping well TW4-2. In evaluating average hydraulic conductivities along these paths, estimates assuming both confined and unconfined conditions were used. This methodology is considered appropriate for this area of the site because of the potential for semi-confined conditions to exist at least locally (HGC, 2004).

The average hydraulic conductivity along Path 2A is assumed to be the geometric average of the conductivities of nearby wells MW-26, TW4-5, TW4-9, TW4-10, and TW4-18 (Table 7). Using a geometric average conductivity of 3.88×10^{-4} cm/s (1.1 ft/day), a hydraulic gradient of 0.022 ft/ft, and a porosity of 0.18, the estimated average pore velocity along Path 2A is approximately 48 ft/yr. This pore velocity implies that, under current conditions, approximately 22 years would be required to traverse Path 2A.

The average hydraulic conductivity along Path 2B is assumed to be the geometric average of the conductivities of nearby wells MW-4A, TW4-2, TW4-8, TW4-9, TW4-28 and TW4-38 (Table 7). Estimates based on the early time data for MW-4A (formerly located approximately 10 feet south of MW-4) were used in calculating the averages because these data are considered more representative of conditions in the immediate vicinity of MW-4. Using a geometric average conductivity of 1.21×10^{-4} cm/s (0.34 ft/day), a hydraulic gradient of 0.039 ft/ft, and a porosity of 0.18, the estimated average pore velocity along Path 2B is approximately 27 ft/yr. This pore velocity implies that, under current conditions, approximately 44 years would be required to traverse Path 2B.

Historic hydraulic gradients within the northern (upgradient) areas of the eastern portion of the chloroform plume (prior to about 1990) were likely larger and contributed to relatively rapid movement of chloroform from the abandoned scale house leach field (located immediately north of TW4-18) to MW-4 where chloroform was detected in 1999. The assumptions are made that 1) water levels near the abandoned scale house leach field were affected relatively early by wildlife and/or historical pond seepage (owing to the close proximity of the northern wildlife ponds and historical pond); and 2) that the water level at TW4-18, which was relatively stable and averaged approximately 5,586 ft amsl between installation in 2002 and cessation of water delivery to the northern wildlife ponds in 2012, is representative of the water level at the leach field circa 1980. Based on these assumptions and the historic water level maps provided in Appendix D, the hydraulic gradient over the approximate 1,200 foot distance between the abandoned scale house leach field and MW-4 was approximately 0.048 ft/ft in 1990 and approximately 0.029 ft/ft in 1999, averaging 0.038 ft/ft. This is more than three times the overall average site hydraulic gradient of approximately 0.011 ft/ft (calculated between TWN-19 and Ruin Spring) but is within the range of hydraulic gradients occurring at present within and adjacent to the chloroform plume, and is similar to the current hydraulic gradient of approximately 0.041 ft/ft just east the plume, between non-pumping wells TW4-36 and TW4-27.

Using a geometric average hydraulic conductivity of 1.1 ft/day based on Table 3 estimates from wells MW-4A, TW4-5, TW4-9, TW4-10, and TW4-18 (located near a line connecting MW-4 with the abandoned scale house leach field), an estimated historic hydraulic gradient of 0.038 ft/ft, and a porosity of 0.18, the calculated average pore velocity prior to 1999 was approximately 84 ft/yr. This is sufficient for chloroform to have migrated from the abandoned scale house leach field to MW-4 between 1978 and 1999. This calculation implies that chloroform could have migrated nearly to TW4-4 by 1999.

3.6.3 Beneath and Downgradient of Tailings Management System

Estimated times for a hypothetical conservative solute originating from the tailings management system to migrate downgradient to known discharge points Westwater Seep and Ruin Spring assuming no dispersion are calculated in the following Sections. Because the hypothetical conservative solute is assumed to originate from individual cells within the system, the time for the solute to migrate downward from the base of a cell to the perched water must be taken into account. Vadose zone travel times are estimated in Section 3.6.3.1. Total travel times are estimated in Section 3.6.3.2.

3.6.3.1 Vadose Zone

Depths to perched groundwater near cell 2 vary from approximately 63 feet btoc near the northeast (upgradient) corner of the cell to approximately 112 feet btoc at the northwest corner of the cell. Depths to water near cell 3 vary from approximately 69 feet btoc near the northeast (upgradient) corner of the cell to approximately 115 feet btoc at the southwest (downgradient) corner of the cell. Depths to water near cells 4A and 4B vary from approximately 79 feet btoc near the northeast (upgradient) corner of cell 4A to approximately 112 feet btoc along the western margin of cell 4B. The average depth to water near cell 2 is approximately 77 feet btoc; near cell 3 approximately 92 feet btoc; and near cells 4A and 4B approximately 102 feet btoc. Because the cells are installed a maximum of approximately 25 feet below grade, the average depth to perched water from the base of cell 2 is approximately 52 feet; beneath cell 3 approximately 67 feet; and beneath cells 4A and 4B approximately 77 feet.

Any seepage through the cell liners would have to travel downward through approximately 52 feet of vadose materials to impact perched water beneath cell 2; through approximately 67 feet to impact perched water beneath cell 3; and through approximately 77 feet to impact perched water beneath cells 4A and 4B.

Knight-Piésold (1998) estimated a maximum volumetric seepage rate for cell 3 based on cell construction and liner characteristics, of approximately 80 cubic feet per day (ft/day) or 0.42 gpm over the entire cell. Most of this seepage was estimated to be via diffusion through the liner. This rate was estimated to decrease over time as the cell desaturates once the final cover is emplaced. Assuming a cell footprint of 3.38×10^6 ft^2, this maximum rate is equivalent to 2.37×10^{-5} ft/day or 0.0086 ft/yr.

The average saturation expected in vadose bedrock beneath the tailings management system is approximately 20% based on saturations measured in bedrock samples presented in Table 5 (from TITAN, 1994).

Assuming that the Knight-Piésold estimates from cell 3 are also representative of cell 2 and cells 4A and 4B, and assuming that this rate of seepage would not significantly raise the average saturation of the underlying vadose zone materials, the average rate of downward movement of a conservative solute dissolved in the seepage, assuming 1) no hydrodynamic dispersion, 2) an average water saturation of 0.20, and 3) an average porosity of 0.18, can be approximated as:

$$\frac{0.0086\,ft/yr}{(.20)(.18)} = 0.24\,ft/yr$$

The average times to travel from cell liners to the perched water zone would then be approximately 216 years beneath cell 2; 279 years beneath cell 3; and 320 years beneath cells 4A and 4B. These are conservative estimates because the maximum estimated seepage rate is used, and the average vadose zone water saturations would be likely to increase (because some of the seepage would go into storage), thereby reducing the downward rates of travel, and increasing the travel times.

Numerical modeling of potential tailings management system seepage and rates of downward migration of solutes are provided in MWH (2010). Based on Figure A-3 from MWH (2010), the simulated seepage rates beneath cells 2 and 3 would reach a maximum of approximately 7.7 millimeters per year (mm/yr) [0.025 ft/yr] by year 25, then drop to approximately 0.7 mm/yr (0.0023 ft/yr) by year 70. The average seepage rate over the 240 year simulation period is approximately 0.0043 ft/yr, half the estimate used in the above calculations. Using this rate with the above assumptions would double the travel times estimated for seepage to reach perched water beneath cells 2, 3, and 4A and 4B. However, the MWH analyses used smaller initial water saturations for the vadose zone which correspondingly reduced travel time estimates. Based on personal communication with MWH personnel, a 200+ year vadose zone travel time estimate for cells 2 and 3 is considered reasonable.

The estimates calculated above for cell 2 (216 years), cell 3 (279 years) and cells 4A and 4B (320 years) will be used in subsequent calculations. Because cells 2 and 3 are at least 34 years old, the travel times starting from the present time will be 182 years for cell 2, and 245 years for cell 3. Cell 4B was installed in 2010 and cell 4A refurbished and put into use shortly thereafter so the effective travel time will be assumed to be 312 years for these cells. Furthermore, the estimates for cells 4A and 4B are considered even more conservative because of improvements in cell design and liner quality that were incorporated in these cells but were not available during construction of cells 2 and 3.

3.6.3.2 Perched Water Zone Downgradient of Tailings Management System

Perched groundwater pore velocities and travel times along selected paths between the existing tailings management system and perched water discharge points were calculated for pathlines 3 through 6 shown in Figure 27.

The Figure 27 pathlines were selected as the shortest Figure 25 paths from the tailings management system to a) Westwater Seep (Path 3), b) Ruin Spring via the west side of the Brushy Basin paleoridge (Path 5), and c) Ruin Spring via the east side of the Brushy Basin paleoridge (Path 6). A pathline from the tailings management system to the vicinity of DR-8 (Path 4) is also shown on Figure 27. From the vicinity of DR-8 perched water is expected to flow primarily south (within a paleovalley) toward Ruin Spring. However, a potential pathline from the vicinity of DR-8 is also shown in Figure 27 that posits a hypothetical connection between the perched zone and Cottonwood Seep. Path 4 provides the shortest pathline between the tailings management system and the western edge of the perched zone near DR-8, and the potential path provides the shortest hypothetical connection between the western edge of Path 4 and Cottonwood Seep.

Hydraulic conductivities used in the calculations are summarized in Table 8. Hydraulic conductivity estimates are based on automatically logged slug test data analyzed using the KGS solution method, except for MW-12, MW-14, and MW-15. Hydraulic conductivity estimates at MW-12, MW-14, and MW-15 are based on pumping test analyses reported in Table 4 (from TITAN, 1994). Hydraulic tests could not be performed at DR-2, DR-16, DR-18, nor DR-25. These borings were abandoned after surveying and water level collection based on the criteria presented in HGC (2012b). Tests also could not be performed at DR-6 nor DR-7 due to insufficient water column height. Pore velocity calculations for pathlines 3 through 6 are summarized in Table 9.

Path 3 is approximately 2,200 feet long with an average hydraulic gradient of 0.0132 feet per foot (ft/ft) based on the fourth quarter, 2017 water level at MW-23 (5,497 ft amsl) and the elevation of Westwater Seep (5,468 ft amsl). The geometric average hydraulic conductivity of the perched zone in the vicinity of Path 3 (based on data from DR-5, DR-8, DR-9, DR-10, DR-11, MW-12, MW-23, MW-24, and MW-36) is 9.8 x 10^{-6} cm/s (0.027 ft/day or 10 ft/yr). Assuming an effective porosity of 0.18, the average perched water pore velocity along Path 3 is 0.73 feet per year (ft/yr), yielding a travel time of approximately 3,015 years. Including a vadose zone travel time of approximately 245 years for cell 3, the total travel time is approximately 3,260 years.

Path 4 is approximately 4,125 feet long with an average hydraulic gradient of 0.0046 ft/ft based on the fourth quarter, 2017 water level at MW-36 (5,493 ft amsl) and the water level at DR-8 (5,474 ft amsl). The geometric average hydraulic conductivity of the perched zone in the vicinity of Path 4 (based on data from DR-5, DR-8, DR-9, DR-10, DR-11, MW-12, MW-23, MW-24, and MW-36) is 9.8 x 10^{-6} cm/s (0.027 ft/day or 10 ft/yr). Assuming an effective porosity of 0.18, the average perched water pore velocity along Path 4 is 0.26 feet per year (ft/yr), yielding a travel time of approximately 15,860 years. Including a vadose zone travel time of approximately 312 years for cell 4A, the total travel time is approximately 16,170 years. The additional time to travel along the hypothetical pathway to Cottonwood Seep is not calculated because of the hypothetical nature of the pathway and because the hypothetical pathway is through the Brushy Basin Member which is considered an aquiclude. If such a pathway exists, the combined travel time along Path 4 and the hypothetical pathway (which adds approximately 2,150 horizontal feet to the total path length), would be significantly greater than 16,170 years.

Path 5 is approximately 11,800 feet long with an average hydraulic gradient of 0.0096 ft/ft based on the fourth quarter, 2017 water level at MW-36 (5,493 ft amsl) and the elevation of Ruin Spring (5,380 ft amsl). The geometric average hydraulic conductivity of the perched zone in the vicinity of Path 5 (based on test data from DR-5, DR-8, DR-9, DR-10, DR-11, DR-14, DR-17, DR-19, DR-20, DR-21, DR-23, DR-24, MW-23, MW-24, and MW-36) is 1.1 x 10^{-5} cm/s (0.031 ft/day or 11.3 ft/yr). Assuming an effective porosity of 0.18, the average perched water pore velocity along Path 5 is 0.60 ft/yr, yielding a travel time of approximately 19,660 years. Including a vadose zone travel time of approximately 312 years for cell 4A, the total travel time is approximately 19,970 years.

Path 6 is approximately 9,700 feet long with an average hydraulic gradient of 0.0115 ft/ft based on the first quarter, 2014 water level at MW-37 of 5,492 ft amsl and the elevation of Ruin Spring (5,380 ft amsl). The geometric average hydraulic conductivity of the perched zone in the vicinity of Path 6 (based on test data from DR-11, DR-13, DR-21, DR-23, DR-24, MW-3, MW-14, MW-15, MW-20 and MW-37) is 1.38 x 10^{-5} cm/s (0.039 ft/day or 14.1 ft/yr). Assuming an effective porosity of 0.18, the average perched water pore velocity along Path 6 is 0.90 ft/yr, yielding a travel time of approximately 10,775 years. Including a vadose zone travel time of approximately 312 years for cell 4B, the total travel time is approximately 11,085 years.

3.7 Implications for Seeps and Springs

The lithologic and hydraulic data collected from the southwest area investigation (HGC 2012b) allow a more comprehensive assessment of the hydrogeology of the site and have implications with regard to seeps and springs southwest of the site. The data indicate that dilution of perched water by local recharge is expected to occur in the vicinities of Westwater Seep and Ruin Spring, and that perched zone permeabilities and flow rates in the southwestern portion of the site are too low (by several orders of magnitude) for the perched zone to serve as the primary source of water for Cottonwood Seep.

3.7.1 Westwater Seep and Ruin Spring

As discussed in HGC (2010g) the water source for both Westwater Seep and Ruin Spring is lateral flow from upgradient portions of the perched zone enhanced by local recharge near the edge of the mesa. Most of this recharge likely occurs near the mesa rim where weathered Dakota Sandstone and Burro Canyon Formation are exposed. Such recharge is likely to be enhanced within drainages where they cross weathered Dakota Sandstone and Burro Canyon Formation. The results of the southwest area investigation (HGC, 2012b) indicate that the permeability of the perched zone in the southwest area of the site is on average lower than was estimated prior to 2010 (as in HGC, 2009) and that the contribution to flow at Westwater Seep and Ruin Spring by local recharge may be more significant than previously thought.

3.7.2 Cottonwood Seep

The low perched zone permeabilities and small saturated thicknesses in the southwest area of the site are consistent with low rates of perched water flow, as shown by the calculated flow through the area of small saturated thickness southwest of the tailings management system (between DR-6 and DR-10) provided in Section 3.5.4.2. This low rate of perched water flow (approximately 0.00082 gpm) is inadequate (by more than three orders of magnitude) to function as the primary supply to Cottonwood Seep which has historic flows estimated to lie between 1 and 10 gpm. As discussed in Section 3.5.4.2, the estimated flow of between 1 and 10 gpm at Cottonwood Seep is consistent with Dames and Moore (1978).

In summary, the perched zone cannot be the primary source of water to Cottonwood Seep for the following reasons:

1. Cottonwood Seep occurs in the lower third of Brushy Basin Member, approximately 230 feet below the contact between the Burro Canyon Formation and the Brushy Basin Member, more than 1,500 ft west of the termination of the perched zone, and just west of a change in morphology from slope-former to bench-former. The change in morphology is indicative of a change in lithology. As discussed in HGC (2010g) Cottonwood Seep likely originates from coarser-grained materials within the lower portion of the Brushy Basin Member. Alternatively, Cottonwood Seep may originate from coarser-grained materials of the Westwater Canyon (sandstone) Member intertongueing with the overlying Brushy Basin Member at the transition between the two Members. The presence of coarser-grained materials similar to the Salt Wash (sandstone) Member within the lower portion of the Brushy Basin member is discussed in Shawe (2005). The intertongueing of the Westwater Canyon and Brushy Basin Members is discussed in Craig *et al.* (1955) and Flesch (1974). Based on lithologic cross sections provided in TITAN (1994), the elevation of Cottonwood Seep (5,234 ft amsl) is within 5 to 15 feet of the elevation of the contact

between the Brushy Basin Member and the underlying Westwater Canyon Member (5,220 to 5,230 ft amsl). This is also shown in Figure 3.

2. The historic flow at Cottonwood Seep exceeds the flow in the perched zone in the area southwest of the tailings management system by several orders of magnitude. Historic flows at Cottonwood Seep are relatively large compared to seeps and springs known to originate from the perched zone, consistent with a primary source other than perched water.

3. There is no evidence to establish a direct hydraulic connection between the perched zone and Cottonwood Seep, located more than 1,500 ft west of the termination of the Burro Canyon Formation which hosts the perched water zone. Examination of the area between Cottonwood Seep and mesa rim (the edge of the perched zone) reveals that the upper portion of the Brushy Basin Member appears dry and no previously undiscovered seeps originating from the Burro Canyon Formation near Cottonwood Seep were identified.

Because the results of the southwest area investigation do not provide evidence that Cottonwood Seep is hydraulically connected to the perched water system at the site, and because the perched zone near Cottonwood Seep is inadequate as a primary supply, the primary source (or sources) of water to Cottonwood Seep must lie elsewhere. The primary source(s) must be significant to supply consistent historic flows at rates between 1 and 10 gpm. By contrast, flows at Ruin Spring (estimated at approximately $^1/_2$ gpm, consistent with Dames and Moore, 1978) are lower than at Cottonwood Seep (historically between 1 and 10 gpm), and flows at Westwater Seep are too small to measure reliably. Westwater Seep generally consists of damp soil that can be sampled only by excavating and waiting for enough water to seep in for sample collection (see Figures 28 and 29 taken from HGC, 2010g).

Although no evidence of a direct hydraulic connection between the perched zone and Cottonwood Seep was provided by the southwest area investigation, the possibility of a hypothetical, as yet unknown, connection was postulated for the purpose of calculating a travel time from the tailings management system to the western edge of the perched zone (near DR-8), and thence along a potential pathway to Cottonwood Seep. The total travel time from the tailings management system to DR-8 was calculated as approximately 16,170 years. Should a potential pathline such as that shown in Figure 27 exist, the total time needed to travel from the tailings management system to Cottonwood Seep would be significantly larger than 16,170 years.

3.7.3 Potential Dilution of Perched Water Resulting from Local Recharge of the Dakota and Burro Canyon Near Seeps and Springs

As discussed in Section 3.5.4.2, the rate of flow in the perched water zone in the southwest area of the site is small and a contribution from local recharge is needed to explain many areas of relatively high saturated thickness near discharge points such as Westwater Seep and Ruin Spring that are downgradient of areas of relatively low saturated thickness. The presence of local recharge is expected to affect the water quality of seeps and springs and has the potential to dilute any dissolved constituents that may migrate from upgradient areas.

3.8 Implications for Transport of Chloroform and Nitrate

Chloroform and nitrate plumes are under remediation by pumping. Pumping systems are designed to remove chloroform and nitrate mass from the perched zone as quickly as is practical to allow natural attenuation in the far downgradient portions of the plumes to be more effective. Furthermore, nitrate pumping is designed to capture approximately the northern $^{2}/_{3}$ of the nitrate plume. Pumping at the downgradient margin of the chloroform plume has been impractical primarily due to low permeability and low productivity conditions. Pumping at the downgradient margin of the nitrate plume has also been impractical primarily because of the potential to draw chloroform downgradient.

In the absence of remedial pumping, the western portion of the nitrate plume would eventually migrate towards Westwater Seep and the eastern portion toward Ruin Spring (Figure 21 and Figure 30). In the absence of remedial pumping, the western portion of the chloroform plume would eventually migrate towards Ruin Spring and the eastern portion toward the perched groundwater low centered on TW4-31 (located immediately east of TW4-27 near the southeastern tip of the plume [Figure 30]). Should the low at TW4-31 eventually disappear, chloroform within the eastern extremity of the plume would be expected to migrate towards the lobe of the White Mesa between Ruin and Corral Springs. In addition, the continuing decay of the perched groundwater mound associated with the southern wildlife pond and the resulting more southerly to southwesterly flow within the southern portion of the plume, is expected to place Ruin Spring downgradient of the entire plume.

As indicated by calculations in Section 3.6, thousands of years would be required for either the chloroform or nitrate plume to reach a discharge point. That is sufficient time for both chloroform and nitrate to degrade naturally prior to reaching a discharge point as will be discussed in Section 4.4.

The groundwater low at TW4-31 is interpreted to result from partial hydraulic isolation from upgradient and cross-gradient areas that were more strongly affected by wildlife pond seepage. Prior to 2012, wildlife pond seepage resulted in increases in water levels at wells in the vicinity of TW4-27 as shown in Figure 31. Prior to 2012, water levels in wells TW4-6, TW4-26, and

TW4-13 rose relatively rapidly compared with water levels at TW4-14. The permeabilities of TW4-6 and TW4-26 are similar (Table 1) and both exhibit similar water level behavior. The permeability at TW4-27 is relatively low (Table 1), and the similar water level behavior at TW4-14 and TW4-27 between 2012 and 2014 suggests that TW4-14 is also installed in low permeability materials. After 2012, water levels at TW4-27 began to stabilize; however water levels at TW4-14 continued to increase until 2016 before beginning to stabilize. These differences are likely due to the relative distances of these wells from the northern and southern wildlife ponds. That both wells are having a delayed response to reduced wildlife pond recharge is also consistent with low permeability at both locations.

The low permeability at TW4-27, the inferred low permeability at TW4-14, and the low permeability at TW4-36 (Table 1) suggests that a continuous low-permeability zone extends from TW4-27 through TW4-14 to TW4-36. These low permeability materials are the likely cause of the partial hydraulic isolation of TW4-31. Because the groundwater low at TW4-31 is interpreted to result from variable permeability and from transient hydraulic conditions brought on by former wildlife pond seepage, water levels in this area are expected to 'catch up' eventually with water levels in less hydraulically isolated areas.

Water balance calculations near Westwater Seep and Ruin Spring (Section 3.5.4.3) indicate that local recharge is needed to maintain areas having relatively large saturated thicknesses that supply water to known discharge points Westwater Seep and Ruin Spring but that are isolated from other portions of the perched zone by areas of relatively low saturated thickness. The presence of local recharge near these discharge points at least partly explains reported increased flow at these features after precipitation events (HGC, 2010g). In the unlikely event that nitrate or chloroform not removed by pumping did not degrade within the thousands of years needed to reach a discharge point, local recharge would act to reduce concentrations prior to discharge.

4. COMPOSITION OF DAKOTA SANDSTONE AND BURRO CANYON FORMATION

As discussed in HGC (2012c), samples of selected archived drill core and drill cuttings were analyzed visually and quantitatively by an analytical laboratory. Table 10 summarizes the mineralogy of samples submitted to the contract laboratory for quantitative analysis. Table 11 summarizes the occurrence of pyrite, iron oxides, and carbonaceous material in site drilling logs having sufficient detail. Table 12 summarizes the results of laboratory visual (microscopic) analyses for sulfides. Table 13 and Figure 32 summarize the occurrence of pyrite in site borings based on both lithologic logs and laboratory analyses.

4.1 Mineralogy

As discussed in Section 3.1.2, the Dakota Sandstone is a relatively hard to hard, generally fine-to-medium grained sandstone cemented by kaolinite clays. The underlying Burro Canyon Formation is similar to the Dakota Sandstone but is generally more poorly sorted, contains more conglomeratic materials, and becomes argillaceous near its contact with the underlying Brushy Basin Member of the Morrison Formation. Because of the similarity of the Burro Canyon Formation and Dakota Sandstone they are typically not distinguished in lithologic logs at the site.

Based on quantitative analysis of samples for major and minor mineralogy (Table 10), the primary mineral occurring in the Burro Canyon Formation is quartz (greater than or equal to 80% in all analyzed samples except SS-26 which consisted of 'play sand'). Other detected minerals (not necessarily present in all the samples) include potassium feldspar, plagioclase, mica, kaolinite, calcite, dolomite, anhydrite, gypsum, pyrite, hematite, and magnetite. Because of their relatively high reactivity, pyrite, calcite and dolomite are expected to have the most potential to impact perched water chemistry. The presence of carbonaceous matter (Table 11) is also expected to impact perched water chemistry.

4.2 Pyrite Occurrence

As discussed in Section 3.1.4 pyrite occurs within the Dakota Sandstone and Burro Canyon Formations which host the perched water at the site. Table 11 summarizes the occurrence of pyrite, iron oxides, and carbonaceous material in site lithologic logs. These logs were based on field logging of drill cuttings and/or core samples at the time of drilling. Pyrite has been noted in approximately $^2/_3$ of site borings having detailed lithologic logs. These borings are located upgradient, cross-gradient and downgradient of the millsite and tailings management system. In addition, carbonaceous material has been noted at many locations which is consistent with at least locally reducing conditions and the existence of pyrite (Table 11).

As discussed in HGC (2012c), samples of selected archived drill core and drill cuttings were analyzed visually and quantitatively by a contract analytical laboratory. Table 13 and Figure 32 summarize the occurrence of pyrite in site borings based on lithologic logs and laboratory analyses.

The results of the visual and quantitative analyses verify the site-wide, apparently ubiquitous existence of pyrite in the perched zone at the site. The existence of pyrite is confirmed at locations upgradient, cross-gradient, and downgradient of the millsite and tailings management system. The results are consistent with Shawe's (1976) description of the Dakota Sandstone and Burro Canyon Formations as "altered-facies" rocks within which pyrite formed as a result of invasion by pore waters originating from compaction of the overlying Mancos Shale.

Pyrite and/or marcasite were detected in all samples submitted for visual (microscopic) analysis (Table 12) having pyrite noted in their respective lithologic logs. Pyrite occurs primarily as individual grains and as a cementing material, and more rarely as inclusions in quartz grains. Pyrite and/or marcasite were detected in the samples at volume percents ranging from approximately 0.05 to 25. Grain sizes ranged from approximately one micrometer to nearly 2,000 micrometers. Small grain sizes suggest that much of the pyrite present in the formation may not be detectable during field lithologic logging of boreholes and that the actual abundance of pyrite is larger than indicated by the lithologic logs. The detection of marcasite (orthorhombic crystalline FeS_2), which is more reactive than pyrite (cubic crystalline FeS_2), is an important result of the investigation because its reaction rate with either oxygen or nitrate will likely be higher. The laboratory visual (microscopic) analyses confirm the visual observations made during field lithologic logging.

Pyrite was detected by quantitative x-ray diffraction (XRD) analysis in samples from MW-3A, MW-24, MW-26, MW-27, MW-28, and MW-32 at concentrations ranging from 0.1% to 0.8% by weight (Table 10). Based on the iron content via XRD analysis and the total sulfur analysis, pyrite may also be present in samples from MW-23, MW-25, and MW-29 at concentrations ranging from 0.1% to 0.3%. The presence of pyrite is not indicated in MW-30 or MW-31 by either method of analysis, although it was noted in the lithologic logs. This suggests that the samples submitted for analysis from these borings may not have been representative, or that pyrite degraded over time during storage. Except for MW-30 and MW-31, the quantitative analyses confirm the visual observations made during field lithologic logging.

Although pyrite was not directly detected by XRD in samples from MW-23, MW-25, or MW-29, the detected iron and sulfur in these samples is consistent with the presence of pyrite. While at least a portion of the detected sulfur may result from the gypsum or anhydrite detected in some of these samples (Table 10), iron not in the form of pyrite would be expected to exist primarily in the form of iron oxides or perhaps iron carbonates. The absence of detected iron oxides or carbonates in samples from these borings suggests iron in the form of pyrite.

Furthermore, pyrite was either directly detected or possibly detected based on the presence of iron and sulfur in samples from MW-3A, MW-23, MW-24, MW-28, and MW-29, which did not have pyrite noted in the associated lithologic logs. These results are consistent with the small grain sizes noted via the laboratory visual (microscopic) analysis indicating the absence of pyrite in a lithologic log does not necessarily mean pyrite is not present in the associated boring, and that pyrite occurrence at the site has likely been underestimated based on the lithologic logs.

4.3 Expected Influence of Transient Conditions, Oxygen Introduction, and the Mancos and Brushy Basin Shales on Dakota/Burro Canyon Chemistry

Current conditions within the perched groundwater system hosted by the Burro Canyon Formation and Dakota Sandstone do not approach steady state over much of the monitored area. A large part of the site perched water system is transient and affected by long-term changes in water levels due to past and current activities unrelated to the disposal of materials to the site tailings management system. Changes in water levels have historically been related to seepage from the wildlife ponds; however past impacts related to the historical pond, and to a lesser extent the sanitary leach fields, are also expected. Water levels have decreased at some locations due to chloroform and nitrate pumping and reduced recharge from the wildlife ponds.

The transient nature of a large portion of the perched water system, manifested in long-term changes in saturated thicknesses and rates of groundwater flow, is expected to result in trends in pH and in the concentrations of many dissolved constituents that are unrelated to site operations. Changes in saturated thicknesses and rates of groundwater flow can result in changes in concentrations of dissolved constituents (or pH) for many reasons. For example, as discussed in HGC (2012c), groundwater rising into a vadose zone having a different chemistry than the saturated zone can result in changes in pH and groundwater constituent concentrations. If the rise in groundwater represents a long-term trend, long-term changes in groundwater constituent concentrations (or pH) may result.

Under conditions where vadose zone chemistry is not markedly different from saturated zone chemistry, changing groundwater flow rates may result in changing constituent concentrations due to changes in dilution. For example, relatively constant flux of a particular solute into the groundwater zone, resulting in a relatively constant groundwater concentration under conditions of steady groundwater flow, will likely result in changing concentrations should groundwater flow become unsteady. If the change in flow rate is in one direction over a long period of time, a long-term trend in the solute concentration is expected to result. Examples include oxygen dissolved in recharge or a constituent present in vadose zone materials overlying perched groundwater that dissolves in recharge and leaches into perched water at a steady rate. An increase in perched flow may cause an increase in dilution and a reduction in constituent concentration and vice-versa. For example, the decrease in dilution related to reduced wildlife pond recharge has caused increases in dissolved constituent concentrations within the chloroform plume and, to a lesser extent, the nitrate plume as discussed in Section 3.4.1.2.

Furthermore the lined cells within the tailings management system are expected to act as barriers to natural recharge and exchange of gas with the atmosphere; their mere presence may thus result in changes in perched water chemistry. Any such changes are likely to be relatively slow and in one direction, potentially yielding long term trends in parameter values.

The perched groundwater chemistry at the Mill is also expected to be impacted by the following factors:

1. The relatively low permeability of the perched zone. This condition increases groundwater residence times and the time available for groundwater to react with the formation.
2. The location of the perched system between two shales, the underlying Brushy Basin Member of the Morrison Formation and the overlying Mancos Shale. Both are potential sources of numerous dissolved constituents. Potential interaction between the Brushy Basin Member and perched water are discussed in TITAN (1994).
3. The rate of interaction between the Mancos and Brushy basin Member shales and the perched water. Interaction with the Mancos Shale at any particular location will depend on the presence, thickness, and composition of the Mancos, the rate of recharge through the Mancos into the perched zone, and the saturated thickness and rate of groundwater flow in the perched zone. Interaction with the Brushy Basin Member at any particular location will depend on the composition of the Brushy Basin, and the saturated thickness and rate of flow in the perched zone. Oxygen introduced into site monitoring wells may also react

with the Brushy Basin Member and affect the chemistry of perched groundwater in contact with the Brushy Basin.

4. The rate of oxygen introduction into the perched zone via recharge or via site groundwater monitoring wells. Introduced oxygen is available to oxidize constituents such as pyrite, which impacts the local groundwater chemistry near each recharge source and near each well by releasing acid and sulfate. The resulting increased acidity can also destabilize various mineral phases in the aquifer matrix. The degree of impact on perched groundwater chemistry will depend on the amount of pyrite, the rate of oxygen transfer, the neutralization capacity and saturated thickness of the perched zone, and the rate of groundwater flow.

5. Elements other than iron and sulfur as contaminants in pyrite. Pyrite reacting with oxygen introduced into the formation will release these elements, potentially altering both the vadose zone and the groundwater chemistry. The likelihood of pyrite having significant contaminants (such as selenium) is enhanced considering its origin from fluids expelled from the Mancos Shale.

Changes in perched zone constituent concentrations and pH are therefore expected to result from the introduction of oxygen into the subsurface, the oxidation of pyrite and other constituents, changes in recharge rates, and past and current recharge passing through the Mancos Shale.

For example, the Mancos Shale is a significant source of selenium (Baker, 2007; Colorado Department of Health and Environment, 2011; Tuttle, 2005). Because the Mancos overlies the perched zone over much of the site (Figure 11) it could represent a past and ongoing source of selenium. Selenium originating from the Mancos Shale could potentially increase concentrations in the perched zone by three mechanisms: 1) ongoing leaching from the Mancos Shale via recharge; 2) oxidation of Mancos-derived selenium in the Burro Canyon Formation and Dakota Sandstone by dissolved nitrate in the perched water and/or oxygen introduced into the perched zone via perched well casings; and 3) oxidation of pyrite containing Mancos-derived selenium by dissolved perched zone nitrate and/or oxygen introduced into the perched zone via perched well casings. Selenium already present in the Dakota Sandstone and Burro Canyon Formation (including as a constituent in pyrite) could have originated from the Mancos Shale in the past, and could affect the entire formation rather than just the areas beneath the current erosional remnants of the Mancos.

Precipitation percolating downward from the land surface is expected to leach selenium from the Mancos Shale and carry it downward into the perched zone. Beneath the tailings management system, any such leaching is expected to have occurred for the most part prior to the installation of the individual cells which represent barriers to infiltration of precipitation. Vadose pore waters in the Dakota Sandstone and Burro Canyon Formation beneath the tailings management system may thus be expected to contain selenium leached from the Mancos in the past. Perched water rising into vadose pore waters containing selenium may enhance mass transfer and result in increased selenium concentrations in the perched water.

Potentially increasing selenium concentrations may also result from the oxidation of selenium already present in the Dakota Sandstone and Burro Canyon Formation. Oxidation of selenium by nitrate present in perched water and/or by oxygen introduced into the formation via the well casings may result in increasing dissolved selenium concentrations. The possibility of nitrate oxidation of selenium is presented in Potoroff (2005).

A third potential source for increasing dissolved selenium concentrations in perched water is oxidation of pyrite by nitrate and/or oxygen introduced into the formation via well casings. Pyrite typically contains trace elements including selenium. Selenium has been measured at concentrations as high as 0.2% by weight in pyrite (Deditius, 2011). As discussed in HGC (2012c), pyrite oxidation is expected to result in other changes that include an increase in dissolved sulfate (unless a sink for sulfate is present). Oxidation of pyrite by dissolved oxygen is expected to result in a decrease in pH as acid is released in the reaction:

$$FeS_2 + 3^3/_4O_2 + 3^1/_2H_2O = Fe(OH)_3 + 2SO_4^{2-} + 4H^+$$

Oxidation of pyrite by nitrate may also occur as discussed in HGC (2012c). This process may result in either an increase or decrease in pH depending on the reaction pathway:

$$5\ FeS_2 + 14NO_3^- + 4H^+ = 7N_2 + 10SO_4^{2-} + 5Fe^{2+} + 2H_2O;\ \text{or}$$

$$2\ FeS_2 + 6NO_3^- + 2H_2O = 3N_2 + 4SO_4^{2-} + 2FeOOH + 2H^+$$

The interaction between nitrate and pyrite will be discussed in more detail in the following Section.

4.4 Implications for Perched Water Chemistry and Natural Attenuation of Nitrate and Chloroform

As discussed above, past, current, and future interaction of the perched groundwater zone with the overlying Mancos Shale and underlying Brushy Basin Member can be expected to affect perched water chemistry at the site. Changes in perched water chemistry related to oxidation of pyrite by oxygen introduced into the subsurface dissolved in recharge and via well casings is also expected to occur.

Concentrations of chloroform and nitrate already present in the perched zone will be affected over time by various processes, including direct mass removal by pumping. Natural attenuation of both constituents is expected to result from physical processes that include dilution by recharge and hydrodynamic dispersion. Volatilization into the vadose zone is another physical process that is expected to lower chloroform concentrations in perched water. Mass reduction processes expected to lower both nitrate and chloroform concentrations include chemical and biologically-mediated processes. The impacts of pyrite degradation by oxygen, degradation of nitrate by pyrite, and reductive dechlorination of chloroform are discussed in Sections 4.4.1 through 4.4.3.

4.4.1 Pyrite Degradation by Oxygen

As discussed in HGC (2012c), the pH values measured in many site groundwater monitoring wells located upgradient, within the vicinity of, and downgradient of the mill site and tailings management system displayed decreasing trends. pH decreases in many of these wells were accompanied by increases in sulfate concentrations. Ten of the MW-series groundwater monitoring wells were out of compliance (OOC) with respect to pH due to a decreasing trend.

As discussed in INTERA (2012a and 2102b) and Section 5 below, changes in pH were determined to result from natural causes unrelated to the operation of the tailings management system. Based on work described in HGC (2012c), the decreases in pH and increases in sulfate in OOC wells were explainable by oxidation of pyrite, which releases acid and sulfate as described above. Screening-level calculations and geochemical modeling using PHREEQC (Parkhurst and Appelo, 1999) indicated that pyrite measured in samples from the perched zone existed in more than sufficient quantity to have resulted in the measured changes in pH and sulfate at three representative wells located immediately upgradient (MW-27), immediately downgradient (MW-24), and far downgradient (MW-3A) of the tailings management system. The calculations also indicated that pyrite existed in sufficient quantity to maintain these trends provided sufficient oxygen was available. Continued release of any contaminants within site pyrite is expected as is release of pH sensitive constituents present in the Burro Canyon Formation and Dakota Sandstone.

4.4.2 Nitrate Degradation by Pyrite

As discussed in HGC (2012c), nitrate will degrade in the presence of pyrite. Nitrate will also degrade, and more readily, in the presence of organic matter. Both pyrite and organic material in the form of carbonaceous matter have been logged in drill cuttings from the perched groundwater zone.

As discussed in (Korom, 1992), the thermodynamically favored electron donor for reduction of nitrate in groundwater is typically organic matter. This process under neutral conditions is represented via the following generalized reaction (e.g. van Beek, 1999; Rivett *et al.*, 2008; Tesoriero and Puckett, 2011; Zhang, 2012):

$$5CH_2O + 4NO_3^- = 2N_2 + 4HCO_3^- + H_2CO_3 + 2H_2O \text{ (Reaction 1);}$$

In acidic (pH < 6.4) aquifer conditions, reduction of nitrate by organic matter can be generalized by the following pathway:

$$5CH_2O + 4NO_3^- + 4H^+ = 2N_2 + 5H_2CO_3 + 2H_2O \text{ (Reaction 2).}$$

In both cases, five moles of organic matter are required to reduce four moles of nitrate. Under acidic conditions the alkalinity generated by denitrification by organic matter consumes acid.

In the absence of dissolved oxygen, pyrite can also be oxidized by nitrate. Denitrification by pyrite may occur via two primary reaction pathways. The pathway most commonly applied in geochemical studies (Kolle *et al.*, 1983, 1985; Postma *et al.*, 1991; Korom, 1992; Robertson *et al.*, 1996; Pauwels *et al.*, 1998; Hartog *et al.*, 2001, 2004; Spiteri *et al.*, 2008) is a bacteria-mediated reaction that yields ferrous iron, sulfate, water, and nitrogen gas as follows:

$$5FeS_2 + 14NO_3^- + 4H^+ = 7N_2 + 10SO_4^{2-} + 5Fe^{2+} + 2H_2O \text{ (Reaction 3).}$$

By Reaction 3, five moles of pyrite reduce 14 moles of nitrate, consuming four moles of acid. Reaction 3 is considered applicable when pyrite concentrations exceed nitrate concentrations (van Beek, 1999). Where nitrate concentrations exceed pyrite concentrations, Reaction 4 is a more likely mechanism (Kolle *et al.*, 1987; van Beek, 1999; Schlippers and Jorgensen, 2002):

$$2FeS_2 + 6NO_3^- + 4H_2O = 3N_2 + 4SO_4^{2-} + 2Fe(OH)_3 + 2H^+ \text{ (Reaction 4).}$$

By Reaction 4, two moles of pyrite reduce six moles of nitrate, yielding iron hydroxide, sulfate, acid, and nitrogen gas. Therefore, when nitrate concentrations exceed pyrite concentrations (Reaction 4), denitrification by pyrite is more efficient than when pyrite is in excess (Reaction 3). Additionally, Reaction 4 produces acid, while Reaction 3 consumes acid, indicating that the impact of denitrification by pyrite on aquifer geochemistry is controlled by the relative abundance of pyrite and nitrate.

Reaction 4 is an overall reaction that combines Reaction 3 and a second step whereby ferrous iron is oxidized by nitrate. This second step is more likely to occur when excess nitrate is present and available to oxidize ferrous iron (Kolle *et al.*, 1987; Rivett *et al.*, 2008; Zhang 2012).

Stoichiometric calculations were used to determine the weight percent of perched zone pyrite that would be required to reduce the 'baseline' estimate of 43,700 lbs of nitrate (HGC, 2012a) via reaction mechanisms 3 and 4 (assuming each was the only denitrification reaction occurring). 43,700 lbs of nitrate corresponds to 19,822 kg and 319,684 moles. Although organic matter is noted in lithologic logs, the organic matter content of the perched zone has not been quantified so calculations regarding nitrate degradation by reactions 1 and 2 are not presented, even though significant nitrate reduction via these mechanisms is likely to occur.

Nitrate can either migrate towards Ruin Spring to the south-southwest or to Westwater Seep to the west. Assuming the entire nitrate plume migrated south towards Ruin Spring, the volume of the perched zone through which the nitrate plume would migrate was assumed to be on average 20 feet thick, 1,200 feet wide, and 10,000 feet long, representing a total saturated formation volume of 2.4×10^8 ft^3 or 6.8×10^9 liters. Assuming the entire nitrate plume migrated west toward Westwater Seep, the volume of the perched zone through which the nitrate plume would migrate was assumed to be on average 18 feet thick, 2,800 feet wide, and 4,950 feet long, representing a total saturated formation volume of 2.5×10^8 ft^3 or 7×10^9 liters. To be conservative, the following calculations are based on the smaller volume of 6.8×10^9 liters.

Using these estimates, reaction 3 would require 114,173 moles of pyrite to consume 43,700 lbs of nitrate, and would consume 91,338 moles of acid (1.34×10^{-5} moles H^+ per liter of formation). Reaction 4 would require 106,561 moles of pyrite to degrade the nitrate, producing 106,561 moles of acid or 1.57×10^{-5} moles H^+ per liter of formation.

Assuming a conservatively large porosity of 0.2 for the perched zone (HGC, 2012c), the total volume of water is 1.36×10^9 liters; and assuming a solids density of 2.6 kg L^{-1}, yields a total solid mass of 1.4×10^{10} kg.

Using this solid mass, both Reactions 3 and 4 would require pyrite formation weight percents of 0.000098% (9.8×10^{-5} %) and 0.000091% (9.1×10^{-5} %), respectively, to degrade 43,700 lbs of nitrate.

These calculated pyrite weight percents are orders of magnitude less than conservative estimates of pyrite content based on samples analyzed during the pyrite investigation (HGC, 2012c), which ranged from 0.0056% to 0.08% (5.6×10^{-3} % to 8×10^{-2} %). These results suggest that the available pyrite content in the path of the nitrate plume is two to three orders of magnitude greater than needed to degrade the total mass (43,700 lbs) of nitrate. These calculations are conservative in that they assume the degradation of the entire mass of nitrate and not just the mass needed to reduce concentrations below 10 mg/L. Whether or not pyrite oxidation by nitrate at the site is generating or consuming acid depends largely on whether oxidation of ferrous iron by nitrate is occurring (i.e. whether pyrite denitrification is occurring by Reaction 3 or Reaction 4; whether nitrate exists in excess).

The preferred mechanism for denitrification by pyrite is likely to vary spatially. If pyrite is assumed to be relatively evenly distributed throughout the formation, while nitrate occurs in a discrete plume, Reaction 3 may dominate on the plume edges while Reaction 4 may dominate the core of the plume.

As discussed in HGC (2017), estimated natural nitrate degradation rates range from approximately 172 lb/yr to 200 lb/yr. Based on the third quarter, 2017 residual nitrate plume mass estimate of approximately 33,000 lb, less than 200 years would be required to remediate the nitrate plume, even in the absence of any direct mass removal by pumping.

4.4.3 Chloroform Reduction

As discussed in HGC (2007) and HGC (2018a), the presence of chloroform daughter products indicates that chloroform is degrading naturally via reductive dechlorination. Calculations presented in HGC (2007) and HGC (2018a) based on daughter product concentrations indicated that the entire chloroform plume would be reduced to concentrations below the GCAL of 70 ug/L within approximately 190 years, even in the absence of any direct mass removal by pumping. Reductive dechlorination takes place under anaerobic conditions which were inferred to exist only locally within the perched zone. The low rates of degradation and the persistence of nitrate associated with the chloroform plume are consistent with primarily aerobic conditions.

However, the widespread occurrence of pyrite in the perched zone is consistent with at least locally anaerobic conditions, and with the relatively low calculated rates of chloroform degradation presented in HGC (2007) and HGC (2018a). Continued reductive dechlorination is expected within locally anaerobic portions of the perched zone.

5. SUMMARY OF INTERA WORK AND FINDINGS

Background groundwater quality evaluations have been performed for each MW-series groundwater monitoring well. Groundwater compliance limits (GWCLs) have been established for each permit constituent on an intra-well basis.

A Revised Background Groundwater Quality Report (INTERA, 2007a) evaluated groundwater analytical data collected since the initiation of groundwater sampling. The revisions included a Flow Sheet that was approved by the Utah Division of Waste Management and Radiation Control (DWMRC) and contained steps for analyzing data and setting GWCLs. INTERA (2007a) identified naturally occurring elevated, increasing, and decreasing concentrations of various constituents in monitoring wells located far upgradient, far downgradient, and in the vicinity of the Mill Site. This report also presented a thorough discussion and identification of the most appropriate indicator parameters (chloride, fluoride, sulfate, and uranium) based on constituents in tailings solutions and their behavior in groundwater. Analysis of the indicator parameters in monitoring wells, including monitoring wells that contained increasing trends in other constituents, provided no evidence of tailings management system seepage. Since INTERA (2007a), three additional Background Reports (INTERA 2007b, 2008, and 2014c) evaluate available data and determine GWCLs for each permit constituent in each well based on the DWMRC-approved Flow Sheet.

Upon approval of the GWDP in 2010, constituents with two consecutive GWCL exceedances are subject to a Source Assessment Report (SAR) as defined in the GWDP. The initial SAR was submitted in October of 2012 (INTERA 2012a) and covered all of the constituents in wells with consecutive exceedances since the approval of the GWDP in 2010. The October 2012 SAR (INTERA 2012a) presented a geochemical analysis of parameters that exhibited exceedances as well as an analysis of the indicator parameters in each of those wells to determine if the exceedance could be related to potential tailings management system seepage or Mill-related activities. Since then, seven additional SARs, (INTERA 2013a; 2013b; 2014a; 2014b; 2015; 2016; and 2017) cover additional consecutive exceedances. In all cases the exceedances for which the SARs were performed were determined to result from naturally occurring conditions in the groundwater at the site or from other factors that are affecting groundwater but are unrelated to tailings management system operation. These other factors include the chloride and nitrate plume that is addressed by the nitrate CAP and a sitewide decline in pH that was identified at the time of the Background Report.

At the time of the Background Report, an overall decline in pH across the site was observed. Background analysis and determination of GWCLs for pH were performed using laboratory pH measurements rather than using measurements that are collected in the field at the time of sampling by using a pH probe. Since the latter of these two methods of measuring pH is more reliable, an additional pH analysis was performed in 2012 using only field data. GWCLs for pH were recalculated at this time using the field measurements. As discussed in Section 4.4.1, HGC (2012c) determined that pH decreases resulted from pyrite oxidation enhanced by oxygen delivery to the perched zone. Oxygen delivery mechanisms included advective transport to the perched zone dissolved in wildlife pond seepage, and diffusive and dispersive transport to perched groundwater in the vicinities of perched wells via perched well casings. pH decreases were therefore determined to be unrelated to tailings management system operation.

6. SUMMARY AND CONCLUSIONS REGARDING MILL HYDROGEOLOGY

The Mill, situated on White Mesa within the Blanding Basin physiographic province, has an average elevation of approximately 5,600 feet above mean sea level (ft amsl), and is underlain by unconsolidated alluvium and indurated sedimentary rocks. Indurated rocks include those exposed within the Blanding Basin which consist primarily of sandstone and shale.

The indurated rocks are relatively flat lying with dips generally less than 3º. The alluvial materials overlying the indurated rocks consist primarily of aeolian silts and fine-grained aeolian sands with a thickness varying from a few feet to as much as 25 to 30 feet across the site. The alluvium is underlain by the Dakota Sandstone and Burro Canyon Formation, and where present, the Mancos Shale. The Dakota Sandstone and Burro Canyon Formation are sandstones having a total thickness ranging from approximately 55 to 140 feet. Beneath the Burro Canyon Formation lies the Morrison Formation, consisting, in descending order, of the Brushy Basin Member, the Westwater Canyon Member, the Recapture Member, and the Salt Wash Member. The Brushy Basin and Recapture Members of the Morrison Formation, classified as shales, are very fine-grained and have a very low permeability. The Brushy Basin Member is primarily composed of bentonitic mudstones, siltstones, and claystones. The Westwater Canyon and Salt Wash Members also have a low average vertical permeability due to the presence of interbedded shales.

Beneath the Morrison Formation lie the Summerville Formation, an argillaceous sandstone with interbedded shales, and the Entrada Sandstone. Beneath the Entrada lies the Navajo Sandstone. The Navajo and Entrada Sandstones constitute the primary aquifer in the vicinity of the site. The Entrada and Navajo Sandstones are separated from the Burro Canyon Formation (and the perched water system monitored at the site) by approximately 1,000 to 1,100 feet of materials having a low average vertical permeability. Groundwater within the Entrada/Navajo system is under artesian pressure in the vicinity of the site, is of generally good quality, and is used as a secondary source of water at the site. Stratigraphic relationships beneath the site are summarized in Figure 3.

The site and vicinity has a dry to arid continental climate, with an average annual precipitation of approximately 13.3 inches, and an average annual lake evaporation rate of approximately 47.6 inches. Recharge to major aquifers (such as the Entrada/Navajo) occurs primarily along the mountain fronts (for example, the Henry, Abajo, and La Sal Mountains), and along the flanks of folds such as Comb Ridge Monocline.

Perched groundwater beneath the site occurs in the Dakota Sandstone and Burro Canyon Formation and is used on a limited basis to the north (upgradient) of the site because it is more easily accessible than the Navajo/Entrada aquifer. Perched groundwater originates mainly from precipitation and local recharge sources such as unlined reservoirs (Kirby, 2008) and is supported within the Burro Canyon Formation by the underlying, fine-grained, and bentonitic Brushy Basin Member, considered an aquiclude.

Water quality of the Dakota Sandstone and Burro Canyon Formation is generally poor due to high total dissolved solids (TDS) in the range of approximately 1,100 to 7,900 milligrams per liter (mg/L) and is used primarily for stock watering and irrigation. Nitrate and chloroform plumes occur in site perched groundwater as shown in Figure 1B. The nitrate plume extends from upgradient (north-northeast) of the tailings management system to beneath the tailings management system. The chloroform plume is located primarily upgradient to cross-gradient (northeast to east) of the tailings management system. Sources of the nitrate plume are not well-defined but the historical pond shown on Figures 1A and 1B is considered a source of nitrate and chloride to the plume. The only potentially active source of nitrate to the plume is related to ammonium sulfate crystal handling near the ammonium sulfate crystal tanks located southeast of TWN-2 (Figures 1A and 1B) and has been addressed through implementation of Phase I of the nitrate CAP. Past sources of the chloroform plume are two abandoned sanitary leach fields (located near TW4-18 and TW4-19 [Figures 1A and 1B]) that received laboratory wastes prior to any cells within the tailings management system becoming operational circa 1980. Both plumes are under remediation by pumping.

The saturated thickness of the perched groundwater zone generally increases to the north of the site, increasing the yield of the perched zone to wells installed north of the site. The generally low permeability of the perched zone limits well yields. Although sustainable yields of as much as 4 gallons per minute (gpm) have been achieved in site wells penetrating higher transmissivity zones near the unlined wildlife ponds (Figures 1A and 1B), yields are typically low (<$^1/_2$ gpm) due to the generally low permeability of the perched zone. Even site wells that yielded as much as 4 gpm during the first few months of pumping eventually saw yields drop to about 1 gpm or less. Many of the perched monitoring wells purge dry and take several hours to more than a day to recover sufficiently for groundwater samples to be collected. During redevelopment (HGC, 2011b) many of the wells went dry during surging and bailing and required several sessions on subsequent days to remove the proper volumes of water.

As shown in Figure 5 and Appendix D, perched water flow across the site is generally (and historically) from northeast to southwest. Perched water discharges in seeps and springs located to the west, southwest, east, and southeast of the site (Figure 1B).

Beneath and south of the tailings management system, in the west central portion of the site, perched water flow is south-southwest to west-southwest. Flow on the western margin of the mesa south of the tailings management system is generally southerly, approximately parallel to the mesa rim (where the Burro Canyon Formation is terminated by erosion). On the eastern side of the site perched water flow is also generally southerly to southwesterly.

Perched water flow beneath and downgradient of the millsite and tailings management system is influenced by perched water discharge points Westwater Seep, located west to west-southwest of the tailings management system, and Ruin Spring, located southwest of the tailings management system. Hydraulic gradients at the site currently range from approximately 0.002 ft/ft in the northeastern corner of the site (between TWN-19 and TWN-16) to nearly 0.09 ft/ft east of cell 2 (within the chloroform plume, between TW4-10 and TW4-11).

Because of relict mounding near the northern wildlife ponds, flow direction ranges from locally westerly (west of the ponds) to locally easterly (east of the ponds). The March 2012 cessation of water delivery to the northern ponds, which are generally upgradient of the nitrate and chloroform plumes at the site, resulted in changing conditions that were expected to impact constituent concentrations and migration rates within these plumes. Specifically, past recharge from the ponds helped limit many constituent concentrations within these plumes by dilution while the associated groundwater mounding increased hydraulic gradients and contributed to plume migration. Since use of the northern wildlife ponds ceased in March 2012, the reduction in recharge and decay of the associated groundwater mound have increased many constituent concentrations within the plumes while reducing hydraulic gradients and acting to reduce rates of plume migration. The impacts associated with cessation of water delivery to the northern ponds have been expected to propagate downgradient (south and southwest) over time.

Reduced recharge from the southern wildlife pond resulting from reduced water delivery, and the decay of the associated (southern) perched groundwater mound, is causing changes in hydraulic gradients in the vicinity. In particular the decay of the southern mound has resulted in more southerly (rather than southeasterly) flow within the southern portion of the chloroform plume. Continued decay of the southern mound is expected to result in eventual restoration of the typical site southwesterly flow pattern within this portion of the plume.

Flow onto the site occurs as underflow from areas northeast of the millsite where perched zone saturated thicknesses are generally greater. Any flow that does not discharge in seeps or springs presumably exits as underflow to the southeast of Ruin Spring, along the southwest extending lobe of White Mesa located between Ruin Spring and Corral Springs. Darcy’s Law calculations of perched water flow to Ruin Spring and Westwater Seep yield reasonable results and suggest that local recharge contributes to seep/spring flow.

Hydraulic testing of perched zone wells yields a hydraulic conductivity range of approximately 2 x 10^{-8} to 0.01 cm/s (Tables 1- 4). In general, the highest permeabilities and well yields are in the area of the site immediately northeast and east (upgradient to cross gradient) of the tailings management system. A relatively continuous, higher permeability zone associated with the chloroform plume and consisting of poorly indurated coarser-grained materials has been inferred to exist in this portion of the site (HGC, 2007). Because their existence requires both coarse grain size and poor cementation, such relatively continuous, higher permeability zones are expected to be relatively rare at the site.

Permeabilities downgradient (southwest) of the tailings management system are generally low. The low permeabilities and shallow hydraulic gradients downgradient of the tailings management system result in average perched groundwater pore velocity estimates that are among the lowest on site. Furthermore, more than 37 years of groundwater monitoring indicate no impacts to perched water from tailings management system operation.

As discussed above, perched groundwater discharges in seeps and springs located along the mesa margins. The relationships between seeps and springs and site geology/stratigraphy are provided in Figure E.1 and Figure E.2. Seep and spring investigation (HGC, 2010g) and investigation of the southwest portion of the site (HGC, 2012b) indicate the following:

1. Incorporating the seep and spring elevations in perched water elevation contour maps produces little change with regard to perched water flow directions except in the area west of the tailings management system and near Entrance Spring. West of the tailings management system, incorporation of Westwater Seep creates a more westerly hydraulic gradient. Westwater Seep appears to be downgradient of the western portion of the tailings management system (Figure 25); and Ruin Spring is downgradient of the eastern portion of the tailings management system (Figure 25). Westwater Seep is the closest apparent discharge point west of the tailings management system and Ruin Spring is the closest discharge point south-southwest of the tailings management system. Including the Entrance Spring elevation on the east side of the site creates a more easterly gradient in the perched water contours, and places Entrance Spring more directly downgradient of the northern wildlife ponds. Seeps and springs on the east side of the mesa are either cross-

gradient of the tailings management system or are separated from the tailings management system by a groundwater divide.

2. Ruin Spring and Westwater Seep are interpreted to occur at the contact between the Burro Canyon Formation and the Brushy Basin Member of the Morrison Formation. Corral Canyon Seep, Entrance Spring, and Corral Springs are interpreted to occur at elevations within the Burro Canyon Formation at their respective locations but above the contact with the Brushy Basin Member. All seeps and springs (except Cottonwood Seep which is located within the Morrison Formation near the Brushy Basin Member/Westwater Canyon Member contact) are associated with conglomeratic portions of the Burro Canyon Formation. Provided they are poorly indurated the more conglomeratic portions of the Burro Canyon Formation are likely to have higher permeabilities and the ability to transmit water more readily than finer-grained portions. This behavior is consistent with on-site drilling and hydraulic test data that associates higher permeability with the poorly indurated coarser-grained horizons detected east and northeast of the tailings management system that are associated with the chloroform plume.

3. Cottonwood Seep is located more than 1,500 feet west of the mesa rim in an area where the Dakota Sandstone and Burro Canyon Formation (which hosts the perched water system) are absent due to erosion (Figures E.1 and E.2). Cottonwood Seep occurs near a transition from slope-forming to bench-forming morphology (indicating a change in lithology). Cottonwood Seep (and 2nd Seep located immediately to the north [Figure 6]) is interpreted to originate from coarser-grained materials within the lower portion of the Brushy Basin Member (or upper portion of the Westwater Canyon Member) of the Morrison Formation. Alternatively, Cottonwood Seep may originate from coarser-grained materials of the Westwater Canyon (sandstone) Member intertongueing with the overlying Brushy Basin Member at the transition between the two Members. The presence of coarser-grained materials similar to the Salt Wash (sandstone) Member within the lower portion of the Brushy Basin member is discussed in Shawe (2005). The intertongueing of the Westwater Canyon and Brushy Basin Members is discussed in Craig *et al.* (1955) and Flesch (1974). Based on lithologic cross sections provided in TITAN (1994), the elevation of Cottonwood Seep (5,234 ft amsl) is within 5 to 15 feet of the elevation of the contact between the Brushy Basin Member and the underlying Westwater Canyon Member (5,220 to 5,230 ft amsl). This is also shown in Figure 3. Cottonwood Seep is therefore not (directly) connected to the perched water system at the site.

4. Only Ruin Spring appears to receive a predominant and relatively consistent proportion of its flow from perched groundwater. Ruin Spring originates from conglomeratic Burro Canyon Formation sandstone where it contacts the underlying Brushy Basin Member, at an elevation above the alluvium in the associated drainage. Westwater Seep, which also originates at the contact between the Burro Canyon Formation and the Brushy Basin Member, likely receives a significant contribution from perched water. All seeps and springs other than Ruin Spring (and 2nd Seep just north of Cottonwood Seep) are located within alluvium occupying the basal portions of small drainages and canyons. The relative contribution of flow to these features from bedrock and from alluvium is indeterminate.

5. All seeps and springs are reported to have enhanced flow during wet periods. For seeps and springs associated with alluvium, this behavior is consistent with an alluvial contribution to flow. Enhanced flow during wet periods at Ruin Spring, which originates from bedrock above the level of the alluvium, likely results from direct recharge of Burro Canyon Formation and Dakota Sandstone exposed near the mesa margin in the vicinity of Ruin Spring. This recharge would be expected to temporarily increase the flow at Ruin Spring (as well as other seeps and springs where associated bedrock is directly recharged) after precipitation events. As discussed previously, local recharge is consistent with Darcy's law calculations of perched water flow to Ruin Spring and Westwater Seep.
6. The assumption that the seep or spring elevation is representative of the perched water elevation is likely to be correct only where the feature receives most or all of its flow from perched water and where the supply is relatively continuous (for example at Ruin Spring). The perched water elevation at the location of a seep or spring that receives a significant proportion of water from a source other than perched water may be different from the elevation of the seep or spring. The elevations of seeps that are dry for at least part of the year will not be representative of the perched water elevation when dry. Some uncertainty therefore results from including these seeps and springs in the contouring of perched water levels. However, even if such springs are sometimes dry, the presence of cottonwoods suggests that perched groundwater is close to the surface at these locations.

The rate of flow in the perched water zone in the southwest area of the site (downgradient of the tailings management system) is small and contributions from local recharge are needed to explain many areas of higher saturated thickness affected by discharge points such as Westwater Seep and Ruin Spring that are downgradient of areas of low saturated thickness (HGC, 2012b). The presence of local recharge is expected to affect the water quality of seeps and springs and has the potential to dilute any dissolved constituents that may migrate from upgradient areas.

As discussed in HGC (2012c), samples of selected archived drill core and drill cuttings were analyzed visually and quantitatively by a contract analytical laboratory. Table 13 and Figure 32 summarize the occurrence of pyrite in site borings based on lithologic logs and laboratory analyses. The results verify the site-wide, apparently ubiquitous existence of pyrite in the perched zone at the site. The existence of pyrite is confirmed at locations upgradient, cross-gradient, and downgradient of the millsite and tailings management system. The results are consistent with Shawe's (1976) description of the Dakota Sandstone and Burro Canyon Formations as "altered-facies" rocks within which pyrite formed as a result of invasion by pore waters originating from compaction of the overlying Mancos Shale.

A large portion of the perched water system at the site is in a transient state, manifested in long-term changes in saturated thicknesses and rates of groundwater flow. This condition is expected to result in trends in pH and concentrations of many dissolved constituents that are unrelated to site operations. Changes in saturated thicknesses and rates of groundwater flow can result in changes in concentrations of dissolved constituents (or pH) for many reasons. For example, as discussed in HGC (2012c), groundwater rising into a vadose zone having a different chemistry than the saturated zone can result in changes in pH and groundwater constituent concentrations. If the rise in groundwater represents a long-term trend, long-term changes in groundwater constituent concentrations (or pH) may result.

Under conditions where vadose zone chemistry is not markedly different from saturated zone chemistry, changing groundwater flow rates may result in changing constituent concentrations due to changes in dilution. For example, relatively constant flux of a particular solute into the groundwater zone, resulting in a relatively constant groundwater concentration under conditions of steady groundwater flow, will likely result in changing concentrations should groundwater flow become unsteady. If the change in flow rate is in one direction over a long period of time, a long-term trend in the solute concentration is expected to result. Examples include oxygen dissolved in recharge or a constituent present in vadose zone materials overlying perched groundwater that dissolves in recharge and leaches into perched water at a steady rate. An increase in perched flow may cause an increase in dilution and a reduction in constituent concentration and vice-versa. For example, the decrease in dilution related to cessation of water delivery to the northern wildlife ponds has caused increases in dissolved constituent concentrations within the chloroform plume and, to a lesser extent, the nitrate plume.

Furthermore the lined cells within the tailings management system are expected to act as barriers to natural recharge and exchange of gas with the atmosphere; their mere presence may thus result in changes in perched water chemistry. Any such changes are likely to be relatively slow and in one direction, potentially yielding long term trends in parameter values.

The perched groundwater chemistry at the Mill is also expected to be impacted by the following factors:

1. The relatively low permeability of the perched zone. This condition increases groundwater residence times and the time available for groundwater to react with the formation.
2. The location of the perched system between two shales, the underlying Brushy Basin Member of the Morrison Formation and the overlying Mancos Shale. Both are potential sources of numerous dissolved constituents.
3. The rate of interaction between the Mancos and Brushy Basin Member shales and the perched water. Interaction with the Mancos Shale at any particular location will depend on the presence, thickness, and composition of the Mancos, the rate of recharge through the Mancos into the perched zone, and the saturated thickness and rate of groundwater flow in the perched zone. Interaction with the Brushy Basin Member at any particular location

will depend on the composition of the Brushy Basin, and the saturated thickness and rate of flow in the perched zone. Oxygen introduced into site monitoring wells may also react with the Brushy Basin and affect the chemistry of perched groundwater in contact with the Brushy Basin.

4. The rate of oxygen introduction into the perched zone via recharge or via site groundwater monitoring wells. Introduced oxygen is available to oxidize constituents such as pyrite, which impacts the local groundwater chemistry near each recharge source and near each well by releasing acid and sulfate. The resulting increased acidity can also destabilize various mineral phases in the aquifer matrix. The degree of impact on groundwater chemistry will depend on the amount of pyrite, the rate of oxygen transfer, the neutralization capacity and saturated thickness of the perched zone, and the rate of groundwater flow.
5. Elements other than iron and sulfur as contaminants in pyrite. Pyrite reacting with oxygen introduced into the formation will release these elements, potentially altering both the vadose zone and the groundwater chemistry. The likelihood of pyrite having significant contaminants (such as selenium) is enhanced considering its origin from fluids expelled from the Mancos.

Changes in perched zone constituent concentrations and pH are therefore expected to result from the introduction of oxygen into the subsurface, the oxidation of pyrite and other constituents, changes in recharge rates, and past and current recharge passing through the Mancos Shale.

Decreasing trends in pH accompanied by increasing sulfate concentrations in MW-series wells that were OOC for pH were determined to result from oxidation of pyrite based on screening-level calculations and geochemical modeling presented in HGC (2012c). The calculations also indicated that pyrite existed in sufficient quantity to maintain these trends provided sufficient oxygen was available.

6.1 Perched Water Pore Velocities in the Nitrate Plume Area

Perched groundwater pore velocities and travel times calculated within the nitrate plume along Path 1 (Figure 27) yield an estimated average pore velocity of approximately 17 ft/yr and a travel time of approximately 84 years, based on a fourth quarter, 2017 hydraulic gradient of 0.023 ft/ft.

Historic hydraulic gradients within the area of the nitrate plume were likely much larger than the current hydraulic gradient of 0.023 ft/ft during the time prior to Mill construction when the historical pond was active (Figure 1B). Based on historic water levels in the vicinities of MW-30 and MW-31, located along the downgradient margin of cell 2 (Appendix D), and at the downgradient margin of the nitrate plume, an historic hydraulic gradient is estimated as approximately 0.048 ft/ft. This is more than four times the overall average site hydraulic gradient of approximately 0.011 ft/ft (calculated between TWN-19 and Ruin Spring).

Using the estimated historic hydraulic gradient of 0.048 ft/ft, the estimated historic pore velocity downgradient of the historical pond is approximately 35 ft/yr, implying that nitrate originating from the historical pond could have migrated to the downgradient edge of cell 2 within 63 years. Assuming the historical pond was active by 1920, that nitrate was conservative, and ignoring hydrodynamic dispersion, nitrate originating from the historical pond could have reached the vicinities of MW-30 and MW-31 by 1983.

6.2 Perched Water Pore Velocities in the Vicinity of the Chloroform Plume

Perched groundwater pore velocities and travel times in the vicinity of the chloroform plume along Paths 2A and 2B (Figure 27) were calculated based on fourth quarter, 2017 hydraulic gradients of 0.022 ft/ft and 0.039 ft/ft, respectively. The estimated average pore velocity along Path 2A is approximately 48 ft/yr, implying that approximately 22 years would be required to traverse Path 2A. The estimated average pore velocity along Path 2B is approximately 27 ft/yr, implying that approximately 44 years would be required to traverse Path 2B.

Historic hydraulic gradients within the northern (upgradient) areas of the eastern portion of the chloroform plume (prior to about 1990) were likely larger than current hydraulic gradients and contributed to relatively rapid movement of chloroform from the abandoned scale house leach field (located immediately north of TW4-18) to MW-4 where chloroform was detected in 1999. Based on historic water levels (Appendix D) the hydraulic gradient between the abandoned scale house leach field and MW-4 is estimated as approximately 0.048 ft/ft in 1990 and approximately 0.029 ft/ft in 1999, averaging 0.038 ft/ft. This is more than three times the overall average site hydraulic gradient of approximately 0.011 ft/ft (calculated between TWN-19 and Ruin Spring), but is within the range of hydraulic gradients occurring at present within and adjacent to the chloroform plume, and is similar to the current hydraulic gradient of approximately 0.041 ft/ft just east the plume, between non-pumping wells TW4-36 and TW4-27.

The estimated historic hydraulic gradient implies an average pore velocity prior to 1999 of approximately 84 ft/yr, sufficient for chloroform to have migrated from the abandoned scale house leach field to MW-4 between 1978 and 1999. This calculation implies that chloroform could have migrated nearly to TW4-4 by 1999.

6.3 Hydrogeology and Perched Water Pore Velocities in the Southwest Area

Investigation of the southwest area of the site, including seeps and springs (HGC, 2012b), indicates that permeabilities in the southwest portion of the site are on average lower than estimated prior to 2010 (as for example in HGC, 2009), and that perched water discharges to Westwater Seep and Ruin Spring, but there is no evidence for a direct hydraulic connection between the perched water zone and Cottonwood Seep. The hydraulic test and water level data also demonstrate that the perched zone southwest of cell 4B is inadequate as a primary supply to Cottonwood Seep by several orders of magnitude and that that the primary source of Cottonwood Seep lies elsewhere. However, a hypothetical connection between the perched zone near piezometer DR-8 and Cottonwood Seep is postulated for the purposes of calculating perched water travel times and to allow for the possibility that an as yet unidentified connection may exist.

Important results of the southwest area investigation are:

1. The Brushy Basin Member erosional paleosurface in the southwest area of the Mill site is dominated by a paleoridge extending from beneath cell 4B to abandoned boring DR-18 (Figure 8). The paleoridge is flanked to the west by a north-south trending paleovalley oriented roughly parallel to the western mesa rim (Figure 8).
2. The southwest area of the Mill site is characterized by generally low saturated thicknesses, low permeabilities, and relatively shallow hydraulic gradients. This is illustrated in Table 1 and Figure 14. Hydraulic gradients in the southwest portion of the site are typically close to 0.1 ft/ft, but are less than approximately 0.005 ft/ft west/southwest of cell 4B, between cell 4B and DR-8.
3. The paleotopography of the Brushy Basin Member erosional surface has a greater influence on perched water flow in the southwest portion of the site than other areas because of the low saturated thicknesses and dry areas associated with the paleoridge extending south-southwest from the tailings management system (Figures 8, 14, 18, and 19).
4. The low transmissivities implied by the low permeabilities and low saturated thicknesses combined with the shallow hydraulic gradients imply low rates of perched water flow in the southwest portion of the site. Calculated average pore velocities along Pathlines 3, 5, and 6 (Figure 27) from the tailings management system to known discharge points Westwater Seep and Ruin Spring range from 0.60 ft/yr to 0.90 ft/yr, and travel times from approximately 3,015 to 19,660 years based on fourth quarter, 2017 water level data. If vadose zone travel times from the base of the individual cells to the perched water are included, the range of calculated travel times is approximately 3,260 to 19,970 years.

5. The estimated travel time from the tailings management system to the vicinity of DR-8 (Path 4) is approximately 15,860 years based on fourth quarter, 2017 water level data and a calculated pore velocity of 0.26 ft/yr. Including the vadose travel time of approximately 312 years yields a total travel time of 16,170 years. Assuming a hypothetical pathway to Cottonwood Seep, the time to travel along Path 4 and thence along the potential pathway from the edge of Path 4 to Cottonwood Seep (which adds approximately 2,150 horizontal feet) is expected to be significantly greater than 16,170 years.

6. Brushy Basin Member paleotopography influences the locations of Westwater Seep and Ruin Spring; both are located in paleovalleys within the Brushy Basin Member paleosurface (Figure 8).

7. Local recharge is needed to explain areas of relatively large saturated thickness that supply Westwater Seep and Ruin Spring, because lateral flow into these areas from upgradient low saturated thickness portions of the perched zone is inadequate. The calculated perched zone recharge rate in the approximate 175 acre area southwest of Westwater Seep (near DR-2 [abandoned] and DR-5) is approximately 0.001 in/yr.

8. The perched water system in the southwestern portion of the site is inadequate as the primary supply to Cottonwood Seep by several orders of magnitude. Therefore the primary source(s) of Cottonwood Seep must lie elsewhere.

6.4 Fate of Chloroform and Nitrate

Natural attenuation of nitrate and chloroform in the perched water is expected to result from physical processes that include dilution by recharge and hydrodynamic dispersion. Volatilization is another physical process that is expected to lower chloroform concentrations in perched water. Mass reduction processes expected to lower both nitrate and chloroform concentrations include chemical and biologically-mediated processes. These processes include reduction of nitrate by pyrite, and anaerobic reductive dechlorination of chloroform.

Both nitrate and chloroform plumes are under remediation by pumping. Pumping acts to reduce nitrate and chloroform mass as rapidly as is practical, allowing natural attenuation to be more effective.

The nearest potential discharge points for nitrate originating from the nitrate plume are Westwater Seep and Ruin Spring, both located downgradient of the tailings management system at the site. The nearest potential discharge point for chloroform is Ruin Spring. Corral Springs, located cross-gradient of the tailings management system, appears to be positioned too far east for any potential future impacts by chloroform.

Calculations of perched groundwater flow rates indicate that thousands of years will be required for perched groundwater at the downgradient margins of the tailings management system to reach a discharge point. Because both chloroform and nitrate plumes are more distant from discharge points than the tailings management system, even more time would be required for chloroform or nitrate to reach a discharge point. Since both plumes are expected to naturally attenuate within less than 200 years (through physical, chemical, and/or biological processes), even in the absence of direct mass removal by pumping, there is more than sufficient time for any residual chloroform or nitrate within the respective plumes to degrade before reaching a discharge point.

7. HYDROGEOLOGY OF THE AREA NEAR PROPOSED CELLS 5A AND 5B AND RECOMMENDED LOCATIONS OF NEW PERCHED MONITORING WELLS

The hydrogeology of the portion of the site beneath proposed cells 5A and 5B, the recommended placement of new perched groundwater monitoring wells, and the rationale for the recommended placement and spacing of wells is discussed in the following Sections.

7.1 Hydrogeology

Figure 33 is a fourth quarter, 2017 perched groundwater level contour map showing the locations of hydrogeologic cross-sections in the vicinity of proposed new cells 5A and 5B. Cross section WNW-ESE (Figure 34) extends from piezometer DR-7 (to the west of proposed cell 5A), along the upgradient (northern) dikes of proposed cells 5A and 5B, to MW-17, located on the east dike of proposed cell 5B. Cross section W-E (Figure 35) extends from piezometer DR-8 (to the west of proposed cell 5A), beneath the southwest corner of proposed cell 5A, to MW-17 on the east dike of proposed cell 5B.

The hydrogeology depicted on cross-sections in Figures 34 and 35 is similar to the hydrogeology beneath the existing tailings management system at the site. Alluvium is underlain locally by Mancos Shale. The alluvium (and Mancos where present) is (are) underlain by Dakota Sandstone and Burro Canyon Formation. Both are sandstones that are often not readily distinguishable in the field and are not separately defined on the cross sections. The Burro Canyon Formation is underlain by the Brushy Basin Member of the Morrison Formation. The Brushy Basin Member, a bentonitic shale, functions as an aquiclude supporting the perched groundwater system.

The Dakota Sandstone and Burro Canyon Formations locally contain relatively thin, sub-horizontal, interbedded shale and conglomerate horizons that are often discontinuous between boreholes. Although the lithology shown for MW-17 is more general (due to the less-detailed nature of the log for the boring), shale and 'conglomeratic' horizons within the Burro Canyon and Dakota are described in the log (Appendix A). Detailed logs showing variations in the lithology of the Dakota and Burro Canyon are unavailable for MW-14 and MW-15.

Figures 34 and 35 show that perched groundwater saturated thicknesses vary from negligible at MW-33 (consistently dry well located at the northwest corner of proposed cell 5A) to approximately 33 feet at MW-17 (located on the east dike of proposed cell 5B). Figure 33 shows that a dry area extends from beneath cell 4B under the northwest portion of proposed cell 5A.

Figure 33 also shows that perched groundwater flow beneath the proposed cells is generally to the south-southwest, towards perched groundwater discharge point Ruin Spring.

As discussed in Section 3.1.2, porosity within the Dakota Sandstone and Burro Canyon Formation is primarily intergranular, and no significant joints or fractures have been documented in any wells or borings installed across the site (Knight-Piésold, 1998). Any fractures observed in cores collected from site borings are typically cemented, showing no open space. The Knight-Piésold findings are consistent with the evaluation of a 1994 drilling program provided in HGC (2001a) and with examination of drill core samples collected during installation of MW-3A, MW-23, MW-24, MW-28, MW-30, and TW4-22 in 2005 (HGC, 2005).

The installation of proposed cells 5A and 5B will extend the tailings management system farther downgradient; the southern (downgradient) boundary will be closer to perched water discharge point Ruin Spring. However, as noted in Section 2.1.3, hydraulic conductivities and perched water migration rates to the southwest of the tailings management system (between the tailings management system and Ruin Spring) are among the lowest at the site.

Figure 36 depicts inferred perched groundwater flow pathlines downgradient of the existing tailings management system, and beneath and downgradient of proposed cells 5A and 5B. Figure 37 depicts the shortest pathline from the downgradient (southern) dikes of proposed cells 5A and 5B to the nearest discharge point, Ruin Spring. The length of this pathline is approximately 8,550 feet.

Using an average hydraulic conductivity of 14.1 ft/yr (as calculated for Path 6 in Figure 27), the Figure 37 path length of 8,550 feet, an average hydraulic gradient of 0.0123 ft/ft (between DR-13 and Ruin Spring), and a porosity of 0.18, the estimated average groundwater pore velocity is approximately 0.96 ft/yr. The estimated time for perched groundwater to travel from the downgradient edge of proposed cells 5A and 5B to Ruin Spring is therefore approximately 8,870 years.

7.2 Recommended Well Locations

Five new perched groundwater monitoring wells (MW-41 through MW-45, as shown in Figure 38) are proposed to monitor proposed cells 5A and 5B. As discussed in Section 1, cell 5A and associated groundwater monitoring wells are to be installed first. Therefore, proposed groundwater monitoring wells MW-41 through MW-44 would be installed as part of the construction of cell 5A, and MW-45 would be installed later as part of the construction of cell

5B. Proposed wells MW-41 through MW-44 are considered adequate to monitor proposed cell 5A even if the construction of cell 5B is delayed indefinitely.

Due to the location of cell 5A above and near the topographic high in the Brushy Basin Member surface, three of the proposed wells (MW-41, MW-42, and MW-43) are (unavoidably) expected to have relatively small saturated thicknesses, although MW-42 and MW-43 are likely to have saturated thicknesses of at least 5 feet or greater.

Narrow-diameter pilot borings are proposed to be installed to ensure adequate saturated thicknesses within the proposed monitoring wells. Should the saturated thickness within a pilot boring be inadequate (less than 5 feet), the boring (with the concurrence of DWMRC) will either be converted to a piezometer or abandoned. A new pilot boring will be installed within approximately 100 feet in a direction along the cell margin likely to have adequate saturated thickness. Pilot borings having saturated thicknesses of 5 feet or greater will be reamed and completed as monitoring wells.

The spacing of the four wells along the southern (downgradient) dikes of the proposed cells is similar to the spacing of existing wells along the southern (downgradient) dikes of cells 4A and 4B. An additional well is proposed along the west (generally cross-gradient) dike of proposed cell 5A. Existing well MW-17 will function as the up- to cross-gradient well along the east dike of proposed cell 5B.

The spacing of the proposed wells (approximately 750 ft) is conservative with regard to reliable detection of potential future impacts to groundwater that may arise from any future seepage from the proposed cells. As discussed in HGC (2001b), numerical simulations of hypothetical point source leaks from the existing tailings management system indicate that such leaks could be reliably detected using well spacings of between 850 and 900 ft. However, the advanced design and leak detection systems that are to be incorporated in the construction of the proposed cells makes it highly unlikely that any potential future seepage could bypass the leak detection systems to an extent that could impact groundwater. The proposed well spacing is likely overly conservative considering that the cell design includes multiple liners with a leak detection system installed between the liners.

Simulations of the hypothetical leaks presented in HGC (2001b) assumed a relatively conservative 10:1 ratio of horizontal to vertical permeability within vadose materials (unsaturated Dakota Sandstone and Burro Canyon Formation) underlying the tailings management system at the site. In reality, the effective ratio of horizontal to vertical permeability is likely to be larger than 10:1, making the resulting potential for lateral spreading, and the reliability of the monitoring well network, greater than was simulated. A large ratio of horizontal to vertical permeability is likely to exist due to the sub-horizontal layering that is present in both the Dakota Sandstone and Burro Canyon Formation.

In addition, interbedded sub-horizontal shale and/or coarse-grained (conglomeratic) horizons that exist beneath proposed cells 5A and 5B (cross-sections presented in Figures 34 and 35) are both likely to enhance lateral spreading of any future seepage that may potentially originate from the proposed cells. Such lateral spreading would increase the area of perched groundwater impacted by any potential future seepage and thus reduce the number of wells needed for reliable detection.

Sub-horizontal shale horizons are expected to have low vertical permeability (and therefore low vertical hydraulic conductivity). Any seepage percolating vertically downward that encountered a shale horizon would be likely to perch, then spread laterally. Lateral spreading would continue until the perched area was large enough that seepage through the low-permeability shale became equal to the incoming seepage rate. The footprint of seepage through the base of the shale horizon would thus be larger than the footprint of incoming seepage above the shale horizon.

Sub-horizontal coarse-grained (conglomeratic) horizons at the site may have either relatively high or relatively low permeability depending on the degree of cementation. HGC (2010a and 2010b) summarize the lithology and hydraulic testing of angle borings GH-94-1 and GH-94-2A (angled beneath cell 3, as described in HGC, 2001a). The majority of the hydraulic tests within these angle borings were conducted within the vadose zone and are considered generally representative of vadose conditions beneath the tailings management system. The test results discussed in HGC (2010a and 2010b) indicate the following:

1. Horizontal hydraulic conductivities of the Dakota Sandstone ranged from 5.9×10^{-6} cm/s to 8.8×10^{-5} cm/s; horizontal hydraulic conductivities of the underlying Burro Canyon Formation ranged from 4×10^{-5} cm/s to 6.3×10^{-4} cm/s. Less than half of the higher conductivities occurred in conglomeratic materials, with three of the tests conducted in conglomeratic material yielding conductivity estimates less than 10^{-5} cm/s. Only one test yielded a conductivity estimate greater than 10^{-5} cm/s.
2. The available (pre-2010) borehole data near cell 4B indicate poor correlation between conglomeratic intervals and enhanced permeability. Only one (possibly two) reported zone(s) of higher permeability within conglomeratic materials exist(s) near the saturated portion of the Burro Canyon Formation. Cross-gradient to up-gradient (east to northeast) of the tailings management system, in the vicinity of the chloroform plume, conglomeratic materials within the deep saturated Burro Canyon Formation appear to be associated with higher permeability, at least in the vicinity of MW-4 (within the chloroform plume).

However, available data from the vicinity of cell 4B do not indicate a consistent association between conglomeratic materials and higher permeability in the vadose zone.

3. Overall, vadose conglomeratic intervals do not consistently have higher hydraulic conductivities (or permeabilities) than the surrounding sandstones. However, conglomeratic intervals having higher conductivities than surrounding materials would likely spread any seepage laterally so that the seepage would contact a larger area of perched groundwater.

With regard to lateral spreading, potential seepage encountering a relatively high permeability, sub-horizontal conglomeratic horizon is expected to spread laterally as a result of two factors: 1) the conglomeratic material would likely behave as a capillary barrier; and 2) the relatively high lateral permeability of the conglomeratic material would facilitate lateral spreading of any seepage percolating into the material.

First, as a capillary barrier, a relatively high permeability conglomeratic material would prevent infiltration of seepage from finer-grained, lower-permeability, overlying materials until near-saturated conditions were reached in the overlying material above the contact. As saturations build up within the overlying materials, the potential for lateral spreading increases.

Second, any seepage percolating into a relatively high permeability conglomeratic horizon would tend to perch on the underlying lower permeability materials, causing lateral spreading within the conglomeratic horizon, and increasing the area of the underlying materials impacted by the continuing downward percolation of the seepage.

Overall, the vertical heterogeneity encountered beneath proposed cells 5A and 5B is expected to enhance the likelihood for timely detection of any groundwater impacts from potential future seepage originating from the cells. Furthermore, as discussed above, improvements in cell design since installation of cells 1 through 3 at the site make it highly unlikely that any potential future seepage could bypass the leak detection systems incorporated in proposed cells 5A and 5B to an extent that could impact groundwater.

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9. LIMITATIONS STATEMENT

The opinions and recommendations presented in this report are based upon the scope of services and information obtained through the performance of the services, as agreed upon by HGC and the party for whom this report was originally prepared. Results of any investigations, tests, or findings presented in this report apply solely to conditions existing at the time HGC's investigative work was performed and are inherently based on and limited to the available data and the extent of the investigation activities. No representation, warranty, or guarantee, express or implied, is intended or given. HGC makes no representation as to the accuracy or completeness of any information provided by other parties not under contract to HGC to the extent that HGC relied upon that information. This report is expressly for the sole and exclusive use of the party for whom this report was originally prepared and for the particular purpose that it was intended. Reuse of this report, or any portion thereof, for other than its intended purpose, or if modified, or if used by third parties, shall be at the sole risk of the user.

TABLES

TABLE 1

Results of Slug test Analyses Using KGS and Bouwer-Rice Solutions

		Automatically Logged Data			Hand Collected Data		
		KGS		Bouwer-Rice	KGS		Bouwer-Rice
Test	Saturated Thickness	K (cm/s)	Ss (1/ft)	K (cm/s)	K (cm/s)	Ss (1/ft)	K (cm/s)
TWN-1	54	1.70E-04	2.22E-03	NI	1.97E-04	1.25E-03	1.36E-04
TWN-2	74	1.49E-05	3.20E-04	2.25E-05	2.04E-05	1.16E-04	2.73E-05
TWN-3	60	8.56E-06	8.73E-06	8.97E-06	7.75E-06	1.53E-05	8.89E-06
TWN-4	85	1.76E-03	3.43E-04	2.79E-05	1.25E-03	1.84E-06	NI
TWN-5	77	4.88E-04	3.88E-07	4.06E-04	4.88E-04	3.88E-07	3.70E-04
TWN-6	79	1.74E-04	2.22E-03	NI	3.50E-04	2.22E-12	3.36E-04
TWN-7	11	3.57E-07	2.22E-03	4.59E-07	3.57E-07	2.21E-03	NI
TWN-8	80	1.51E-04	3.66E-04	7.55E-05	4.73E-04	1.41E-06	2.48E-04
TWN-9	29	2.99E-05	6.92E-03	2.86E-05	6.02E-05	5.59E-03	7.93E-05
TWN-10	20	3.83E-05	0.1	2.31E-05	8.71E-05	8.12E-03	1.10E-04
TWN-11	68	1.18E-04	1.08E-05	9.83E-05	9.34E-05	7.18E-05	9.78E-05
TWN-12	67	8.05E-05	4.65E-05	7.69E-05	1.28E-04	1.27E-07	7.39E-05
TWN-13	68	2.62E-06	0.1	4.77E-06	2.09E-06	0.1	6.93E-06
TWN-14	57	3.61E-06	6.39E-03	2.74E-06	3.98E-06	3.17E-03	7.93E-06
TWN-15	58	4.75E-05	1.04E-03	2.61E-05	5.86E-05	3.49E-04	6.42E-05
TWN-16	41	0.0142	8.02E-04	6.47E-03	NI	NI	NI
TWN-17	69	3.73E-06	0.033	6.18E-06	1.41E-06	0.061	1.96E-06
TWN-18	83	2.27E-03	2.44E-06	1.14E-03	2.67E-03	2.22E-12	NI
TWN-19	50	2.69E-05	2.49E-03	1.81E-05	3.83E-05	3.34E-03	NI
MW-03 (mlt)	5.2	4.00E-07	1.92E-02	1.50E-05	--	--	--
MW-05 (lt)	10	3.50E-06	4.40E-03	3.90E-06	3.20E-06	--	4.30E-06
MW-05 (et)				2.40E-05			1.80E-05
MW-17	18	2.60E-05	1.71E-04	2.70E-05	2.20E-05	--	3.00E-05
MW-18	58	2.90E-04	4.60E-07	2.40E-04	3.20E-04	--	2.50E-04
MW-19	80	1.70E-05	1.44E-06	1.30E-05	1.20E-05	--	1.50E-05
MW-19, confined	47	1.60E-05	3.24E-06	1.20E-05	--	--	--
MW-20 (mlt)	12	--	--	9.30E-06	--	--	--
MW-20 (mlt)				5.90E-06			2.50E-06
MW-22	51	1.00E-06	2.00E-03	7.90E-06	9.00E-07	--	--
MW-22				4.40E-06			3.40E-06
MW-23	12	3.20E-08	0.1	1.60E-06	NI	NI	NI
MW-23b	12	2.30E-07	2.30E-03	2.50E-07	NI	NI	2.00E-07
MW-24	3.4	4.16E-05	5.20E-03	3.15E-05	3.03E-05	0.0152	3.03E-05
MW-25	33	1.10E-04	3.00E-04	7.40E-05	1.70E-04	2.00E-04	1.00E-04
MW-27	36	8.20E-05	5.30E-04	3.60E-05	1.40E-04	8.70E-05	3.10E-05
MW-28	23	1.70E-06	0.02	1.70E-06	1.70E-06	0.02	2.00E-06
MW-29	18	1.10E-04	1.90E-04	9.30E-05	1.30E-04	2.10E-04	1.00E-04
MW-30	24	1.00E-04	2.90E-04	6.40E-05	1.10E-04	1.40E-04	5.10E-05
MW-31	53	7.10E-05	2.50E-05	6.90E-05	7.40E-05	7.20E-06	6.90E-05
MW-32	46	3.00E-05	8.80E-05	2.60E-05	2.80E-05	2.50E-04	3.00E-05
MW-35	12	3.48E-04	1.95E-05	2.18E-04	2.59E-04	1.78E-05	1.65E-04
MW-36	6.2	4.51E-04	4.29E-04	NA	7.73E-04	2.66E-04	6.52E-04
MW-36 (lt)	6.2	NA	NA	1.84E-04	NA	NA	NA
MW-36 (et)	6.2	NA	NA	5.07E-04	NA	NA	NA
MW-37	2.9	1.28E-05	2.22E-12	1.21E-05	NA	NA	NA
TW4-4 (et)	22	NA	NA	1.26E-03	NA	NA	NA
TW4-4 (lt)	22	1.66E-03	6.21E-05	2.89E-04	1.63E-03	3.01E-04	7.91E-04
TW4-6	24	1.15E-05	3.67E-05	1.00E-05	1.19E-05	1.49E-04	1.32E-05
TW4-20	43	5.90E-05	1.60E-05	4.20E-05	7.00E-05	1.20E-05	5.30E-05
TW4-21	63	1.90E-04	1.10E-04	3.20E-05	1.90E-04	3.20E-05	9.40E-06
TW4-22	55	1.30E-04	6.80E-06	1.10E-04	1.30E-04	4.50E-06	1.10E-04
TW4-23	43	3.80E-05	7.40E-03	2.90E-05	3.40E-01	6.40E-04	7.90E-05
TW4-24	53	1.60E-04	1.10E-03	1.00E-04	1.20E-04	1.70E-03	5.20E-05
TW4-25	89	5.80E-05	0.001	3.70E-05	7.40E-05	1.10E-03	5.00E-05
TW4-26	18	2.40E-05	3.23E-04	2.16E-05	2.28E-05	3.13E-04	2.55E-05
TW4-27 (uncorrected)	9	NA	NA	NA	2.13E-06	1.51E-03	1.59E-06
TW4-27 (100% correction)		7.01E-07	2.22E-03	1.99E-06	NA	NA	NA
TW4-27(60% correction)		1.35E-06	1.27E-03	1.15E-06	NA	NA	NA
TW4-28	67.9	3.52E-04	1.22E-06	3.92E-04	3.29E-04	7.49E-06	4.07E-04
TW4-29	17.7	4.24E-05	1.19E-03	5.24E-05	4.52E-05	9.62E-04	5.66E-05
TW4-29 (lt)	17.7	NA	NA	2.00E-05	NA	NA	3.80E-05
TW4-30	9.6	1.44E-04	1.00E-02	6.22E-05	1.34E-04	1.00E-02	1.38E-04
TW4-30 (et)	9.6	NA	NA	1.63E-04	NA	NA	2.91E-04
TW4-30 (lt)	9.6	NA	NA	1.12E-05	NA	NA	1.41E-05
TW4-31	18.1	4.18E-05	2.54E-05	3.87E-05	3.24E-05	9.65E-05	4.01E-05
TW4-32	64.8	9.53E-05	1.15E-04	NA	5.34E-05	7.97E-04	5.86E-05
TW4-32(et)	64.8	NA	NA	1.09E-04	NA	NA	1.34E-04
TW4-32(lt)	64.8	NA	NA	2.51E-05	NA	NA	1.17E-05
TW4-33	13.1	5.51E-05	3.73E-04	5.78E-05	5.25E-05	5.32E-04	5.76E-05
TW4-34	25.2	9.98E-05	1.13E-03	1.54E-04	9.39E-05	1.54E-03	1.25E-04
TW4-34 (lt)	25.2	NA	NA	1.17E-04	NA	NA	NA
TW4-35	8.8	6.27E-05	1.49E-03	5.72E-05	5.72E-05	1.69E-03	6.42E-05
TW4-36	36.7	3.23E-06	1.07E-03	6.39E-06	1.82E-06	2.83E-03	4.79E-06
TW4-37	51.6	1.43E-04	2.14E-04	2.17E-04	1.93E-04	8.60E-05	2.33E-04
TW4-38	57.97	6.37E-05	1.15E-04	NA	4.76E-05	2.81E-05	NA
TW4-38 (mlt)		NA	NA	7.16E-05	NA	NA	5.54E-05
TW4-38 (lt)		NA	NA	5.68E-05	NA	NA	3.76E-05
TW4-39	56.30	5.27E-05	2.03E-04	NA	6.15E-05	1.70E-04	NA
TW4-39 (mlt)		NA	NA	7.21E-05	NA	NA	8.41E-05
TW4-39 (lt)		NA	NA	2.85E-05	NA	NA	3.17E-05
DR-5	12.3	2.95E-05	4.21E-05	3.80E-05	2.86E-05	2.65E-03	3.76E-05
DR-8, Oct 2012	7.8	2.46E-08	1.00E-02	3.56E-07	4.46E-08	1.00E-02	4.45E-07
DR-8, Oct 2011	7.7	3.40E-08	0.01	NA	1.07E-07	0.0011	NA
DR-9	24.5	4.49E-04	4.30E-06	3.41E-04	4.73E-04	1.21E-05	4.73E-04
DR-10	3	2.92E-06	6.54E-03	5.56E-06	9.71E-06	8.41E-04	9.71E-06
DR-11	8.9	8.88E-06	8.88E-04	1.54E-05	5.83E-06	2.22E-03	1.11E-05
DR-13	11.2	5.90E-06	7.33E-05	5.38E-06	4.93E-06	1.57E-04	1.49E-06
DR-13(et)	11.2	NA	NA	NA	NA	NA	6.81E-06
DR-14	18.8	1.26E-05	7.34E-05	1.66E-05	7.78E-06	4.84E-04	6.18E-06
DR-14(et)	18.8	NA	NA	NA	NA	NA	1.23E-05
DR-17	6.5	1.24E-05	1.53E-04	1.43E-05	3.17E-06	5.00E-03	2.19E-06
DR-17(et)	6.5	NA	NA	NA	NA	NA	8.35E-06
DR-19	3.5	3.29E-05	2.54E-03	3.78E-05	3.39E-05	1.86E-03	4.08E-05
DR-20	17.9	2.14E-06	1.91E-05	2.69E-06	1.43E-06	1.90E-05	1.89E-06
DR-21	13.5	3.29E-05	7.17E-06	3.60E-05	2.21E-05	1.87E-04	3.49E-05
DR-23	7.5	1.96E-05	3.85E-04	2.35E-05	7.49E-06	5.00E-03	4.51E-06
DR-23(et)	7.5	NA	NA	NA	NA	NA	2.16E-05
DR-24	17.4	1.64E-05	7.49E-05	1.43E-05	1.64E-05	7.49E-05	8.23E-06
DR-24(et)	17.4	NA	NA	NA	NA	NA	1.97E-05

Notes:

Bouwer-Rice = Unconfined Bouwer-Rice solution method in Aqtesolv™ unless otherwise noted
cm/s = centimeters per second
ft = feet
K = hydraulic conductivity
KGS = Unconfined KGS solution method in Aqtesolv™ unless otherwise noted
Ss= specific storage
NI= Not Interpretable .
et= early time data
mlt=middle to late time data
lt=late time data
NA=not applicable

TABLE 2
Results of Recovery and Slug Test Analyses Using Moench Solution

			Automatically-Logged Data				Hand Data
Well ID	**Interpretation Method**	**Type**	**Hydraulic Conductivity (cm/sec)**	**Storativity**	**Saturated Thickness (feet)**	**Skin**	**Hydraulic Conductivity (cm/sec)**
MW-01	WHIP	pump/recovery	7.70E-07	0.0082	20	none	7.70E-07
	AQTESOLV (Moench, Leaky)	pump/recovery	7.70E-07	0.0082	20	none	7.70E-07
	AQTESOLV (Moench, Unconfined)	pump/recovery	8.90E-07	0.01	40	none	--
MW-03	WHIP	slug	4.30E-05	0.01	5.2	none	--
MW-05	WHIP	slug	1.10E-05	0.1	10	none	--
MW-17	WHIP	slug	2.90E-05	0.01	18	none	--
MW-18	WHIP	slug	4.40E-04	2.20E-05	45	none	--
	WHIP	slug	5.30E-04	0.02	45	6.54	--
MW-19	WHIP	slug	7.10E-06	0.032	47	none	--
	WHIP	slug	1.70E-05	0.027	47	2.24	--
	AQTESOLV (Moench, Leaky)	slug	1.70E-05	0.027	47	2.24	--
MW-20	WHIP	slug	8.20E-06	0.02	12	none	--
MW-22	WHIP	slug	4.20E-06	0.014	51	none	--

Notes:
cm/sec = Centimeters per second
WHIP analyses via modfied Moench Leaky Solution

TABLE 3
Estimated Perched Zone Hydraulic Properties Based on Analysis of Observation Wells Near MW-4 and TW4-19 During Long Term Pumping of MW-4 and TW4-19

Observation Well	Theis Solution (Confined or Unconfined)	Transmissivity (ft^2/day)	Storage Coefficient	Water Bearing Zone Thickness (feet)	Average Hydraulic Conductivity (ft/day)	Average Hydraulic Conductivity (cm/sec)
TW4-1	Unconfined	8.9	0.023	39	0.23	8.20E-05
	Confined	8.4	0.023	24	0.35	1.30E-04
TW4-2	Unconfined	4.6	0.0065	39	0.12	4.30E-05
	Confined	3.8	0.0063	24	0.16	5.70E-05
TW4-7	Unconfined	4.7	0.011	39	0.12	4.30E-05
	Confined	3.3	0.011	24	0.14	5.00E-05
TW4-8	Unconfined	4.5	0.010	39	0.12	4.30E-05
	Confined	3.9	0.010	24	0.16	5.70E-05
MW-4A	Unconfined	5.8	0.019	39	0.15	5.40E-05
	Confined	3.5	0.019	24	0.15	5.40E-05
MW-4A (early time)	Unconfined	12.4	0.0029	39	0.32	1.10E-04
	Confined	9.1	0.0031	24	0.38	1.40E-04
TW4-5	Unconfined	89	0.0043	67	1.3	4.60E-04
	Confined	87	0.0043	31	2.8	1.00E-03
TW4-9	Unconfined	72	0.0043	67	1.1	3.90E-04
	Confined	71	0.0043	31	2.3	8.20E-04
TW4-10	Unconfined	48	0.0077	67	0.72	2.60E-04
	Confined	46	0.0076	31	1.5	5.40E-04
TW4-15 (MW-26)	Unconfined	15	0.0037	67	0.22	7.90E-05
	Confined	12	0.0037	31	0.39	1.40E-04
TW4-16	Unconfined	19	0.0036	67	0.28	1.00E-04
	Confined	18	0.0035	31	0.58	2.10E-04
TW4-18	Unconfined	76	0.0046	67	1.1	3.90E-04
	Confined	74	0.0046	31	2.4	8.60E-04
TW4-19	Unconfined	44	0.12	67	0.66	2.40E-04
	Confined	39	0.12	31	1.3	4.60E-04

Notes:
cm/sec = Centimeters per second
ft/day = Feet per day
ft^2/day = Feet squared per day

TABLE 4
Summary of Hydraulic Properties
White Mesa Uranium Mill
from TITAN (1994)

Boring/ Well Location	Test Type	Interval (ft-ft)	Document Referenced	Hydraulic Conductivity (ft/yr)	Hydraulic Conductivity (cm/sec)
Soils					
6	Laboratory Test	9	D&M	1.20E+01	1.20E-05
7	Laboratory Test	4.5	D&M	1.00E+01	1.00E-05
10	Laboratory Test	4	D&M	1.20E+01	1.20E-05
12	Laboratory Test	9	D&M	1.40E+02	1.40E-04
16	Laboratory Test	4.5	D&M	2.20E+01	2.10E-05
17	Laboratory Test	4.5	D&M	9.30E+01	9.00E-05
19	Laboratory Test	4	D&M	7.00E+01	6.80E-05
22	Laboratory Test	4	D&M	3.90E+00	3.80E-06
			Geometric Mean	2.45E+01	2.37E-05
Dakota Sandstone					
No. 3	Injection Test	28-33	D&M (1)	5.68E+02	5.49E-04
No. 3	Injection Test	33-42.5	D&M	2.80E+00	2.71E-06
No. 12	Injection Test	16-22.5	D&M	5.10E+00	4.93E-06
No. 12	Injection Test	22.5-37.5	D&M	7.92E+01	7.66E-05
No. 19	Injection Test	26-37.5	D&M	7.00E+00	6.77E-06
No. 19	Injection Test	37.5-52.5	D&M	9.44E+02	9.12E-04
			Geometric Mean	4.03E+01	3.89E-05
Burro Canyon Formation					
No. 3	Injection Test	42.5-52.5	D&M	5.80E+00	5.61E-06
No. 3	Injection Test	52.5-63	D&M	1.62E+01	1.57E-05
No. 3	Injection Test	63-72.5	D&M	5.30E+00	5.13E-06
No. 3	Injection Test	72.5-92.5	D&M	3.20E+00	3.09E-06
No. 3	Injection Test	92.5-107.5	D&M	4.90E+00	4.74E-06
No. 3	Injection Test	122.5-142	D&M	6.00E-01	5.80E-07
No. 9	Injection Test	27.5-42.5	D&M	2.70E+00	2.61E-06
No. 9	Injection Test	42.5-59	D&M	2.00E+00	1.93E-06
No. 9	Injection Test	59-82.5	D&M	7.00E-01	6.77E-07
No. 9	Injection Test	82.5-107.5	D&M	1.10E+00	1.06E-06
No. 9	Injection Test	107.5-132	D&M	3.00E-01	2.90E-07
No. 12	Injection Test	37.5-57.5	D&M	9.01E-01	8.70E-07
No. 12	Injection Test	57.5-82.5	D&M	1.40E+00	1.35E-06
No. 12	Injection Test	82.5-102.5	D&M	1.07E+01	1.03E-05
No. 28	Injection Test	76-87.5	D&M	4.30E+00	4.16E-06
No. 28	Injection Test	87.5-107.5	D&M	3.00E-01	2.90E-06
No. 28	Injection Test	107.5-132.5	D&M	2.00E-01	1.93E-07
WMMW1	(7) Recovery	92-112	Peel (2)	3.00E+00	2.90E-06
WMMW3	(7) Recovery	67-87	Peel	2.97E+00	2.87E-06
WMMW5	(7) Recovery	95.5-133.5	H-E	1.31E+01	1.27E-05
WMMW5	(7) Recovery	95.5-133.5	Peel	2.10E+01	2.03E-05
WMMW11	(7) Recovery	90.7-130.4	H-E (3)	1.23E+03	1.19E-03
WMMW11	(7) Single Well Drawdown	90.7-130.4	Peel	1.63E+03	1.58E-03
WMMW12	(7) Recovery	84-124	H-E	6.84E+01	6.61E-05
WMMW12	(7) Recovery	84-124	Peel	6.84E+01	6.61E-05
WMMW14	Single Well Drawdown	90-120	(5) H-E	1.21E+03	1.16E-03
WMMW14	Single Well Drawdown	90-120	(6) H-E	4.02E+02	3.88E-04
WMMW15	Single Well Drawdown	99-129	H-E	3.65E+01	3.53E-05
WMMW15	(7) Recovery	99-129	Peel	2.58E+01	2.49E-05
WMMW16	Injection Test	28.5-31.5	Peel	9.42E+02	9.10E-04
WMMW16	Injection Test	45.5-51.5	Peel	5.28E+01	5.10E-05
WMMW16	Injection Test	65.5-71.5	Peel	8.07E+01	7.80E-05
WMMW16	Injection Test	85.5-91.5	Peel	3.00E+01	2.90E-05
WMMW17	Injection Test	45-50	Peel	3.10E+00	3.00E-06
WMMW17	Injection Test	90-95	Peel	3.62E+00	3.50E-06
WMMW17	Injection Test	100-105	Peel	5.69E+00	5.50E-06
WMMW18	Injection Test	27-32	Peel	1.14E+02	1.10E-04
WMMW18	Injection Test	85-90	Peel	2.59E+01	2.50E-05
WMMW18	Injection Test	85-90	Peel	2.69E+01	2.60E-05
WMMW18	Injection Test	120-125	Peel	4.66E+00	4.50E-06
WMMW19	Injection Test	55-60	Peel	8.69E+00	8.40E-06
WMMW19	Injection Test	95-100	Peel	1.45E+00	1.40E-06
			Geometric Mean	1.05E+01	1.01E-05
Entrada/Navajo Sandstones					
WW-1	Recovery		D'Appolonia (4)	3.80E+02	3.67E-04
WW-1	Multi-well drawdown		D'Appolonia	4.66E+02	4.50E-04
WW-1,2,3	Multi-well drawdown		D'Appolonia	4.24E+02	4.10E-04
			Geometric Mean	4.22E+02	4.08E-04

Notes

(1) D&M = Dames & Moore, Environmental Report, White Mesa Uranium Project, January 1978.
(2) Peel = Peel Environmental Services, UMETCO Minerals Corp., Ground Water Study, White Mesa Facility, June 1994.
(3) H-E = Hydro-Engineering, Ground-Water Hydrology at the White Mesa Tailings Facility, July 1991.
(4) D'Appolonia, Assessment of the Water Supply System, White Mesa Project, Feb. 1981.
(5) Early test data.
(6) Late test data.
(7) Test data reanalyzed by TEC.

TABLE 5
Properties of the Dakota/Burro Canyon Formation
White Mesa Uranium Mill
from TITAN (1994)

Formation	Well No. and Sample Interval		% Moisture Content	Moisture Content, Volumetric	Dry Unit Weight (lbs/cu ft)	% Porosity	Particle Specific Gravity	% Saturation	% Retained Moisture	% Liquid Limit	% Plastic Limit	% Plasticity Index	Rock Type
Dakota	WMMW-16	26.4' - 38.4'	1.50	3.30	135.20	17.90	2.64	18.20	5.10	--	--	--	Sandstone
	WMMW-16	37.8' - 38.4'	0.40	0.80	127.40	22.40	2.63	3.70	6.30	--	--	--	Sandstone
	WMMW-17	27.0' - 27.5'	0.30	0.60	138.80	13.40	2.57	4.80	5.10	--	--	--	Sandstone
	WMMW-17	49.0' - 49.5'	3.60	7.10	121.90	26.00	2.64	27.20	9.60	--	--	--	Sandstone
	Formation Average:		**1.45**	**2.95**	**130.83**	**19.93**	**2.62**	**13.48**	**6.53**				
Burro Canyon	WMMW-16	45.0' - 45.5'	5.60	12.60	140.90	16.40	2.70	77.20	--	29.60	15.40	14.20	Sandy Mudstone
	WMMW-16	47.5' - 48.0'	2.60	5.90	142.80	12.00	2.60	48.90	4.40	--	--	--	Sandstone
	WMMW-16	53.5' - 54.1'	0.70	1.40	129.00	19.90	2.58	7.10	6.40	--	--	--	Sandstone
	WMMW-16	60.5' - 61.0'	0.10	0.20	117.90	27.30	2.61	0.80	9.90	--	--	--	Sandstone
	WMMW-16	65.5' - 66.0'	2.60	5.50	131.50	19.30	2.62	28.20	7.10	--	--	--	Sandstone
	WMMW-16	73.0' - 73.5'	0.10	0.30	130.30	20.60	2.63	1.30	5.50	--	--	--	Sandstone
	WMMW-16	82.0' - 82.4'	0.10	0.10	134.30	18.50	2.64	0.60	4.80	--	--	--	Sandstone
	WMMW-16	90.0' - 90.7'	0.10	0.30	161.50	2.00	2.64	12.80	0.90	--	--	--	Sandstone
	WMMW-16	91.1' - 91.4'	5.20	9.80	118.10	29.10	2.67	33.80	--	33.70	16.20	17.50	Claystone
	WMMW-17	104.0' - 104.5	0.20	0.40	161.40	1.70	2.67	26.60	0.80	--	--	--	Sandstone*
	Formation Average:		**1.90**	**4.01**	**134.03**	**18.34**	**2.63**	**23.41**	**5.57**				

Note:

**Data from this interval is actually from the Brushy Basin and is not included in the averages.*

TABLE 6
Hydraulic Conductivity Estimates For Spring Flow Calculations

Ruin Spring		Westwater Seep		Westwater Seep (2)	
location	**k (cm/s)**	**location**	**k (cm/s)**	**location**	**k (cm/s)**
DR-21	3.29E-05	DR-5	2.95E-05	DR-5	2.95E-05
DR-23	1.96E-05	DR-8	2.46E-08	MW-23	2.30E-07
DR-24	1.64E-05	DR-9	4.49E-04	MW-24	4.16E-05
		DR-10	2.92E-06	MW-35	3.48E-04
		DR-11	8.88E-06		
		MW-12	2.20E-05		
		MW-23	2.30E-07		
		MW-24	4.16E-05		
		MW-36	4.51E-04		
geomean:	2.19E-05	**geomean:**	9.76E-06	**geomean:**	1.77E-05

Notes:
k = hydraulic conductivity
cm/s = centimeters per second

TABLE 7
Hydraulic Conductivity Estimates For Travel Time Calculations
Paths 1, 2A, and 2B

PATH 1 (nitrate plume area near historical pond		PATH 2A (chloroform plume area (near wildlife ponds)		PATH 2B (chloroform plume area (near wildlife ponds)	
location	**k (cm/s)**	**location**	**k (cm/s)**	**location**	**k (cm/s)**
TWN-2	1.49E-05	TW4-5 u	4.60E-04	MW-4A u	1.10E-04
TWN-3	8.56E-06	TW4-5 c	1.00E-03	MW-4A c	1.40E-04
TWN-18	2.27E-03	TW4-9 u	3.90E-04	TW4-2 u	4.30E-05
TW4-21	1.90E-04	TW4-9 c	8.20E-04	TW4-2 c	5.70E-05
TW4-22	1.30E-04	TW4-10 u	2.60E-04	TW4-8 u	4.30E-05
TW4-24	1.60E-04	TW4-10 c	5.40E-04	TW4-8 c	5.70E-05
TW4-37	1.43E-04	TW4-18 u	3.90E-04	TW4-9 u	3.90E-04
MW-11	1.40E-03	TW4-18 c	8.60E-04	TW4-9 c	8.20E-04
MW-27	8.20E-05	MW-26 u	7.90E-05	TW4-28	3.52E-04
MW-30	1.00E-04	MW-26 c	1.40E-04	TW4-38	6.40E-05
MW-31	7.10E-05				
geomean:	1.27E-04	**geomean:**	3.88E-04	**geomean:**	1.21E-04

Notes:
k = hydraulic conductivity
cm/s = centimeters per second
c = confined solution
u = unconfined solution

TABLE 8
Hydraulic Conductivity Estimates for Travel Time Calculations
Paths 3-6

PATHS 3 and 4 (downgradient of tailings management system)		PATH 5 (downgradient of tailings management system)		PATH 6 (downgradient of tailings management system)	
location	**k (cm/s)**	**location**	**k (cm/s)**	**location**	**k (cm/s)**
DR-5	2.95E-05	DR-5	2.95E-05	DR-11	8.88E-06
DR-8	2.46E-08	DR-8	2.46E-08	DR-13	5.89E-06
DR-9	4.49E-04	DR-9	4.49E-04	DR-21	3.29E-05
DR-10	2.92E-06	DR-10	2.92E-06	DR-23	1.54E-05
DR-11	8.88E-06	DR-11	8.88E-06	MW-3	4.00E-07
MW-12	2.20E-05	DR-14	1.26E-05	MW-14	7.50E-04
MW-23	2.30E-07	DR-17	1.24E-05	MW-15	1.90E-05
MW-24	4.16E-05	DR-19	3.29E-05	MW-20	9.30E-06
MW-36	4.51E-04	DR-20	2.14E-06	MW-37	1.28E-05
		DR-21	3.29E-05		
		DR-23	1.96E-05		
		DR-24	1.64E-05		
		MW-23	2.30E-07		
		MW-24	4.16E-05		
		MW-36	4.51E-04		
geomean:	9.76E-06	**geomean:**	1.10E-05	**geomean:**	1.38E-05

Notes:
k = hydraulic conductivity
cm/s = centimeters per second

TABLE 9
Estimated Perched Zone Pore Velocities Along Path Lines

Path	Hydraulic Conductivity[a]		Path Length	Head Change	Hydraulic Gradient	Pore Velocity	General Path Location
	(cm/s)	(ft/yr)	(ft)	(ft)	(ft/ft)	(ft/yr)	(area of site)
1	1.27E-04	130	1,425	33	0.0232	17	nitrate plume area near historical pond
2A	3.88E-04	397	1,045	23	0.0220	48	chloroform plume area near wildlife ponds
2B	1.21E-04	124	1,190	47	0.0395	27	chloroform plume area near wildlife ponds
3	9.76E-06	10.0	2,200	29	0.0132	0.73	downgradient of tailings mgmt system
4	9.76E-06	10.0	4,125	19	0.0046	0.26	downgradient of tailings mgmt system
5	1.10E-05	11.3	11,800	113	0.0096	0.60	downgradient of tailings mgmt system
6	1.38E-05	14.1	9,700	112	0.0115	0.90	downgradient of tailings mgmt system

Notes:
[a] Geometric average (from Tables 7 and 8)
Assumes effective porosity of 0.18
cm/s = centimeters per second
ft/ft = feet per foot
ft/yr = feet per year
mgmt = management

TABLE 10
Results of XRD and Sulfur Analysis in Weight Percent

Mineral	Formula	MW-3A	MW-23	MW-24	MW-25	MW-26	MW-27	MW-28	MW-29	MW-30	MW-31	MW-32 (TW4-17)	SS-26*
		Depth (feet)											
		89.5	108	118.5	65 - 67.5	90 - 92.5	80 - 82.5	88.5	102	65 - 67.5	95 - 97.5	105-107.5	NA
quartz	SiO_2	79.7	96.2	88.4	90	86.9	95.4	90.1	95.8	87	91.7	94.1	39.2
K-feldspar	$KAlSi_3O_8$	ND	0.2	0.6	2.4	2.4	0.7	1.5	0.5	1.4	2	0.8	21.6
plagioclase	$(Na,Ca)(Si,Al)_4O_8$	ND	ND	ND	1.4	1.6	1.5	1.8	1.5	1.5	0.5	0.2	29
mica	$KAl_2(Si_3Al)O_{10}(OH)_2$	0.3	1.2	4.5	2.2	2	0.2	3	0.2	5.9	3.1	1.2	5.2
kaolinite	$Al_2Si_2O_5(OH)_4$	1.1	1	4.3	3.2	2.5	1.4	2.9	1.7	3.6	2.4	1.6	0.8
calcite	$CaCO_3$	14	ND	ND	ND	3.9	ND	ND	ND	ND	ND	1.2	0.6
dolomite	$CaMg(CO_3)_2$	4.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
anhydrite	$CaSO_4$	0.4	0.8	0.4	0.4	ND	ND	ND	ND	ND	ND	ND	ND
gypsum	$CaSO_4 \cdot 2H_2O$	ND	0.2	0.8	ND	ND	ND	0.3	ND	0.3	ND	ND	ND
iron	Fe	0.3	0.4	0.2	0.4	0.4	0.4	0.2	0.3	0.3	0.3	0.4	0.2
pyrite	FeS_2	0.1	ND	0.8	ND	0.3	0.4	0.2	ND	ND	ND	0.5	ND
hematite	Fe_2O_3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.4
magnetite	Fe_3O_4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2
Sulfur Determination													
Total S	S	0.14	0.14	0.63	0.05	0.13	0.15	0.04	0.03	0.02	0.02	0.26	0.02
equivalent FeS_2	FeS_2	0.3	0.3	1.2	0.1	0.2	0.3	0.1	0.1	<0.1	<0.1	0.5	<0.1

Notes:
NA = Not applicable: quality control sample
ND = Not Detected
** = 'play sand'*

TABLE 11
Tabulation of Presence of
Pyrite, Iron Oxide, and Carbonaceous Fragments in Drill Logs

Well	Pyrite	C Fragments	Iron Oxide
MW-3A			X
[a]MW-16			X
[a]MW-17			X
[a]MW-18			X
[a]MW-19			X
[a]MW-20			X
[a]MW-21	X		X
[a]MW-22			X
MW-23			X
MW-24			X
MW-25	X		X
MW-26	X		X
MW-27	X		X
MW-28			X
MW-29			X
MW-30	X		X
MW-31	X		X
MW-32	X		X
MW-33			X
MW-34	X	X	X
MW-35	X	X	X
MW-36	X		X
MW-37	X		X
Piez-2			X
Piez-4	X		X
Piez-5	X		X
DR-2	X		X
DR-5	X		X
DR-6	X		X
DR-7			X
DR-8			X
DR-9	X		X
DR-10			X
DR-11	X		X
DR-12	X		X
DR-13			X
DR-14	X		X
DR-15	X		X
DR-16	X		X
DR-17			
DR-18	X		X
DR-19			X
DR-20	X		X
DR-21			X
DR-22			
DR-23	X		X
DR-24	X		X
DR-25	X		X
TW4-1			X
TW4-2	X		X
TW4-3	X	X	X
TW4-4			
TW4-5	X	X	
TW4-6	X	X	X
TW4-7	X	X	X
TW4-8			X

TABLE 11
Tabulation of Presence of
Pyrite, Iron Oxide, and Carbonaceous Fragments in Drill Logs

Well	Pyrite	C Fragments	Iron Oxide
TW4-9	X	X	X
TW4-10	X	X	
TW4-11		X	
TW4-12	X	X	X
TW4-13	X	X	X
TW4-14			X
TW4-15	X		X
TW4-16	X		X
TW4-17	X		X
TW4-18		X	X
TW4-19			X
TW4-20			X
TW4-21	X		X
TW4-22	X		
TW4-23	X	X	X
TW4-24			X
TW4-25	X		X
TW4-26			X
TW4-27	X		X
TW4-28	X	X	
TW4-29	X	X	X
TW4-30	X	X	X
TW4-31	X	X	X
TW4-32	X	X	X
TW4-33	X		X
TW4-34		X	X
TW4-35	X	X	X
TW4-36	X	X	X
TW4-37			X
TW4-38			X
TW4-39	X		X
TWN-1			X
TWN-2	X		X
TWN-3	X		X
TWN-4			X
TWN-5	X		X
TWN-6	X		X
TWN-7			X
TWN-8	X		X
TWN-9			X
TWN-10			X
TWN-11	X		X
TWN-12	X		X
TWN-13	X		X
TWN-14	X		X
TWN-15	X		X
TWN-16	X		X
TWN-17			X
TWN-18	X		X
TWN-19	X		X

Notes:
C Fragments = particles of carbonaceous material (plant remains, etc)
[a] = only moderately detailed log available

TABLE 12
Sulfide Analysis by Optical Microscopy

				Grain size (micrometers)		
Sample	**Depth (feet)**	**Mineral**	**Volume%**	**Minimum**	**Maximum**	**Mean**
MW-26 (TW4-15)[1]	92.5' - 97.5'	pyrite	4.30	5.6	44.4	128.9
MW-34	67.5' - 70'	pyrite	0.30	1.1	177.8	71.1
MW-36	87.5' - 90'	pyrite	5.20	5.6	88.9	52.2
MW-36	87.5' - 90'	marcasite	0.50	22.2	488.8	121.2
MW-36	112.5' - 115'	pyrite	2.20	16.7	577.7	188.9
MW-36	112.5' - 115'	marcasite	0.20	22.2	333.3	177.8
MW-37	110' - 112.5'	pyrite	9.80	11.1	1666.5	131.1
TW4-16[2]	92.5' - 95'	pyrite	0.10	11.1	105.5	47.8
TW4-22	90' - 92.5'	pyrite	0.30	5.6	66.7	26.7
TWN-5	110' - 112.5'	pyrite	15.80	5.6	1377.6	208.9
TWN-5	112.5' - 115'	pyrite	0.50	5.6	266.6	70
TWN-5	112.5' - 115'	marcasite	0.50	22.2	55.6	36.7
TWN-5	112.5' - 115'	chalcopyrite	0.02	ND	ND	6
TWN-8	117.5' - 120'	pyrite	12.00	5.6	455.1	137.8
TWN-8	117.5' - 120'	marcasite	0.60	66.6	288.9	155.5
AWN-X2[3]	87.5' - 90'	pyrite	2.40	5.6	33.3	17.8
AWN-X2[3]	87.5' - 90'	marcasite	0.60	66.6	288.9	155.5
TWN-16[4]	82.5' - 85'	pyrite	0.10	1.1	11.1	6.1
TWN-16[4]	87.5' - 90'	pyrite	0.16	7	168	35.5
TWN-16[4]	87.5' - 90'	marcasite	0.05	ND	129.5	ND
TWN-19[5]	82.5 ' - 85'	pyrite	1.18	3.5	434	42.1
TWN-19[5]	82.5 ' - 85'	marcasite	0.06	21	42	36.4
DR-9	105' - 107.5'	pyrite	17.00	2.2	677.7	136.7
DR-12	87.5' - 90'	pyrite	0.30	11.1	111.1	52.2
DR-12	87.5' - 90'	marcasite	0.10	22.2	111.1	72.2
DR-16	97.5' - 100'	pyrite	2.40	5.6	33.3	17.8
DR-16	97.5' - 100'	marcasite	0.60	66.6	288.9	155.5
DR-25	75' - 77.5'	pyrite	25.00	1.1	1955	22
DR-25	75' - 77.5'	marcasite	2.50	55.6	621.6	265.5
SS-31*	NA	chalcopyrite	0.01	ND	ND	10
SS-37*	NA	pyrite	0.02	7	14	11.7

Notes:
[1] Samples from 92.5' - 95' and 95' - 97.5' combined due to small sample volume
[2] Sample from 92.5' - 95' submitted instead of sample from 95' - 97.5' because no sample material available
[3] Originally TWN-16
[4] Originally TWN-19
[5] Originally TWN-22
NA = Not applicable: quality control sample
ND = Not determined
** = 'play sand'*

TABLE 13
Summary of
Pyrite in Drill Cuttings and Core

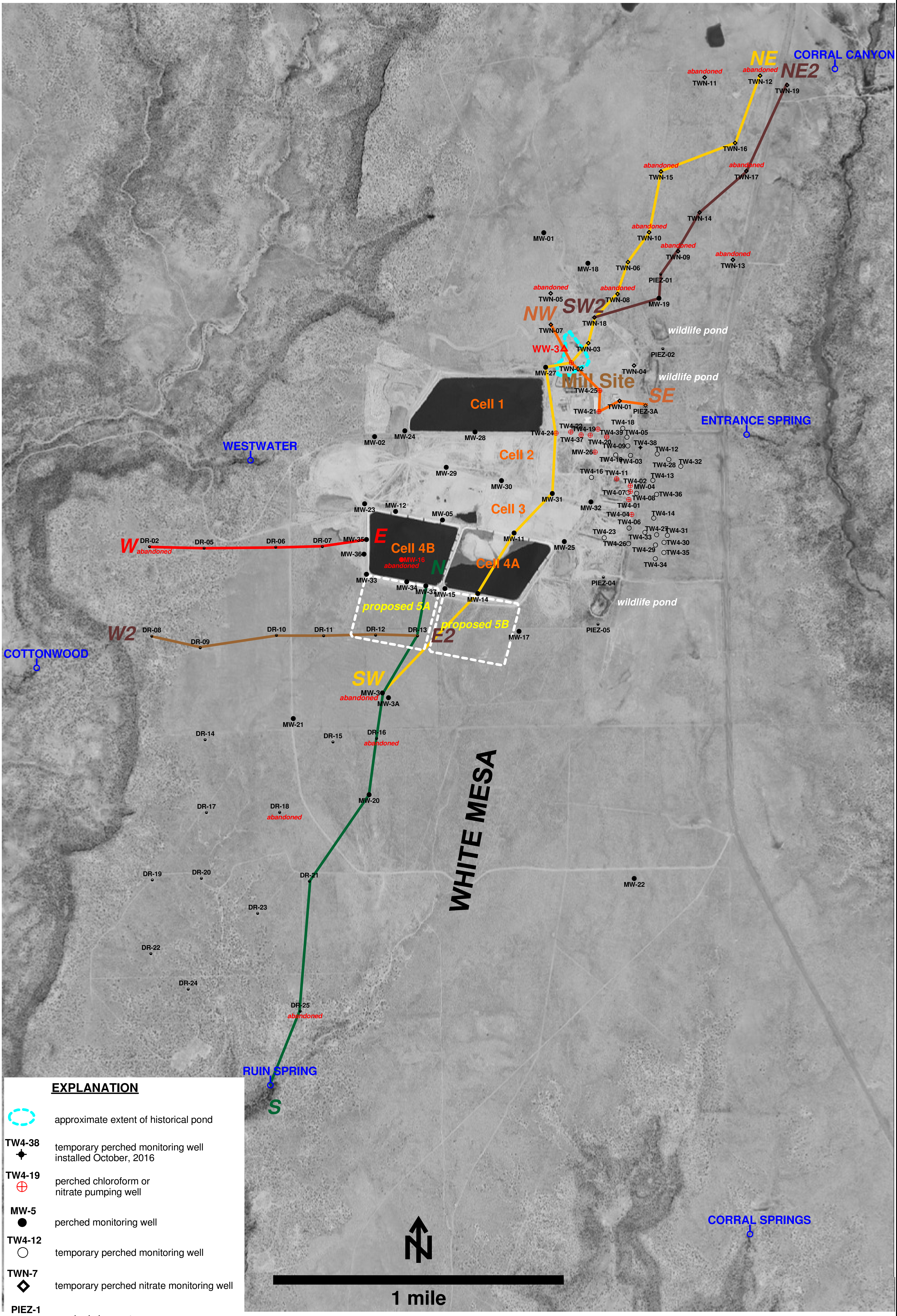
Well	Pyrite Noted in Drill Logs	Pyrite Detected by Laboratory
MW-3A		**X** (Q)
[a]MW-16		NA
[a]MW-17		NA
[a]MW-18		NA
[a]MW-19		NA
[a]MW-20		NA
[a]MW-21	**X**	NA
[a]MW-22		NA
MW-23		possible[b] (Q)
MW-24		**X** (Q)
MW-25	**X**	possible[b] (Q)
MW-26	**X**	**X** (Q)
MW-27	**X**	**X** (Q)
MW-28		**X** (Q)
MW-29		possible[b] (Q)
MW-30	**X**	ND (Q)
MW-31	**X**	ND (Q)
MW-32	**X**	**X** (Q)
MW-33		NA
MW-34	**X**	**X** (V)
MW-35	**X**	NA
MW-36	**X**	**X** (V)
MW-37	**X**	**X** (V)
Piez-2		NA
Piez-4	**X**	NA
Piez-5	**X**	NA
DR-2	**X**	NA
DR-5	**X**	NA
DR-6	**X**	NA
DR-7		NA
DR-8		NA
DR-9	**X**	**X** (V)
DR-10		NA
DR-11	**X**	NA
DR-12	**X**	**X** (V)
DR-13		NA
DR-14	**X**	NA
DR-15	**X**	NA
DR-16	**X**	**X** (V)
DR-17		NA
DR-18	**X**	NA
DR-19		NA
DR-20	**X**	NA
DR-21		NA
DR-22		NA
DR-23	**X**	NA
DR-24	**X**	NA
DR-25	**X**	**X** (V)
TW4-1		NA
TW4-2	**X**	NA
TW4-3	**X**	NA
TW4-4		NA
TW4-5	**X**	NA
TW4-6	**X**	NA
TW4-7	**X**	NA
TW4-8		NA
TW4-9	**X**	NA
TW4-10	**X**	NA
TW4-11		NA
TW4-12	**X**	NA
TW4-13	**X**	NA

TABLE 13
Summary of
Pyrite in Drill Cuttings and Core

Well	Pyrite Noted in Drill Logs	Pyrite Detected by Laboratory
TW4-14		NA
TW4-15	**X**	NA
TW4-16	**X**	**X** (V)
TW4-17	**X**	NA
TW4-18		NA
TW4-19		NA
TW4-20		NA
TW4-21	**X**	NA
TW4-22	**X**	**X** (V)
TW4-23	**X**	NA
TW4-24		NA
TW4-25	**X**	NA
TW4-26		NA
TW4-27		NA
TW4-28	**X**	NA
TW4-29	**X**	NA
TW4-30	**X**	NA
TW4-31	**X**	NA
TW4-32	**X**	NA
TW4-33	**X**	NA
TW4-34		NA
TW4-35	**X**	NA
TW4-36	**X**	NA
TW4-37		NA
TW4-38		NA
TW4-39	**X**	NA
TWN-1		NA
TWN-2	**X**	NA
TWN-3	**X**	NA
TWN-4		NA
TWN-5	**X**	**X** (V)
TWN-6	**X**	NA
TWN-7		NA
TWN-8	**X**	**X** (V)
TWN-9		NA
TWN-10		NA
TWN-11	**X**	NA
TWN-12	**X**	NA
TWN-13	**X**	NA
TWN-14	**X**	NA
TWN-15	**X**	NA
TWN-16	**X**	**X** (V)
TWN-17		NA
TWN-18	**X**	NA
TWN-19	**X**	**X** (V)
AWN-X1		NA
AWN-X2	**X**	**X** (V)
AWN-X3		NA

Notes:
[a] = only moderately detailed log available
[b] = detected iron and sulfur may indicate the presence of pyrite
Q = quantiative analysis by XRD
V = visual (microscopic) analysis
ND = not detected by laboratory
NA = not analyzed by laboratory

FIGURES



EXPLANATION

approximate extent of historical pond

TW4-38 — temporary perched monitoring well installed October, 2016

TW4-19 — perched chloroform or nitrate pumping well

MW-5 — perched monitoring well

TW4-12 — temporary perched monitoring well

TWN-7 — temporary perched nitrate monitoring well

PIEZ-1 — perched piezometer

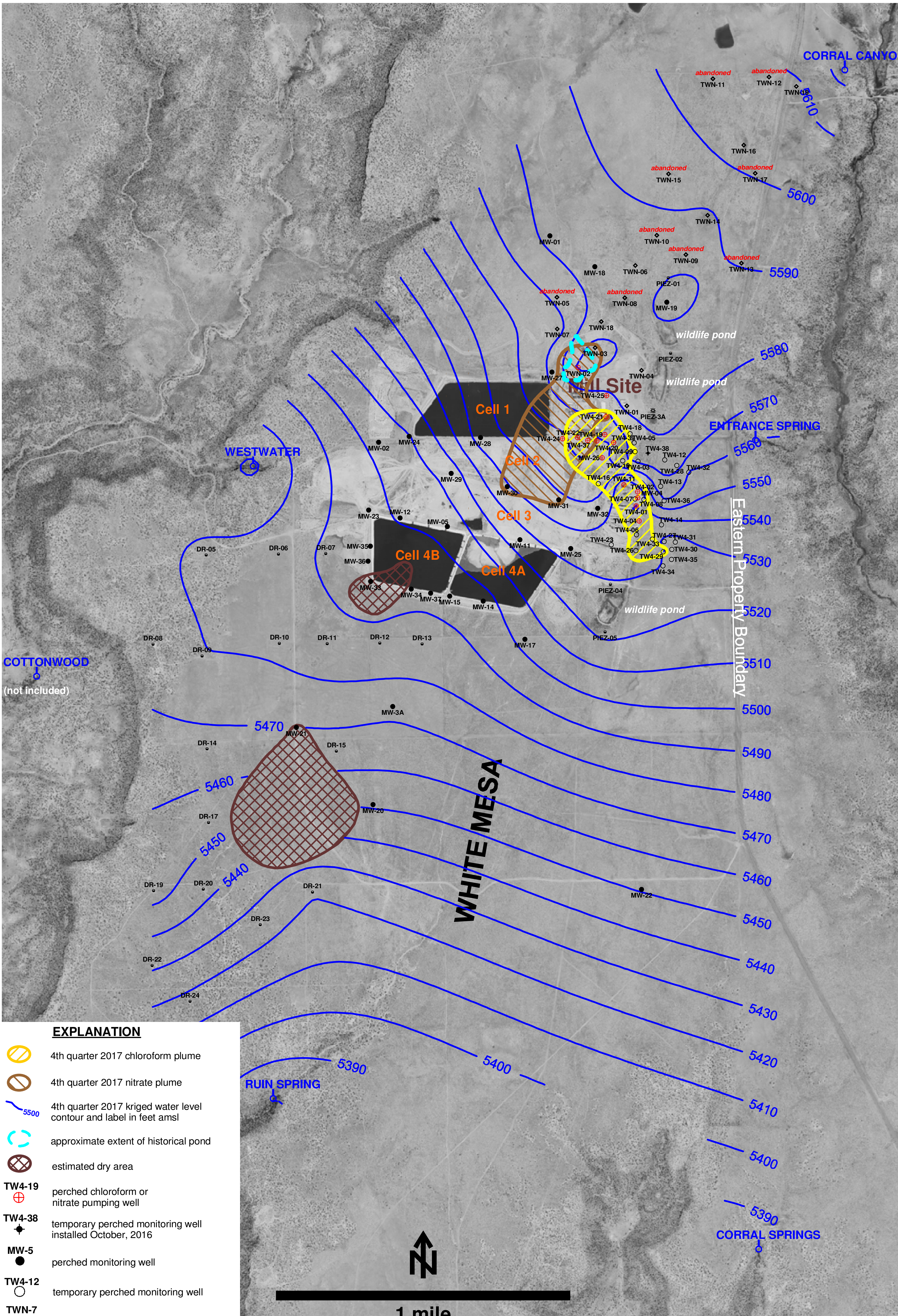
PIEZ-3A — May, 2016 replacement of perched piezometer Piez-03

RUIN SPRING — seep or spring

HYDRO GEO CHEM, INC.

WHITE MESA SITE PLAN SHOWING LOCATIONS OF PERCHED WELLS, PIEZOMETERS, LITHOLOGIC CROSS-SECTIONS (as of 4th quarter, 2017), AND PROPOSED CELLS 5A AND 5B

APPROVED	DATE	REFERENCE	FIGURE
SJS	6/4/2018	H:/718000/ hydrpt2018/maps/Uwellocxs18_rev.srf	1A



EXPLANATION

Symbol	Description
	4th quarter 2017 chloroform plume
	4th quarter 2017 nitrate plume
5500	4th quarter 2017 kriged water level contour and label in feet amsl
	approximate extent of historical pond
	estimated dry area
TW4-19	perched chloroform or nitrate pumping well
TW4-38	temporary perched monitoring well installed October, 2016
MW-5	perched monitoring well
TW4-12	temporary perched monitoring well
TWN-7	temporary perched nitrate monitoring well
PIEZ-1	perched piezometer
PIEZ-3A	May, 2016 replacement of perched piezometer Piez-03
RUIN SPRING	seep or spring

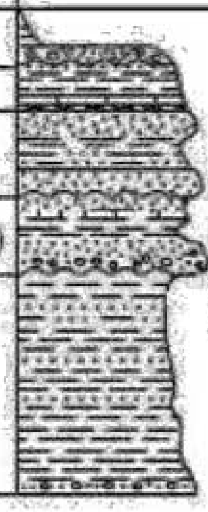
HYDRO GEO CHEM, INC.

WHITE MESA SITE PLAN SHOWING 4th QUARTER 2017 PERCHED WELL AND PIEZOMETER LOCATIONS, KRIGED PERCHED WATER LEVELS AND CHLOROFORM AND NITRATE PLUMES

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/UwlChlNt1217.srf	1B

SYSTEM	SERIES	FORMATION AND MEMBERS		SYMBOL	THICKNESS Meters (Feet)
QUAT.		Surficial deposits		Q	<12 (<40)
CRET.	Upper	Mancos Shale		Km	0-9 (0-30)
CRET.	Upper	Dakota Sandstone		Kd	5-15 (15-50)
CRET.	L.	Burro Canyon Formation		Kbc	24-36 (80-120)
JURASSIC	Upper	Morrison Fm.	Brushy Basin Member	Jmbb	>60 (>200)

LITHOLOGY



Gray marine shale

Thin discontinuous coal beds

Pebble conglomerate and sandstone

Variegated mudstone, claystone, and sandstone

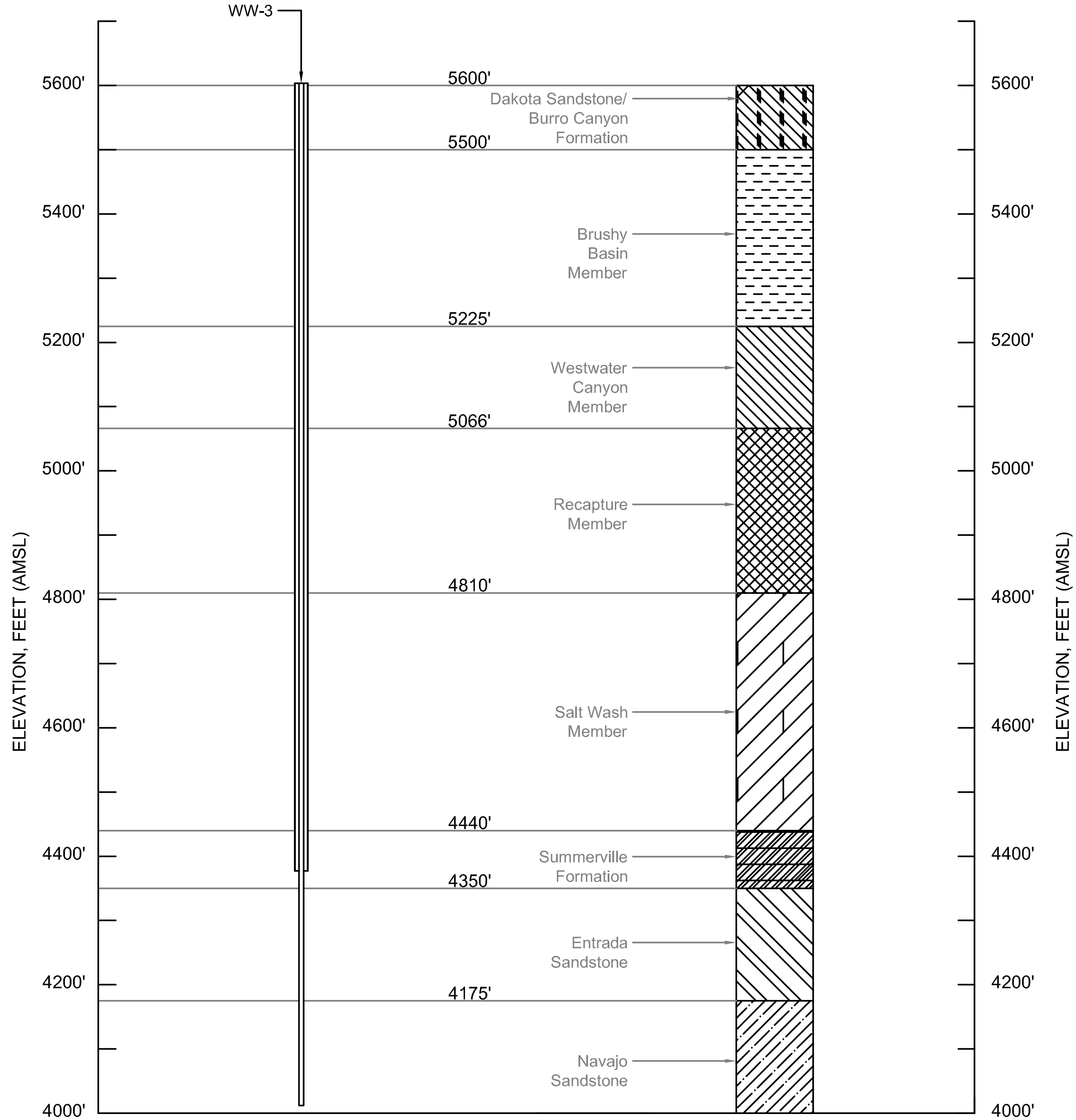
Commonly covered by landslides beneath canyon rims

Modified from Doelling (2004).

HYDRO GEO CHEM, INC.

LITHOLOGIC COLUMN

Approved	Date	Author	Date	File Name	Figure
SJS	11/9/12	SJS	11/9/12	F2 litho clmn	2



HYDRO GEO CHEM, INC.

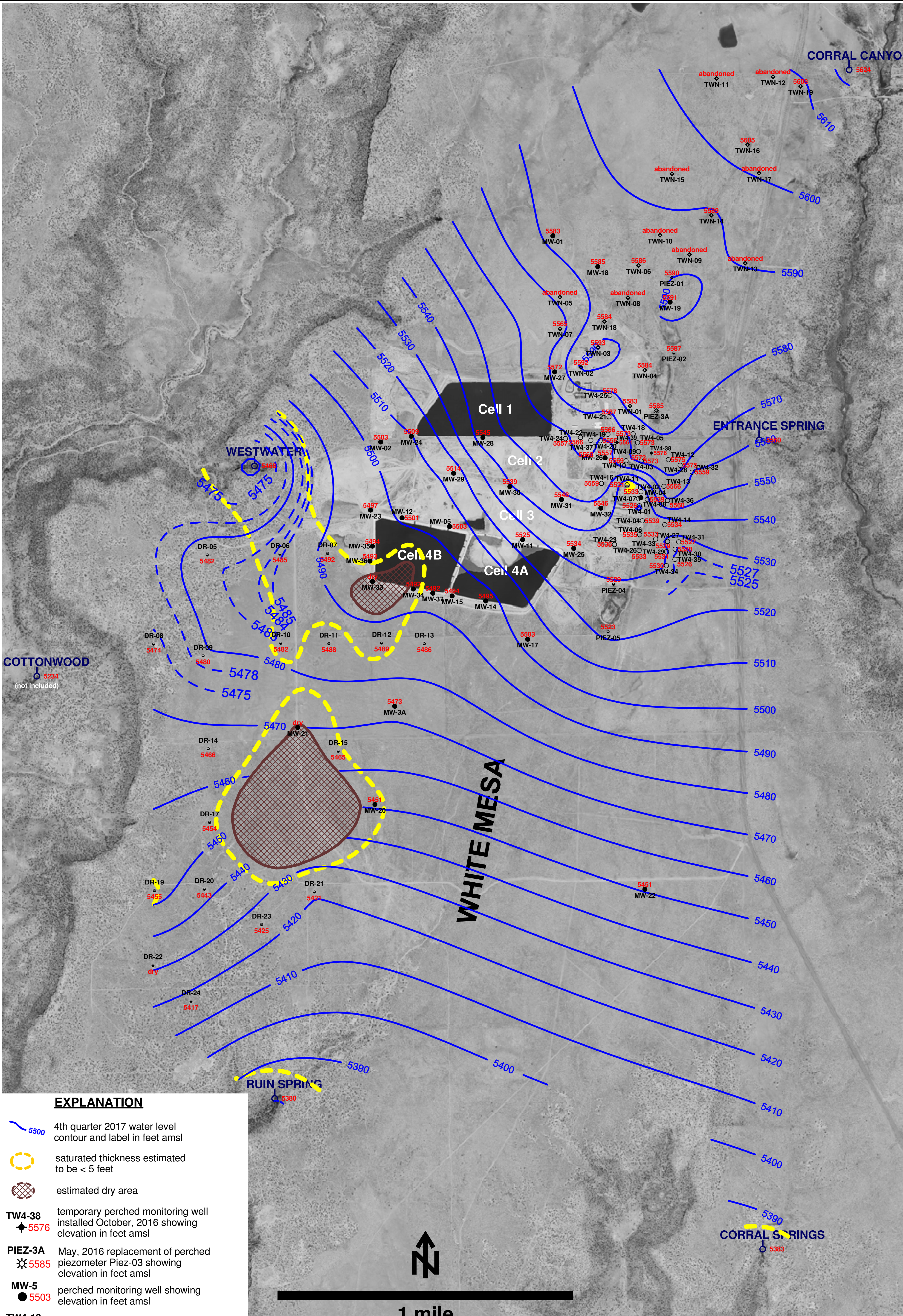
WHITE MESA STRATIGRAPHIC SECTION
BASED ON LITHOLOGY OF WW-3
FROM TITAN (1994)

Approved	Date	File Name	Figure
SJS	05/02/14	718000110A	3

HYDRO GEO CHEM, INC.

PHOTOGRAPH OF THE CONTACT BETWEEN THE BURRO CANYON FORMATION AND THE BRUSHY BASIN MEMBER

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ Figures/contact2.srf	4



EXPLANATION

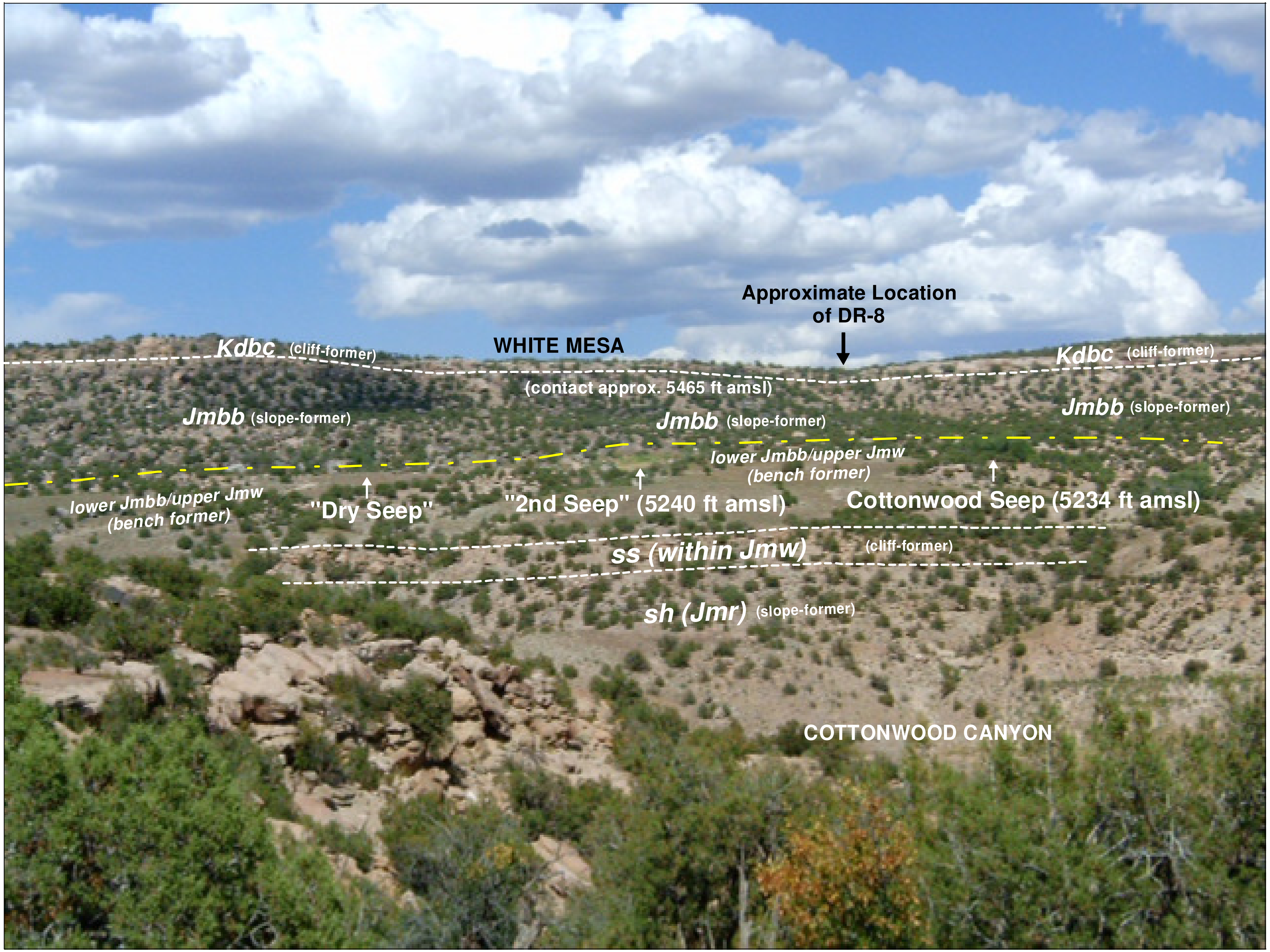
- 5500 — 4th quarter 2017 water level contour and label in feet amsl
- saturated thickness estimated to be < 5 feet
- estimated dry area
- TW4-38 5576 — temporary perched monitoring well installed October, 2016 showing elevation in feet amsl
- PIEZ-3A 5585 — May, 2016 replacement of perched piezometer Piez-03 showing elevation in feet amsl
- MW-5 5503 — perched monitoring well showing elevation in feet amsl
- TW4-12 5575 — temporary perched monitoring well showing elevation in feet amsl
- TWN-7 5565 — temporary perched nitrate monitoring well showing elevation in feet amsl
- PIEZ-1 5590 — perched piezometer showing elevation in feet amsl
- RUIN SPRING 5380 — seep or spring showing elevation in feet amsl

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

KRIGED 4th QUARTER, 2017 WATER LEVELS
WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/Uwl1217_det.srf	5



EXPLANATION

(white dashed line)	Approximate Location of Geologic Contact
(yellow dashed line)	Approximate Change From Slope-Former to Bench-Former
Kdbc	Dakota Sandstone/ Burro Canyon Formation
Jmbb	Brushy Basin (Shale) Member
ss (within Jmw)	sandstone (within Westwater Canyon Member)
sh (Jmr)	shale (Recapture Member)

NOTES: adapted from HGC (2010); "2nd Seep" and "Dry Seep" are described in HGC (2010)

HYDRO GEO CHEM, INC.

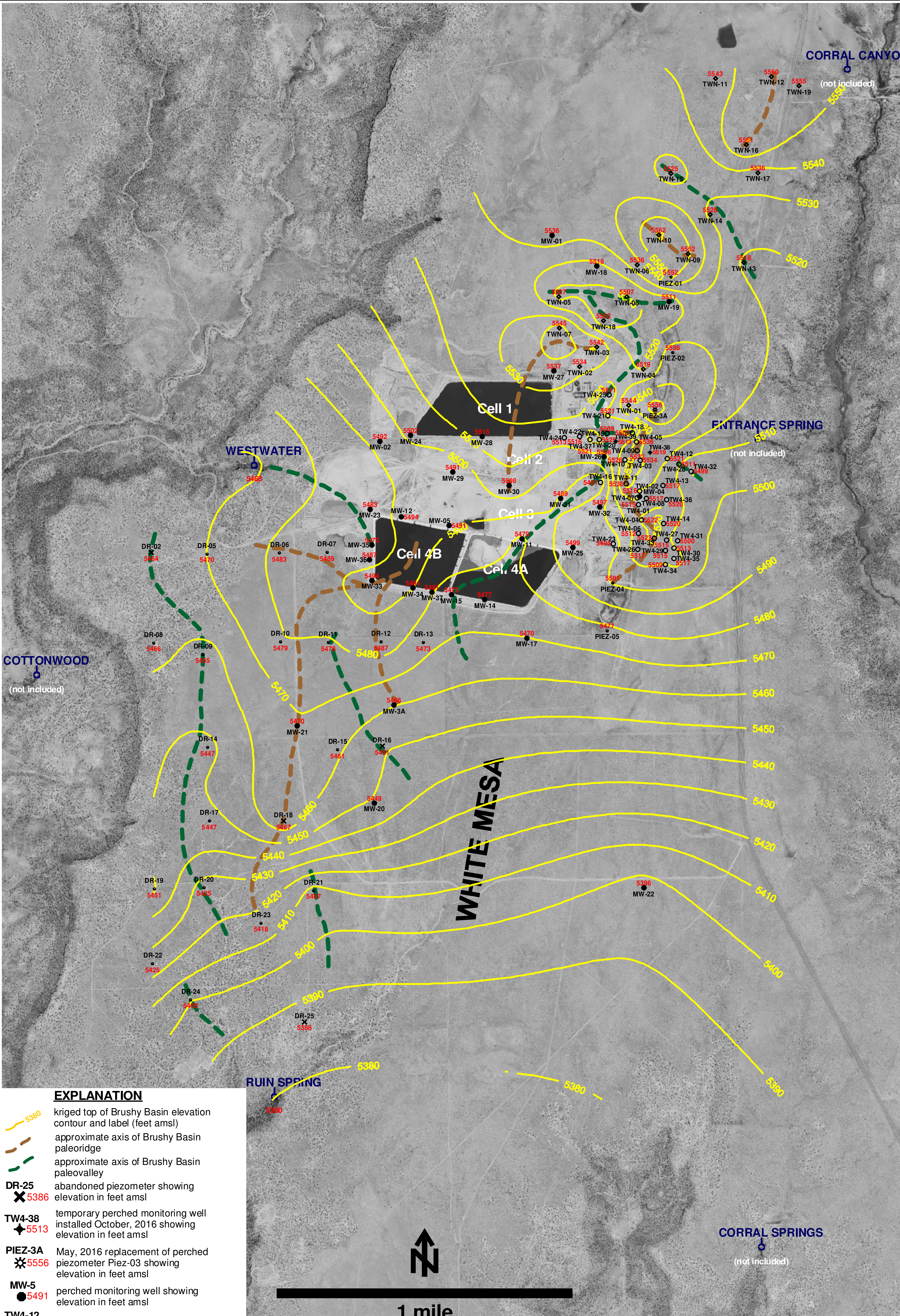
ANNOTATED PHOTOGRAPH SHOWING EAST SIDE OF COTTONWOOD CANYON (looking east toward White Mesa from west side of Cottonwood Canyon)

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ Figures/cottonwood2.srf	6

HYDRO GEO CHEM, INC.

EXTENT OF THE WESTERN INTERIOR SEA (CRETACEOUS)

Approved	Date	Author	Date	File Name	Figure
SJS	11/9/12	SJS	11/9/12	F7 west int sea	7



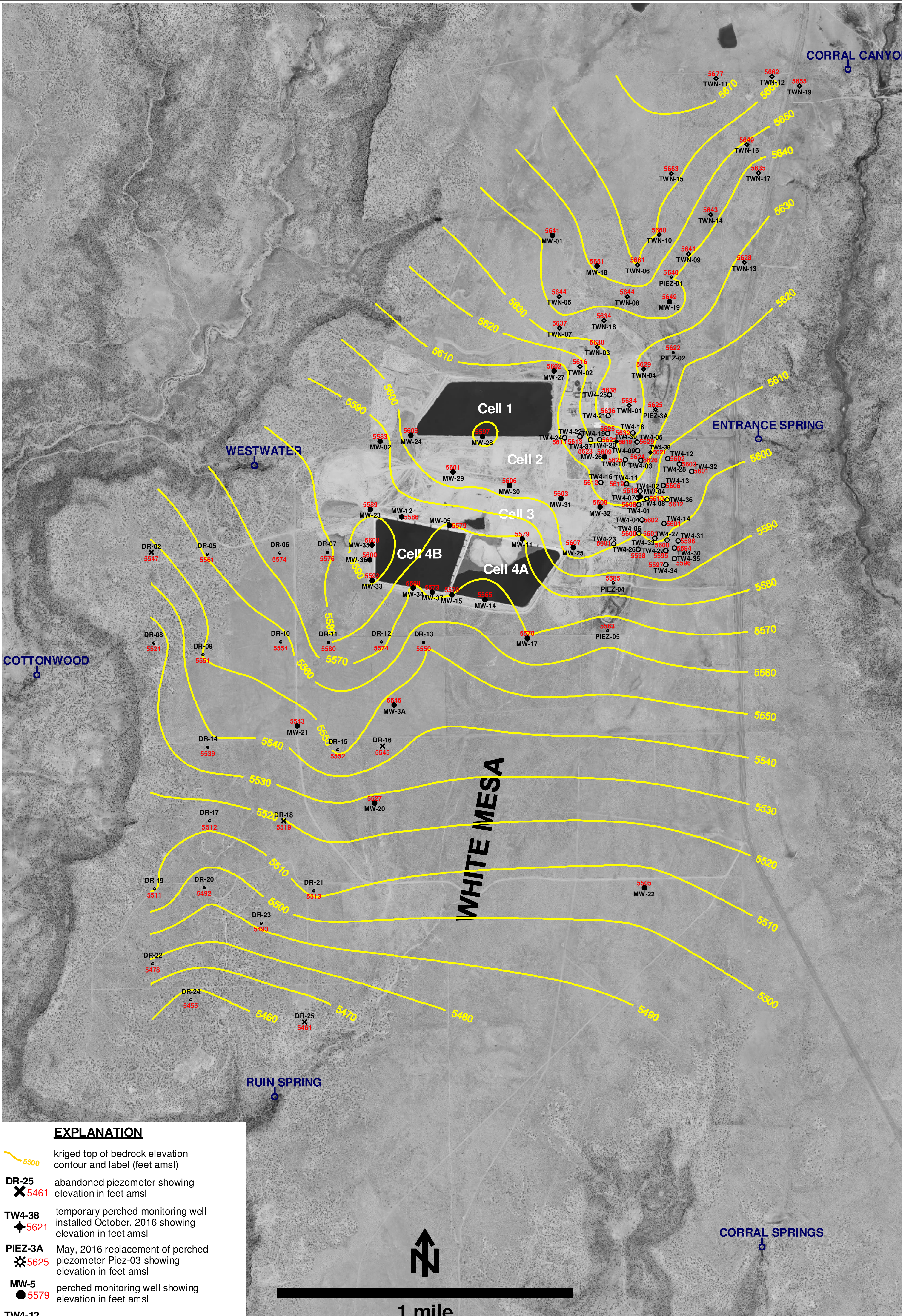
EXPLANATION

- kriged top of Brushy Basin elevation contour and label (feet amsl) (5380)
- approximate axis of Brushy Basin paleoridge
- approximate axis of Brushy Basin paleovalley
- DR-25 ✕ 5386 — abandoned piezometer showing elevation in feet amsl
- TW4-38 ✚ 5513 — temporary perched monitoring well installed October, 2016 showing elevation in feet amsl
- PIEZ-3A ✲ 5556 — May, 2016 replacement of perched piezometer Piez-03 showing elevation in feet amsl
- MW-5 ● 5491 — perched monitoring well showing elevation in feet amsl
- TW4-12 ○ 5521 — temporary perched monitoring well showing elevation in feet amsl
- TWN-7 ◆ 5545 — temporary perched nitrate monitoring well showing elevation in feet amsl
- PIEZ-1 ◒ 5552 — perched piezometer showing elevation in feet amsl
- RUIN SPRING 5380 — seep or spring showing elevation in feet amsl

HYDRO GEO CHEM, INC.

KRIGED TOP OF BRUSHY BASIN
WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/Ubbel1217.srf	8



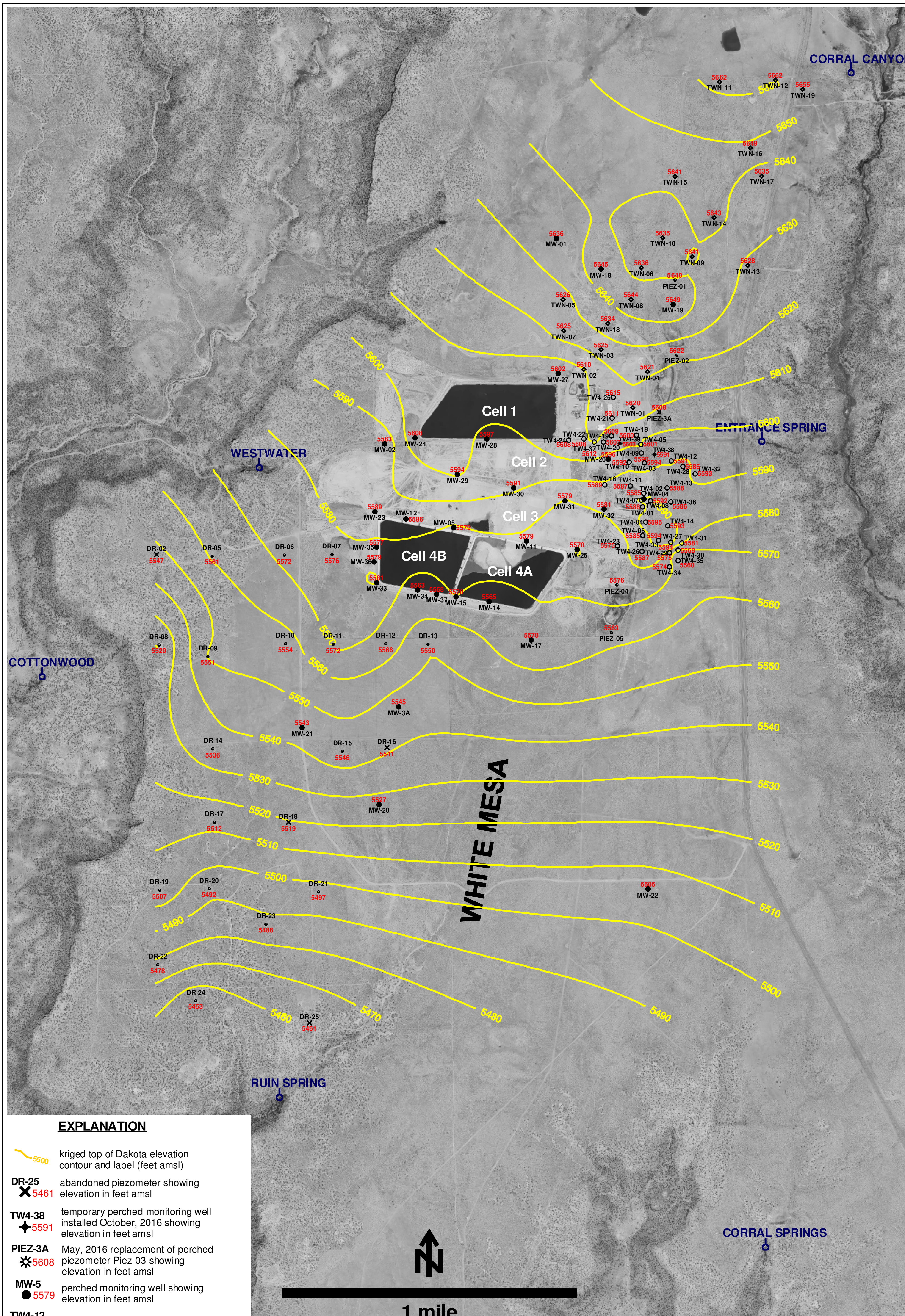
EXPLANATION

- 5500 — kriged top of bedrock elevation contour and label (feet amsl)
- DR-25 ✕ 5461 — abandoned piezometer showing elevation in feet amsl
- TW4-38 ✦ 5621 — temporary perched monitoring well installed October, 2016 showing elevation in feet amsl
- PIEZ-3A ☼ 5625 — May, 2016 replacement of perched piezometer Piez-03 showing elevation in feet amsl
- MW-5 ● 5579 — perched monitoring well showing elevation in feet amsl
- TW4-12 ○ 5602 — temporary perched monitoring well showing elevation in feet amsl
- TWN-7 ◆ 5637 — temporary perched nitrate monitoring well showing elevation in feet amsl
- PIEZ-1 ● 5640 — perched piezometer showing elevation in feet amsl
- RUIN SPRING — seep or spring

HYDRO GEO CHEM, INC.

KRIGED TOP OF BEDROCK
WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/Ubdrkel1217.srf	9



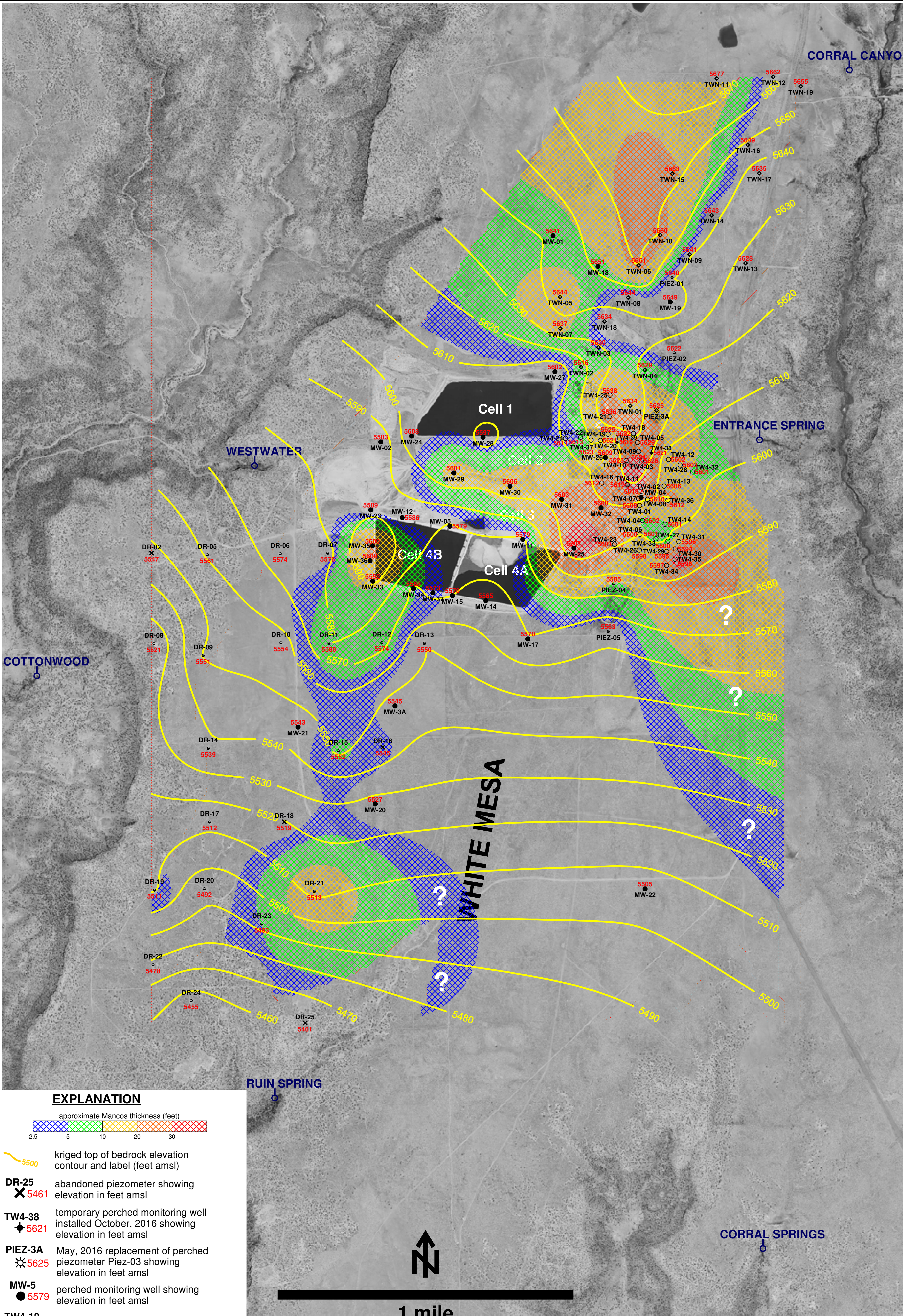
EXPLANATION

Symbol	Description
5500	kriged top of Dakota elevation contour and label (feet amsl)
DR-25 ✕ 5461	abandoned piezometer showing elevation in feet amsl
TW4-38 5591	temporary perched monitoring well installed October, 2016 showing elevation in feet amsl
PIEZ-3A 5608	May, 2016 replacement of perched piezometer Piez-03 showing elevation in feet amsl
MW-5 ● 5579	perched monitoring well showing elevation in feet amsl
TW4-12 ○ 5591	temporary perched monitoring well showing elevation in feet amsl
TWN-7 ◆ 5625	temporary perched nitrate monitoring well showing elevation in feet amsl
PIEZ-1 5640	perched piezometer showing elevation in feet amsl
RUIN SPRING	seep or spring

HYDRO GEO CHEM, INC.

KRIGED TOP OF DAKOTA SANDSTONE WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/Udakotael1217.srf	10



EXPLANATION

approximate Mancos thickness (feet)
2.5 5 10 20 30

Symbol	Description
5500	kriged top of bedrock elevation contour and label (feet amsl)
DR-25 ✕ 5461	abandoned piezometer showing elevation in feet amsl
TW4-38 5621	temporary perched monitoring well installed October, 2016 showing elevation in feet amsl
PIEZ-3A 5625	May, 2016 replacement of perched piezometer Piez-03 showing elevation in feet amsl
MW-5 ● 5579	perched monitoring well showing elevation in feet amsl
TW4-12 ○ 5602	temporary perched monitoring well showing elevation in feet amsl
TWN-7 ◇ 5637	temporary perched nitrate monitoring well showing elevation in feet amsl
PIEZ-1 5640	perched piezometer showing elevation in feet amsl
RUIN SPRING	seep or spring

HYDRO GEO CHEM, INC.

KRIGED TOP OF BEDROCK AND MANCOS SHALE THICKNESS WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/Ubdrkmanc.srf	11

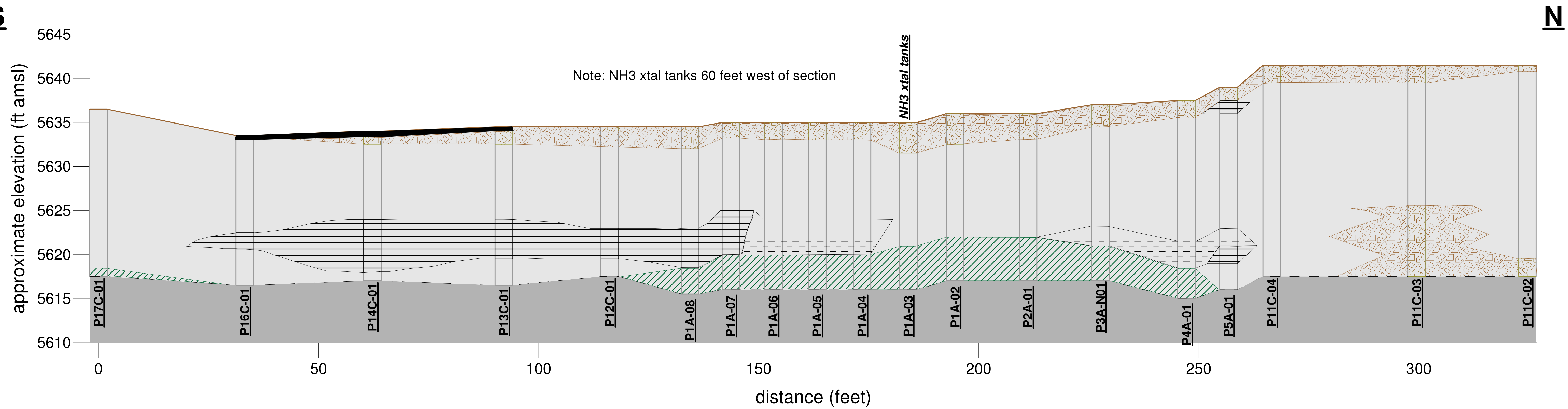
EXPLANATION

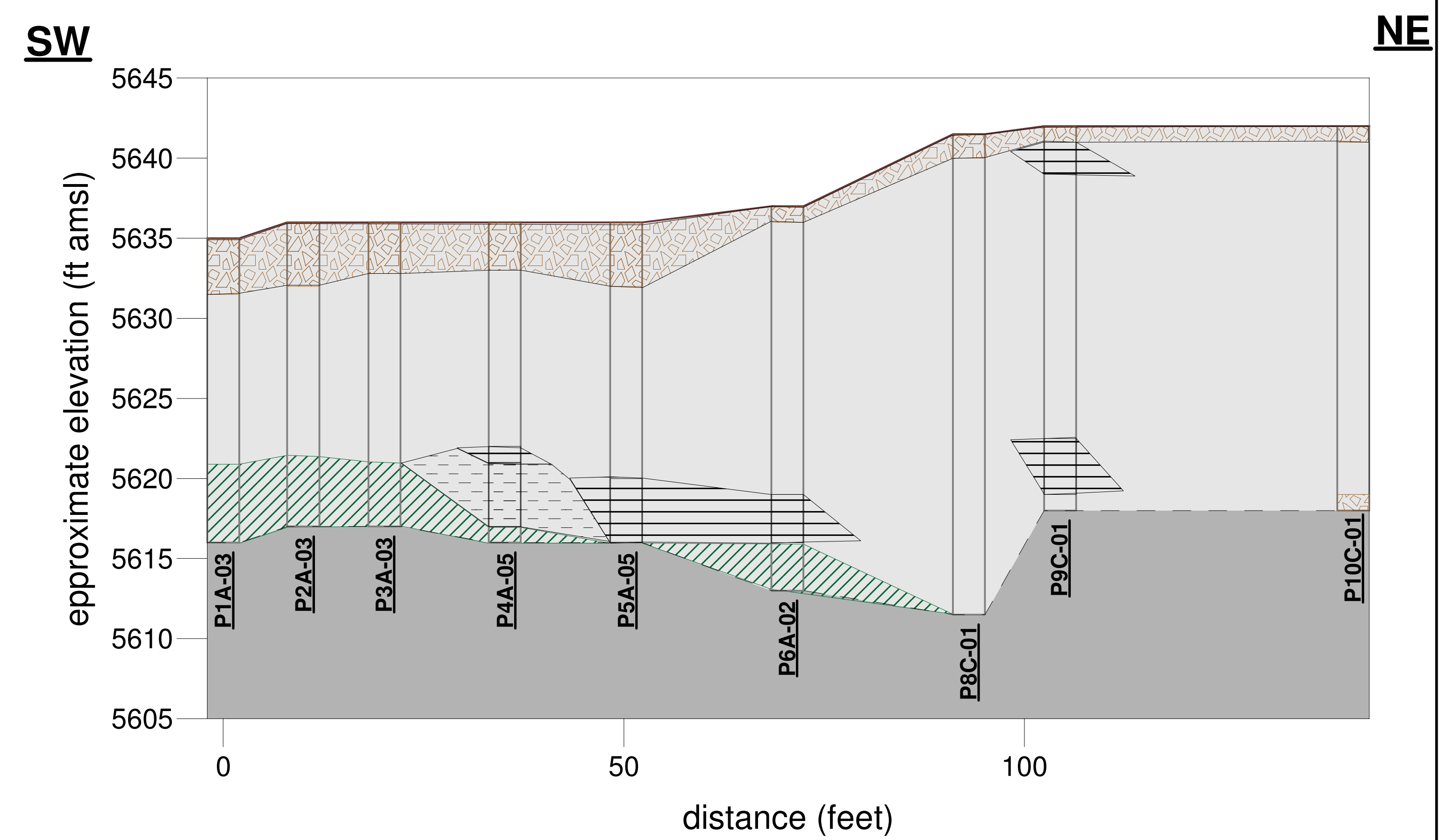
- ● approximate 1st sampling event geoprobe boring location
- ● approximate 2nd sampling event geoprobe boring location
- ● approximate 3rd sampling event geoprobe boring location
- ⊕ ammonium sulfate crystal tank
- north-south (N-S) cross-section
- northeast - southwest (NE-SW) cross-section

HYDRO GEO CHEM, INC.

APPROXIMATE GEOPROBE BORING AND CROSS-SECTION LOCATIONS WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ xsections/soilxs/soilxsloc_rev.srf	12





EXPLANATION

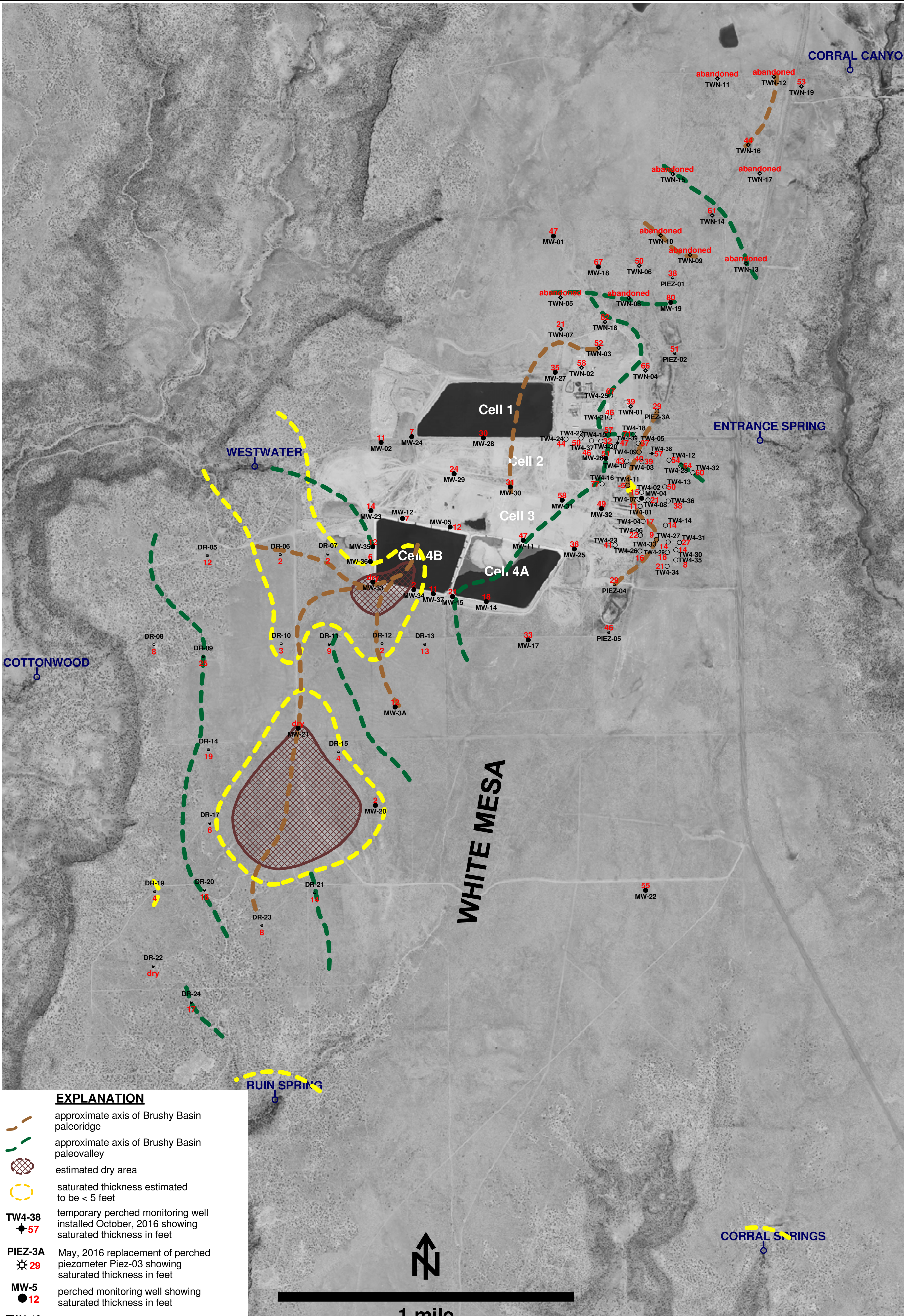
- asphalt
- primarily sand
- primarily silt
- competent bedrock
- silt/clay
- primarily clay
- weathered mancos shale

vertical exaggeration = 2:1

HYDRO GEO CHEM, INC.

SOIL CROSS SECTIONS
EAST OF AMMONIUM SULFATE CRYSTAL TANKS
WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ xsections/soilxs/soilxs.srf	13



EXPLANATION

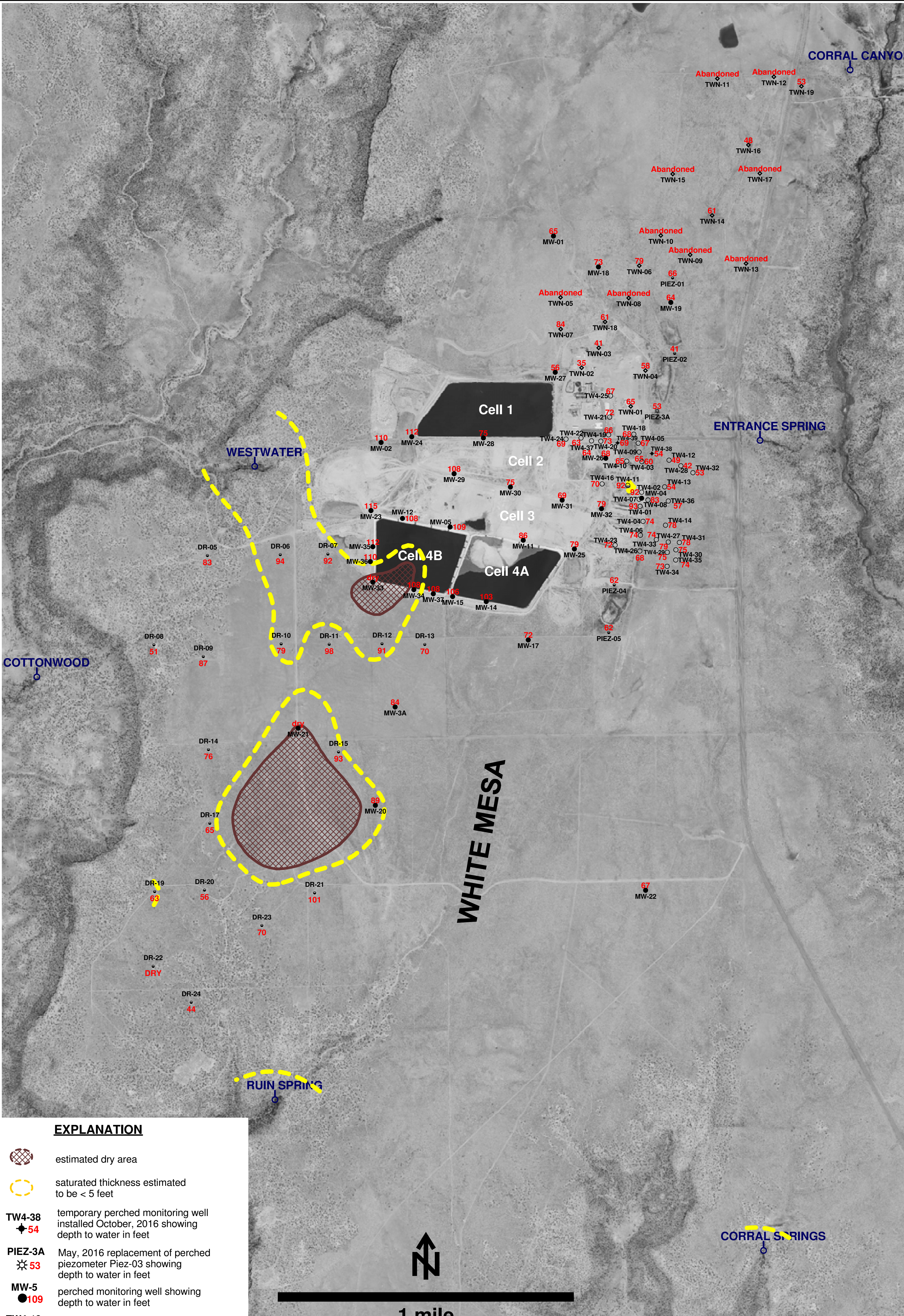
- approximate axis of Brushy Basin paleoridge
- approximate axis of Brushy Basin paleovalley
- estimated dry area
- saturated thickness estimated to be < 5 feet
- TW4-38 57 — temporary perched monitoring well installed October, 2016 showing saturated thickness in feet
- PIEZ-3A 29 — May, 2016 replacement of perched piezometer Piez-03 showing saturated thickness in feet
- MW-5 12 — perched monitoring well showing saturated thickness in feet
- TW4-12 54 — temporary perched monitoring well showing saturated thickness in feet
- TWN-7 21 — temporary perched nitrate monitoring well showing saturated thickness in feet
- PIEZ-1 38 — perched piezometer showing saturated thickness in feet
- RUIN SPRING — seep or spring

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

4th QUARTER, 2017 PERCHED ZONE SATURATED THICKNESSES AND BRUSHY BASIN PALEORIDGES AND PALEOVALLEYS WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/Usat1217.srf	14



EXPLANATION

estimated dry area

saturated thickness estimated to be < 5 feet

TW4-38 54 — temporary perched monitoring well installed October, 2016 showing depth to water in feet

PIEZ-3A 53 — May, 2016 replacement of perched piezometer Piez-03 showing depth to water in feet

MW-5 109 — perched monitoring well showing depth to water in feet

TW4-12 49 — temporary perched monitoring well showing depth to water in feet

TWN-7 84 — temporary perched nitrate monitoring well showing depth to water n feet

PIEZ-1 66 — perched piezometer showing depth to water in feet

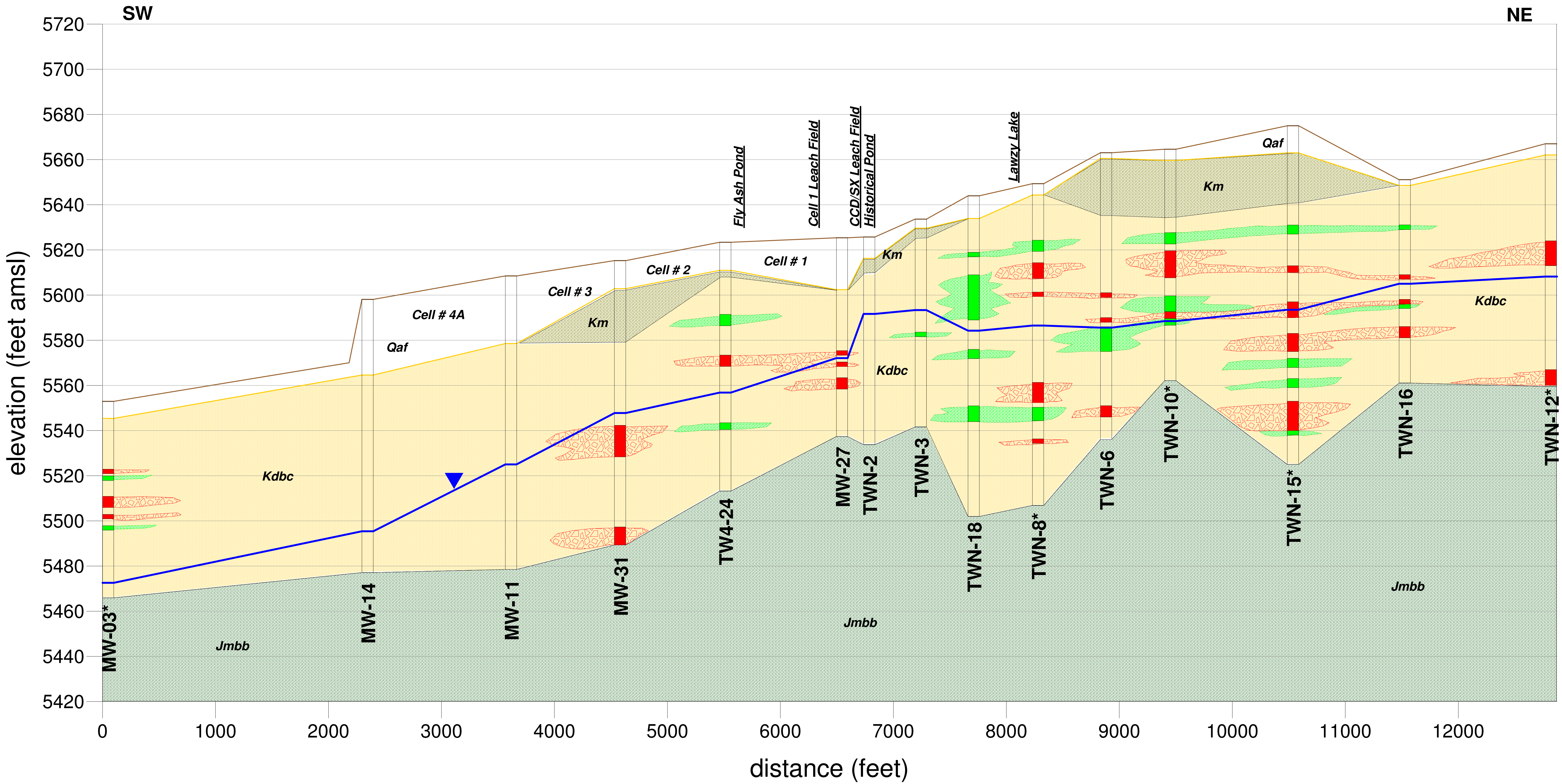
RUIN SPRING — seep or spring

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

4th QUARTER, 2017 DEPTHS TO WATER
WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/Udtw1217.srf	15



EXPLANATION

Qaf — Alluvium/Fill

Km — Mancos Shale

Kdbc — Dakota Sandstone/ Burro Canyon Formation

Jmbb — Brushy Basin Member of Morrison Formation

Shale/claystone in Dakota / Burro Canyon Formation

Conglomerate in Dakota / Burro Canyon Formation

Piezometric Surface

Notes: 1) water levels from TWN-8, TWN-10, TWN-12, and TWN-15 are estimated by kriging;
2) lithology for MW-3 from log of MW-3A

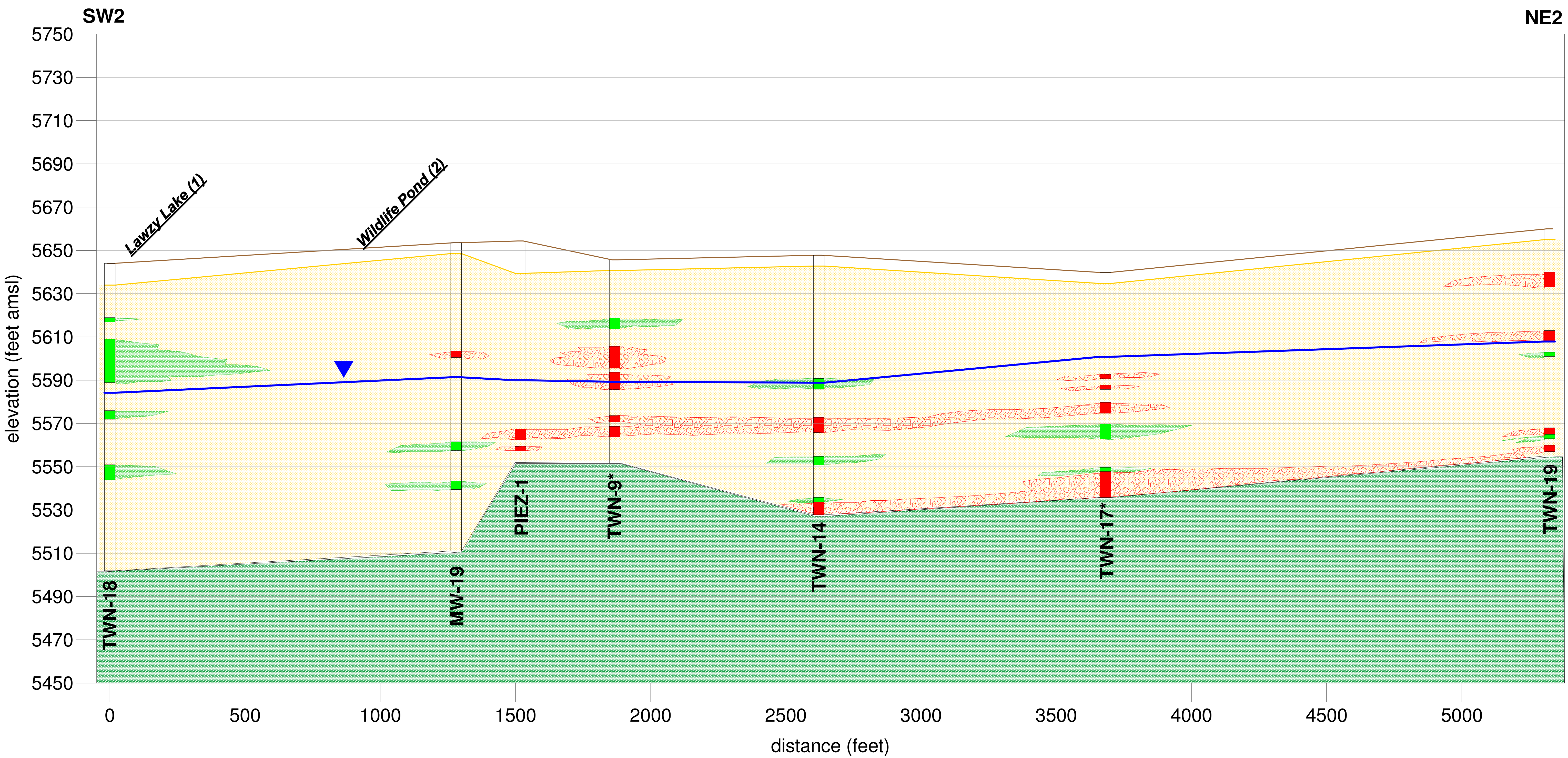
vertical exaggeration = 20 : 1

* denotes abandoned boring

HYDRO GEO CHEM, INC.

INTERPRETIVE NORTHEAST-SOUTHWEST CROSS SECTION (NE-SW) WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/ hydrpt2018/xsections/nsxsne/nsxsne18b.srf	16A



Notes: (1) approximately 200 feet north of cross section
(2) approximately 200 feet south of cross section

vertical exaggeration = 8 : 1

* denotes abandoned boring

EXPLANATION

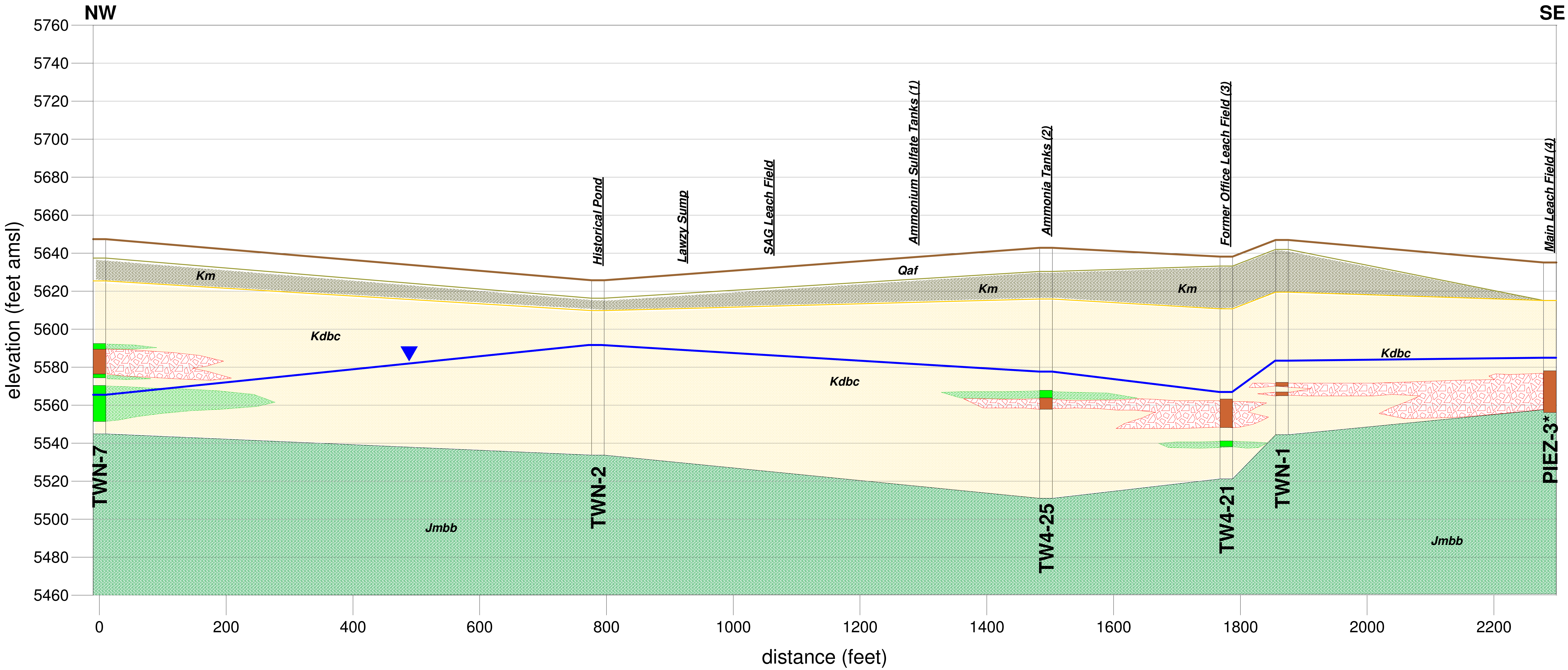
- Qaf — Alluvium/Fill
- Kdbc — Dakota Sandstone/ Burro Canyon Formation
- Jmbb — Brushy Basin Member of Morrison Formation
- Shale/claystone in Dakota / Burro Canyon Formation
- Conglomerate or Conglomeratic Sandstone in Dakota / Burro Canyon Formation
- Piezometric Surface

Note: water levels from TWN-9 and TWN-17 are estimated by kriging

HYDRO GEO CHEM, INC.

INTERPRETIVE NORTHEAST-SOUTHWEST CROSS SECTION (NE2-SW2) WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ xsections/nsxs2ne/nsxs2ne18b.srf	16B



Notes: (1) approximately 115 feet southwest of cross-section
(2) approximately 150 feet southwest of cross-section
(3) approximately 300 feet south of cross-section
(4) immediately south of cross-section

vertical exaggeration = 3 : 1

EXPLANATION

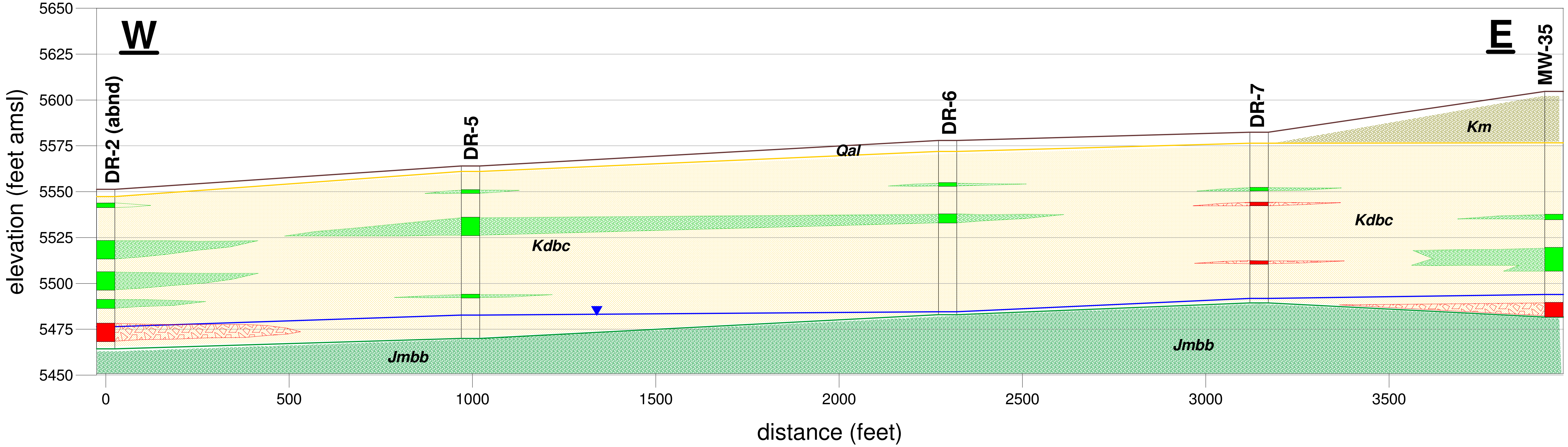
- Qaf — Alluvium/Fill
- Km — Mancos Shale
- Kdbc — Dakota Sandstone/ Burro Canyon Formation
- Jmbb — Brushy Basin Member of Morrison Formation
- Shale/claystone in Dakota / Burro Canyon Formation
- Conglomerate or Conglomeratic Sandstone in Dakota / Burro Canyon Formation
- Piezometric Surface

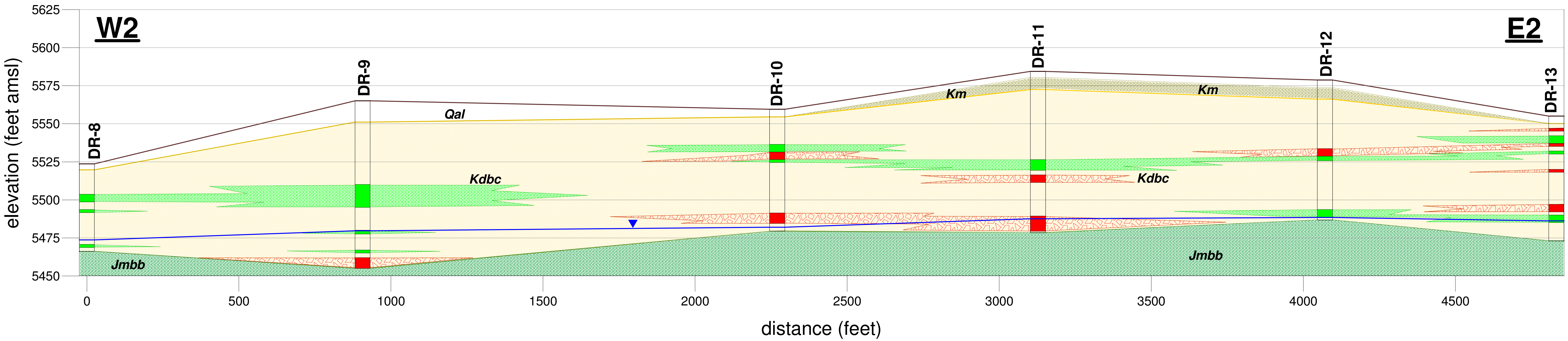
Note: water level shown for Piez-3 is from replacement piezometer Piez-3A

HYDRO GEO CHEM, INC.

INTERPRETIVE NORTHWEST-SOUTHEAST CROSS SECTION (NW-SE) WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ xsections/ewxsne/ewxsne18b.srf	17





EXPLANATION

- Qal — Alluvium/Fill
- Km — Mancos Shale
- Kdbc — Dakota Sandstone/ Burro Canyon Formation
- Shale/claystone within Dakota/Burro Canyon
- Conglomerate within Dakota/Burro Canyon
- Jmbb — Brushy Basin Member of Morrison Formation
- Piezometric surface

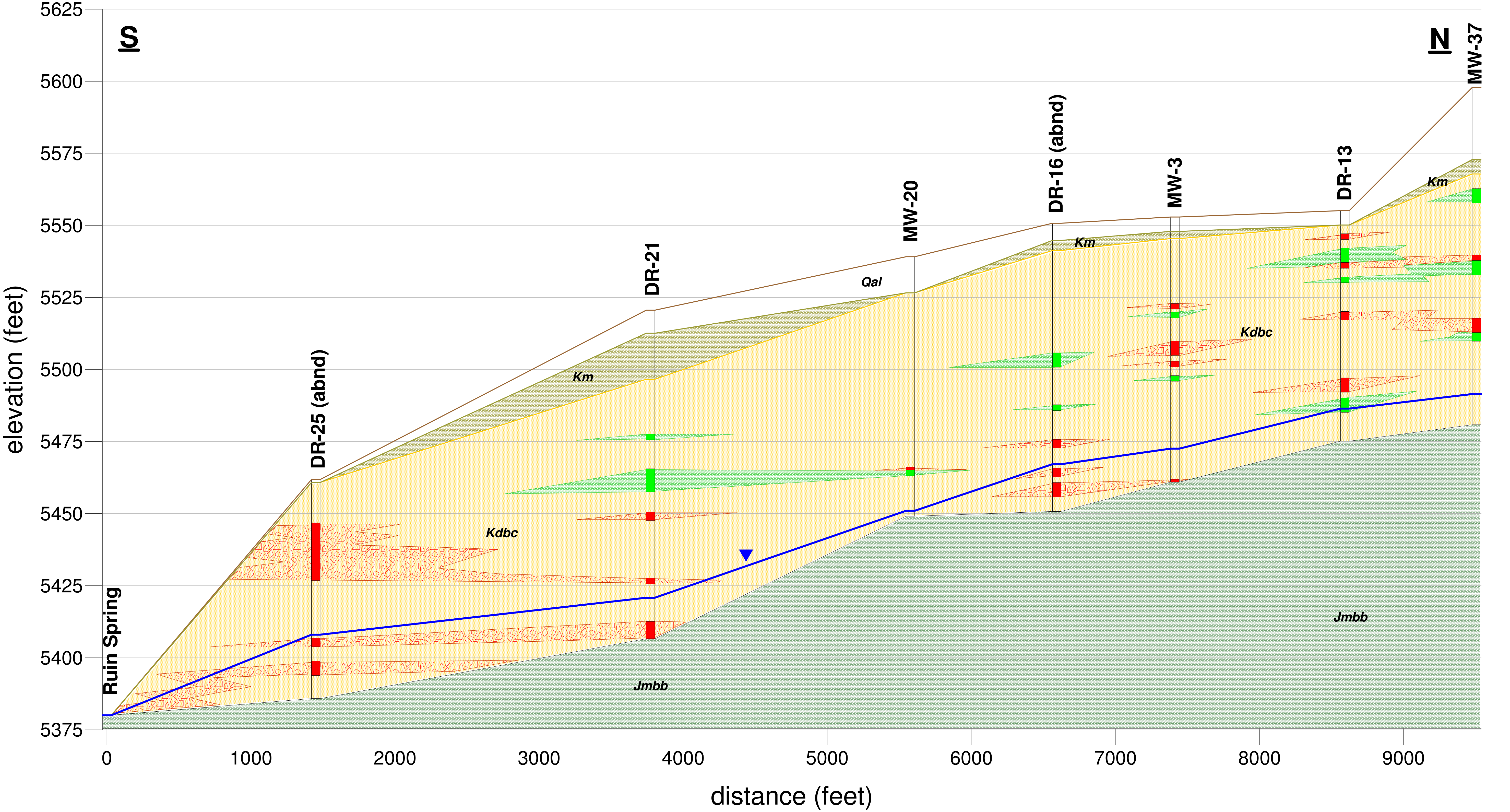
Note: water level for abandoned piezometer DR-2 is from the second quarter of 2011

vertical exaggeration = 5:1

HYDRO GEO CHEM, INC.

INTERPRETIVE EAST-WEST CROSS SECTIONS (W-E and W2-E2) SOUTHWEST INVESTIGATION AREA

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ xsections/ewxssw/ewxsswb.srf	18



EXPLANATION

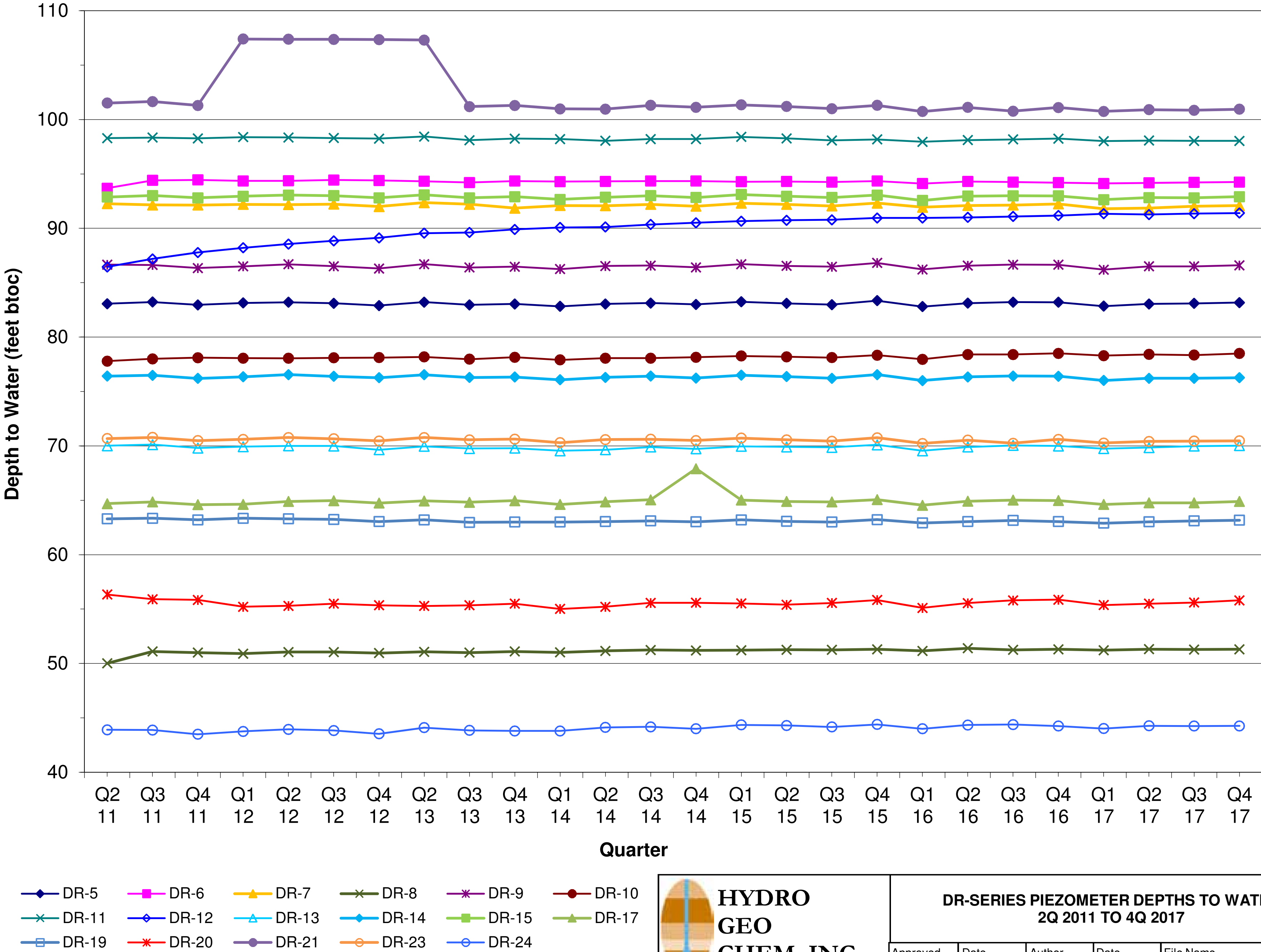
Qal	Alluvium/Fill
Km	Mancos Shale
Kdbc	Dakota Sandstone/ Burro Canyon Formation
	Shale/claystone within Dakota/Burro Canyon
	Conglomerate within Dakota/Burro Canyon
Jmbb	Brushy Basin Member of Morrison Formation
	Piezometric surface

Notes: water levels for abandoned piezometers DR-16 and DR-25 are from the second quarter of 2011; MW-3 lithology from MW-3A

HYDRO GEO CHEM, INC.

INTERPRETIVE NORTH-SOUTH CROSS SECTION (S-N) SOUTHWEST INVESTIGATION AREA

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ xsections/nsxssw/nsxssw18b.srf	19

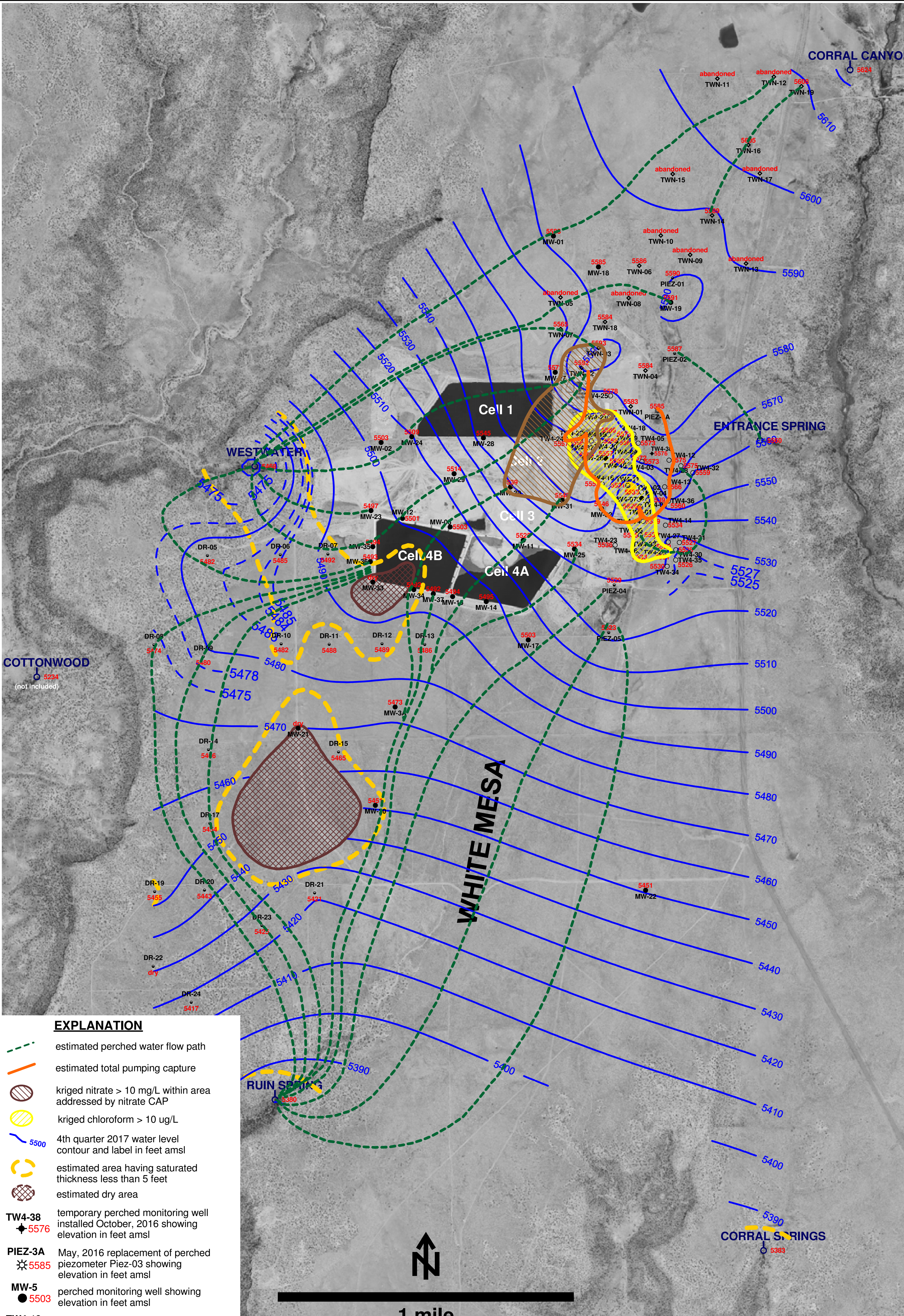


HYDRO GEO CHEM, INC.

DR-SERIES PIEZOMETER DEPTHS TO WATER
2Q 2011 TO 4Q 2017

Approved	Date	Author	Date	File Name	Figure
SJS		SJS		DR Piez Hydrograph	20

H:\718000\hydrpt2018\DR_ Hydrographs_4Q17.xls: DR Piez Hydrographs



EXPLANATION

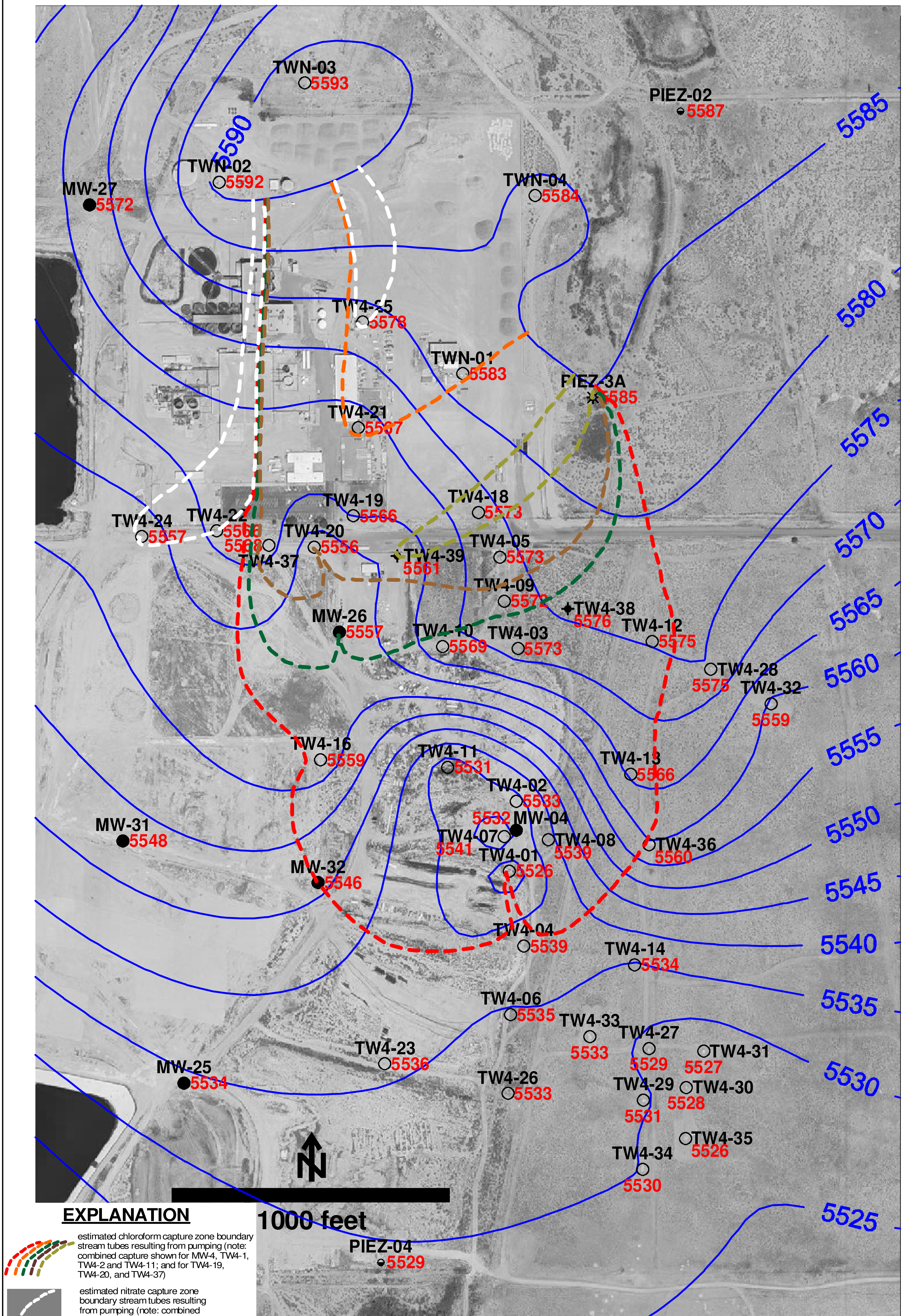
- estimated perched water flow path
- estimated total pumping capture
- kriged nitrate > 10 mg/L within area addressed by nitrate CAP
- kriged chloroform > 10 ug/L
- 5500 — 4th quarter 2017 water level contour and label in feet amsl
- estimated area having saturated thickness less than 5 feet
- estimated dry area
- TW4-38 5576 — temporary perched monitoring well installed October, 2016 showing elevation in feet amsl
- PIEZ-3A 5585 — May, 2016 replacement of perched piezometer Piez-03 showing elevation in feet amsl
- MW-5 5503 — perched monitoring well showing elevation in feet amsl
- TW4-12 5575 — temporary perched monitoring well showing elevation in feet amsl
- TWN-7 5565 — temporary perched nitrate monitoring well showing elevation in feet amsl
- PIEZ-1 5590 — perched piezometer showing elevation in feet amsl
- RUIN SPRING 5380 — seep or spring showing elevation in feet amsl

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

KRIGED 4th QUARTER, 2017 WATER LEVELS SHOWING INFERRED PERCHED WATER PATHLINES AND KRIGED NITRATE AND CHLOROFORM PLUMES

APPROVED	DATE	REFERENCE	FIGURE
SJS	6/18/18	H:/718000/ hydrpt2018/maps/Uflow1217Nchl_rev.srf	21

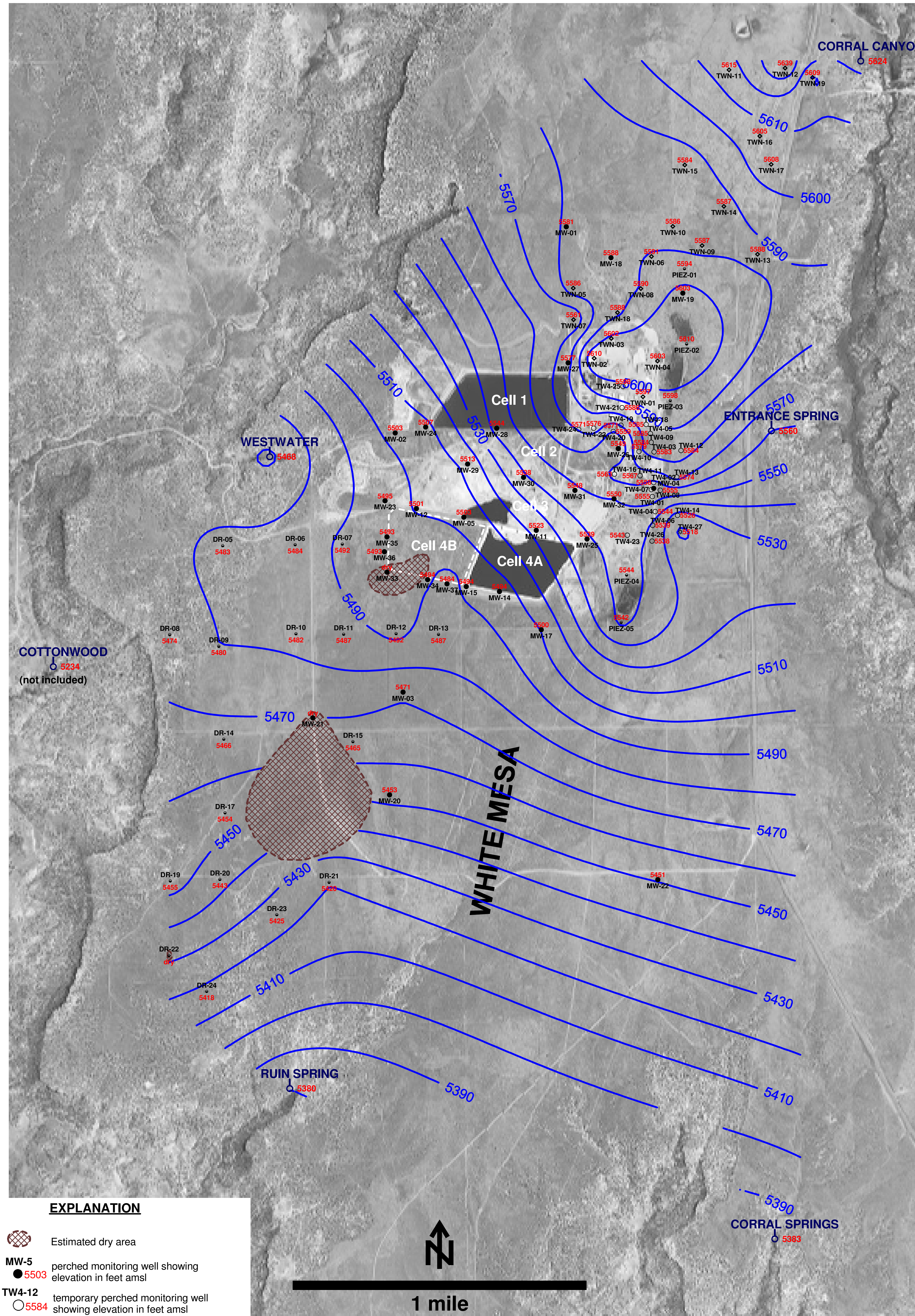


NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

KRIGED 4th QUARTER, 2017 WATER LEVELS AND ESTIMATED CAPTURE ZONES WHITE MESA SITE (detail map)

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/Uwl1217cz.srf	22



EXPLANATION

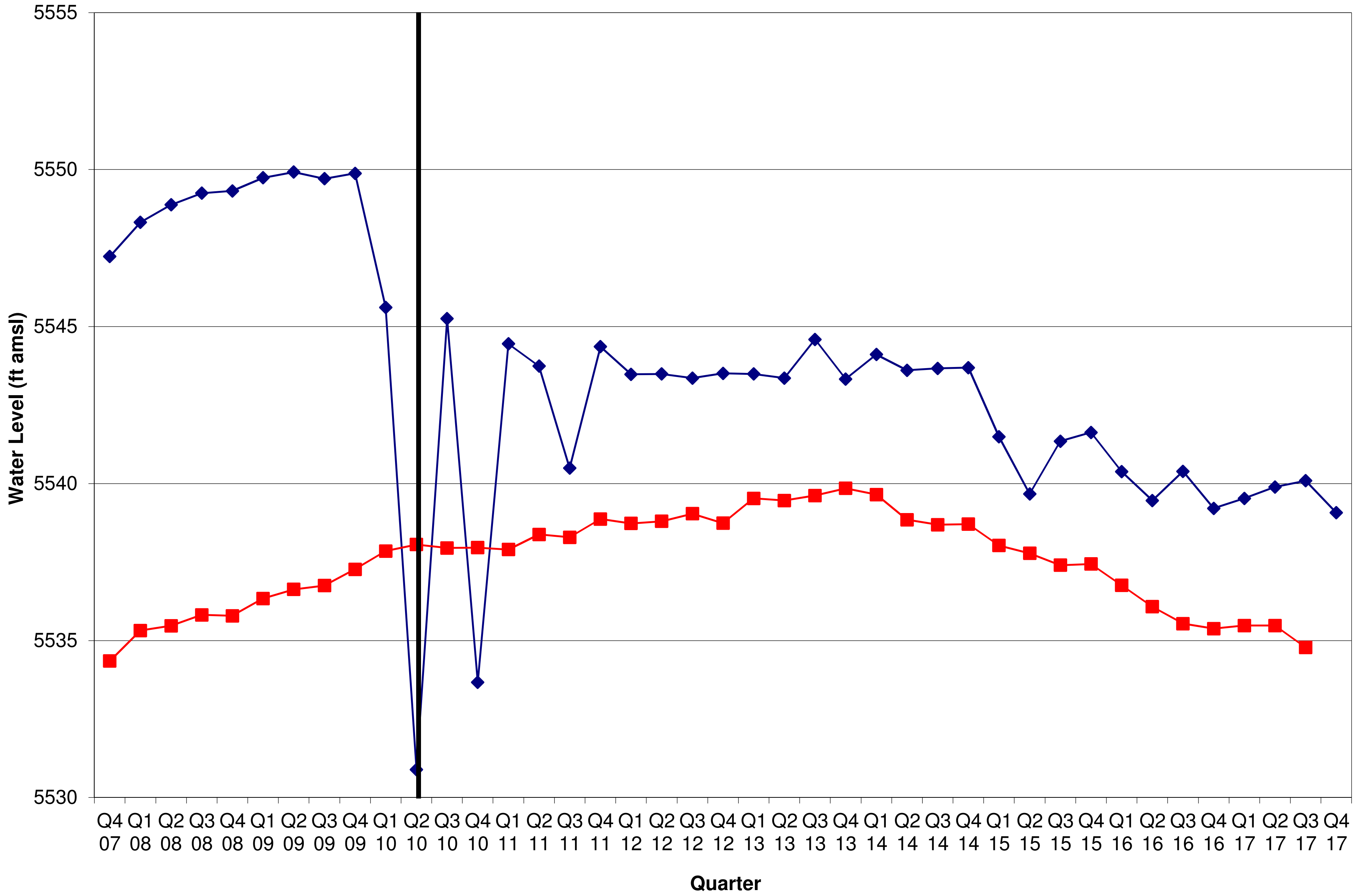
- Estimated dry area
- MW-5 ● 5503 — perched monitoring well showing elevation in feet amsl
- TW4-12 ○ 5584 — temporary perched monitoring well showing elevation in feet amsl
- TWN-10 ◆ 5586 — temporary perched nitrate monitoring well showing elevation in feet amsl
- PIEZ-1 5594 — perched piezometer showing elevation in feet amsl
- TW4-27 5518 — temporary perched monitoring well installed October, 2011 showing elevation in feet amsl
- RUIN SPRING 5380 — seep or spring showing elevation in feet amsl

NOTE: MW-4, MW-26, TW4-4, TW4-19, and TW4-20 are pumping wells

HYDRO GEO CHEM, INC.

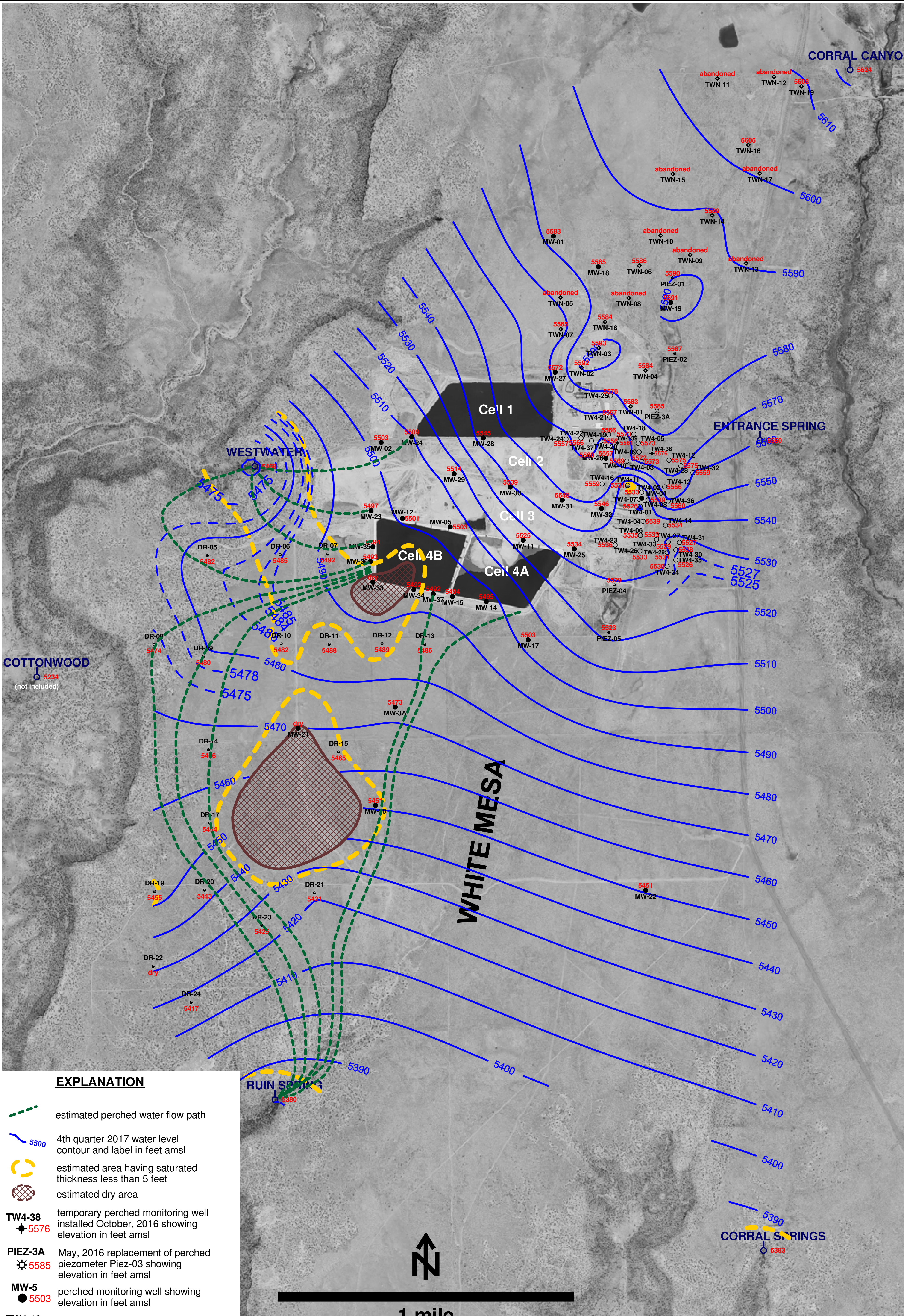
KRIGED 4th QUARTER, 2011 WATER LEVELS WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/Uwl1211b.srf	23



HYDRO GEO CHEM, INC.	TW4-4 AND TW4-6 WATER LEVELS				
Approved SJS	Date	Author SJS	Date	File Name TW6 wltrend plot	Figure 24

H:\718000\hydrpt2018\TW6wltrend_4Q17.xls: TW4_6 plot



EXPLANATION

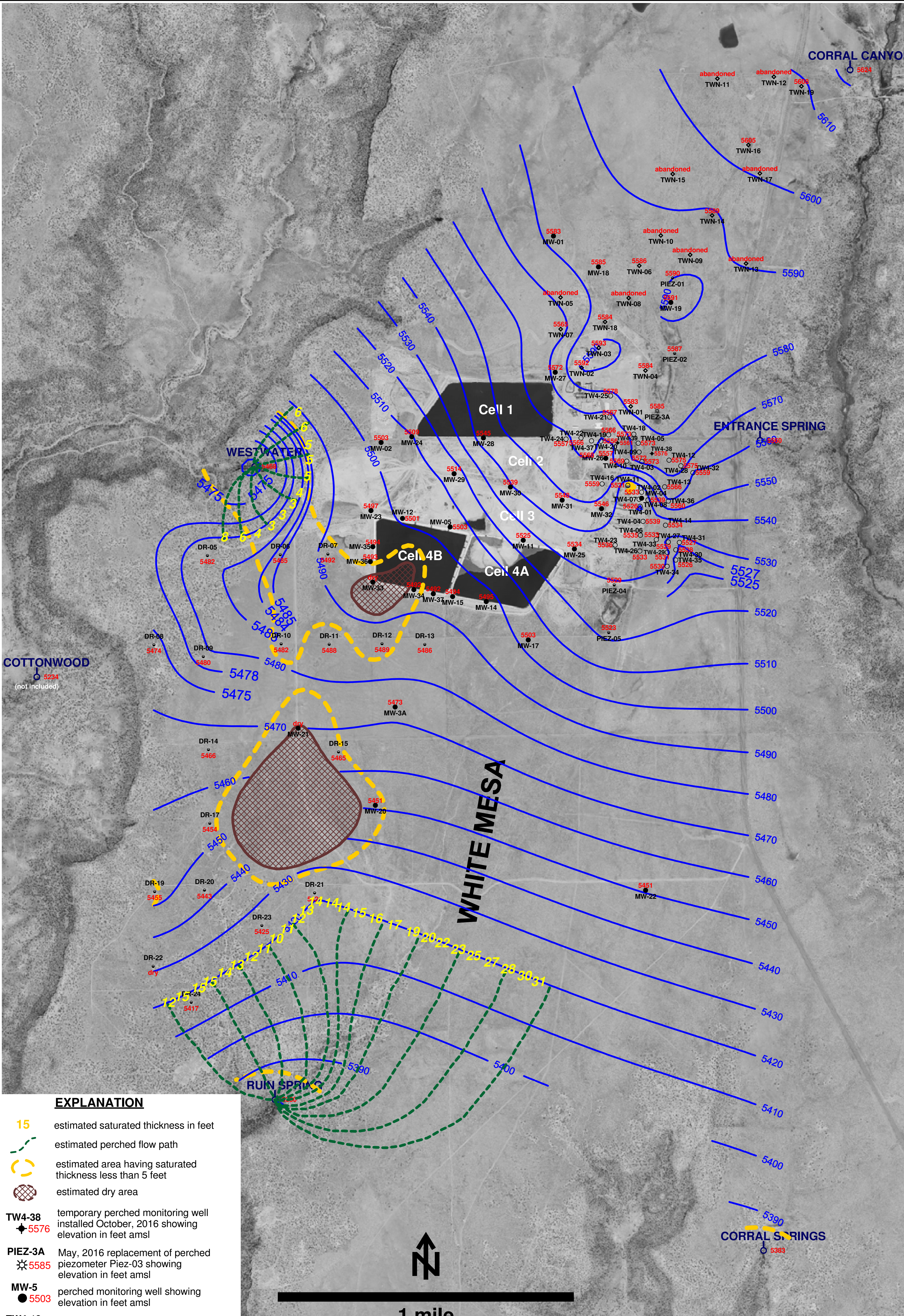
- estimated perched water flow path
- 5500 — 4th quarter 2017 water level contour and label in feet amsl
- estimated area having saturated thickness less than 5 feet
- estimated dry area
- TW4-38 5576 — temporary perched monitoring well installed October, 2016 showing elevation in feet amsl
- PIEZ-3A 5585 — May, 2016 replacement of perched piezometer Piez-03 showing elevation in feet amsl
- MW-5 5503 — perched monitoring well showing elevation in feet amsl
- TW4-12 5575 — temporary perched monitoring well showing elevation in feet amsl
- TWN-7 5565 — temporary perched nitrate monitoring well showing elevation in feet amsl
- PIEZ-1 5590 — perched piezometer showing elevation in feet amsl
- RUIN SPRING 5380 — seep or spring showing elevation in feet amsl

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

KRIGED 4th QUARTER, 2017 WATER LEVELS SHOWING INFERRED PERCHED WATER PATHLINES DOWNGRADIENT OF THE TAILINGS MANAGEMENT SYSTEM WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	6/4/2018	H:/718000/ hydrpt2018/maps/Uflowsw1217_rev.srf	25



EXPLANATION

15 estimated saturated thickness in feet

estimated perched flow path

estimated area having saturated thickness less than 5 feet

estimated dry area

TW4-38 5576 temporary perched monitoring well installed October, 2016 showing elevation in feet amsl

PIEZ-3A 5585 May, 2016 replacement of perched piezometer Piez-03 showing elevation in feet amsl

MW-5 5503 perched monitoring well showing elevation in feet amsl

TW4-12 5575 temporary perched monitoring well showing elevation in feet amsl

TWN-7 5565 temporary perched nitrate monitoring well showing elevation in feet amsl

PIEZ-1 5590 perched piezometer showing elevation in feet amsl

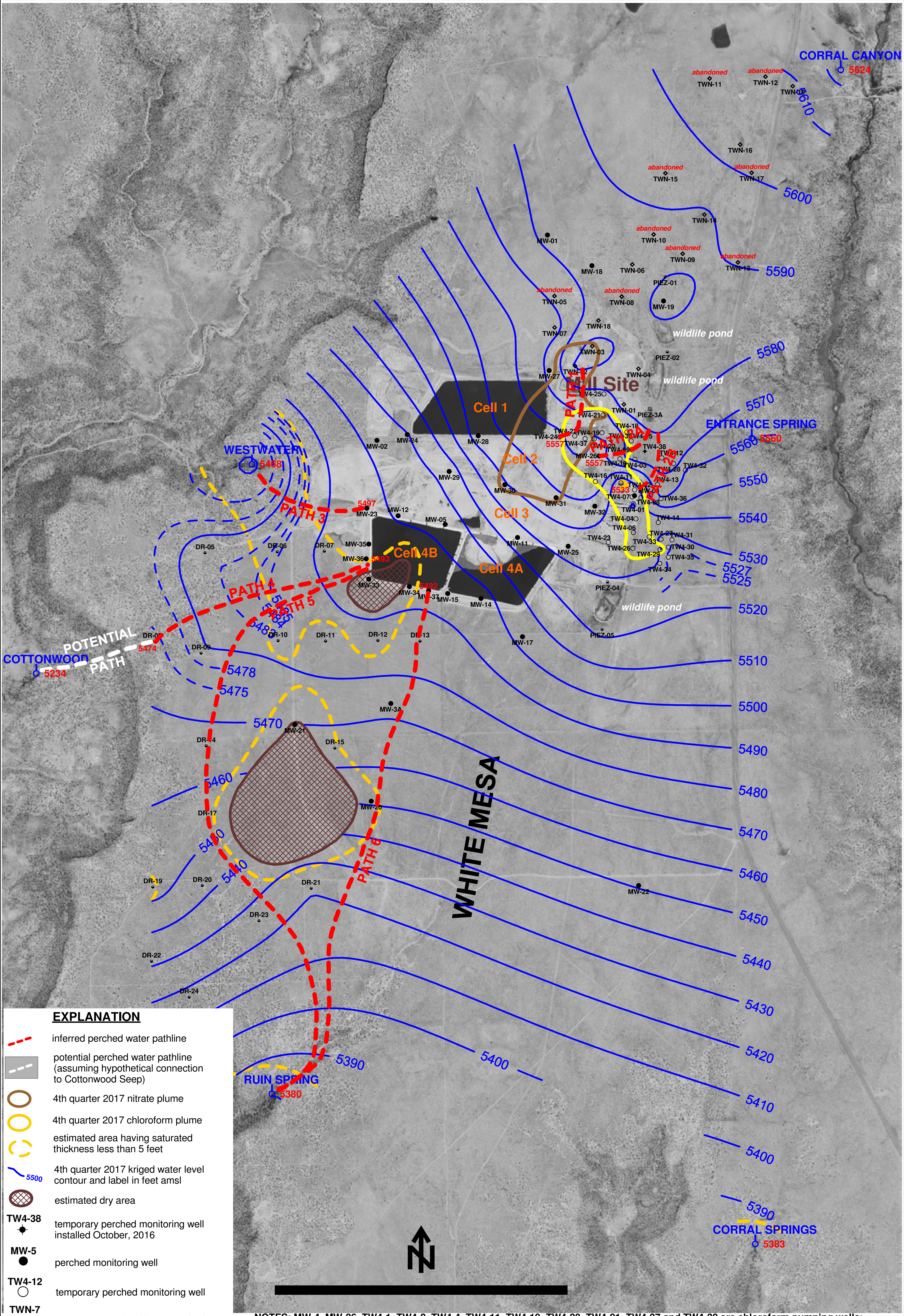
RUIN SPRING 5380 seep or spring showing elevation in feet amsl

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

KRIGED 4th QUARTER, 2017 WATER LEVELS SHOWING INFERRED PERCHED WATER FLOW PATHLINES NEAR RUIN SPRING AND WESTWATER SEEP

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/Uspgfl17.srf	26



NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

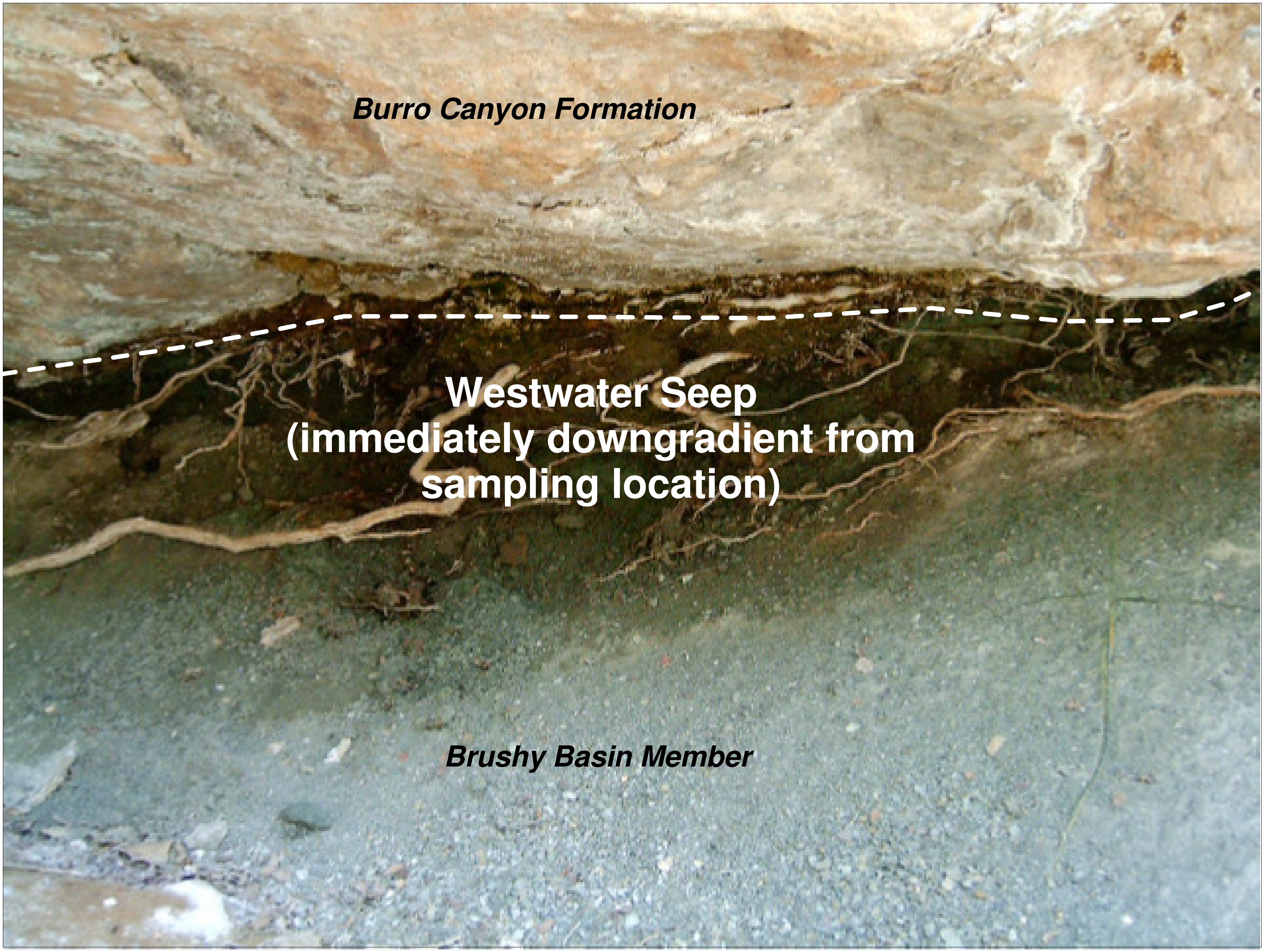
KRIGED 4th QUARTER, 2017 WATER LEVELS SHOWING INFERRED PERCHED WATER FLOW PATHS USED FOR TRAVEL TIME ESTIMATES AND KRIGED NITRATE AND CHLOROFORM PLUMES

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/UpathNchl4Q17.srf	27

HYDRO
GEO
CHEM, INC.

**PHOTOGRAPH OF THE WESTWATER SEEP
SAMPLING LOCATION
JULY, 2010**

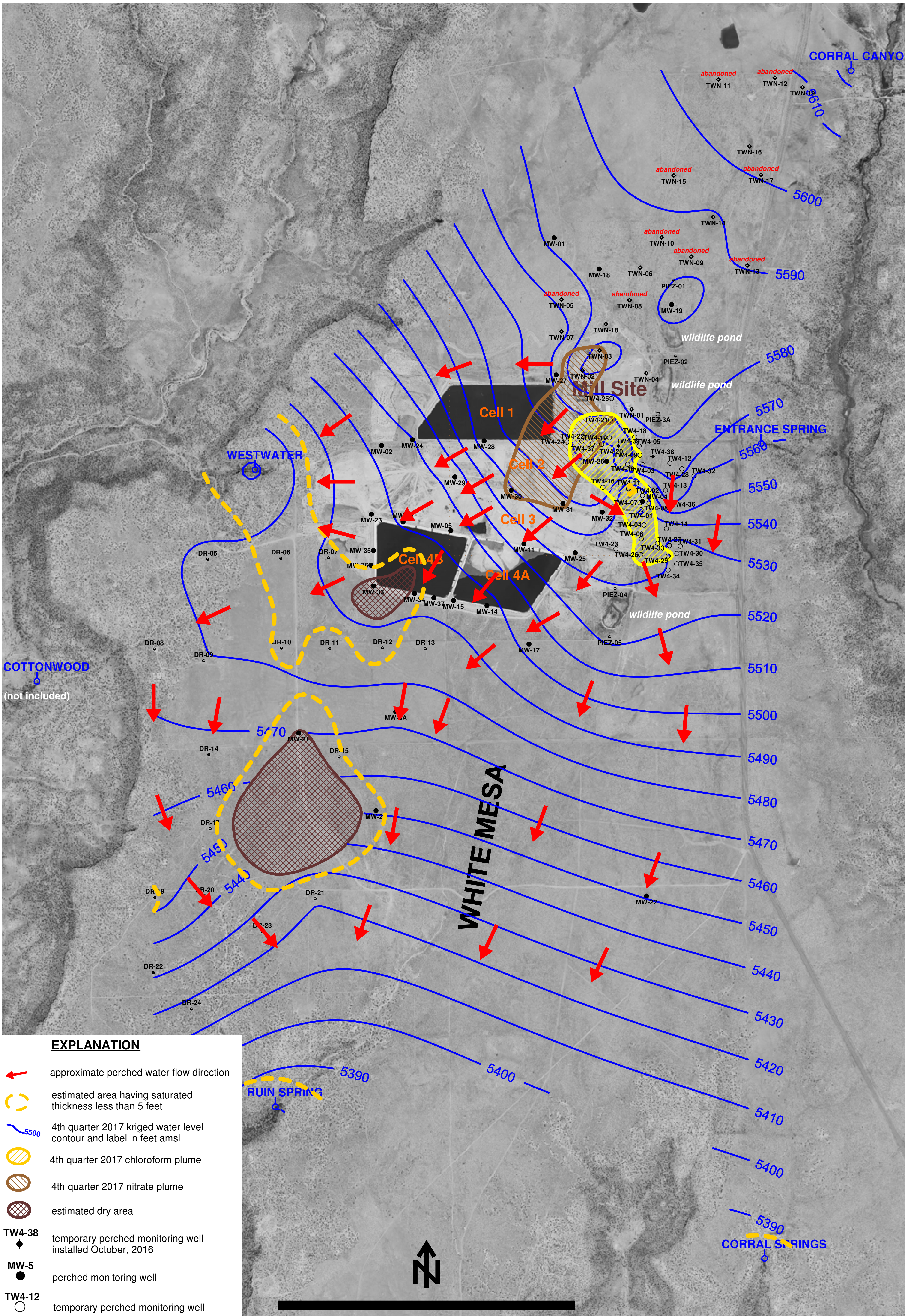
APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ Figures/westsmpl2.srf	28



HYDRO GEO CHEM, INC.

PHOTOGRAPH OF THE CONTACT BETWEEN THE BURRO CANYON FORMATION AND THE BRUSHY BASIN MEMBER AT WESTWATER SEEP

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ Figures/westcontact2.srf	29



EXPLANATION

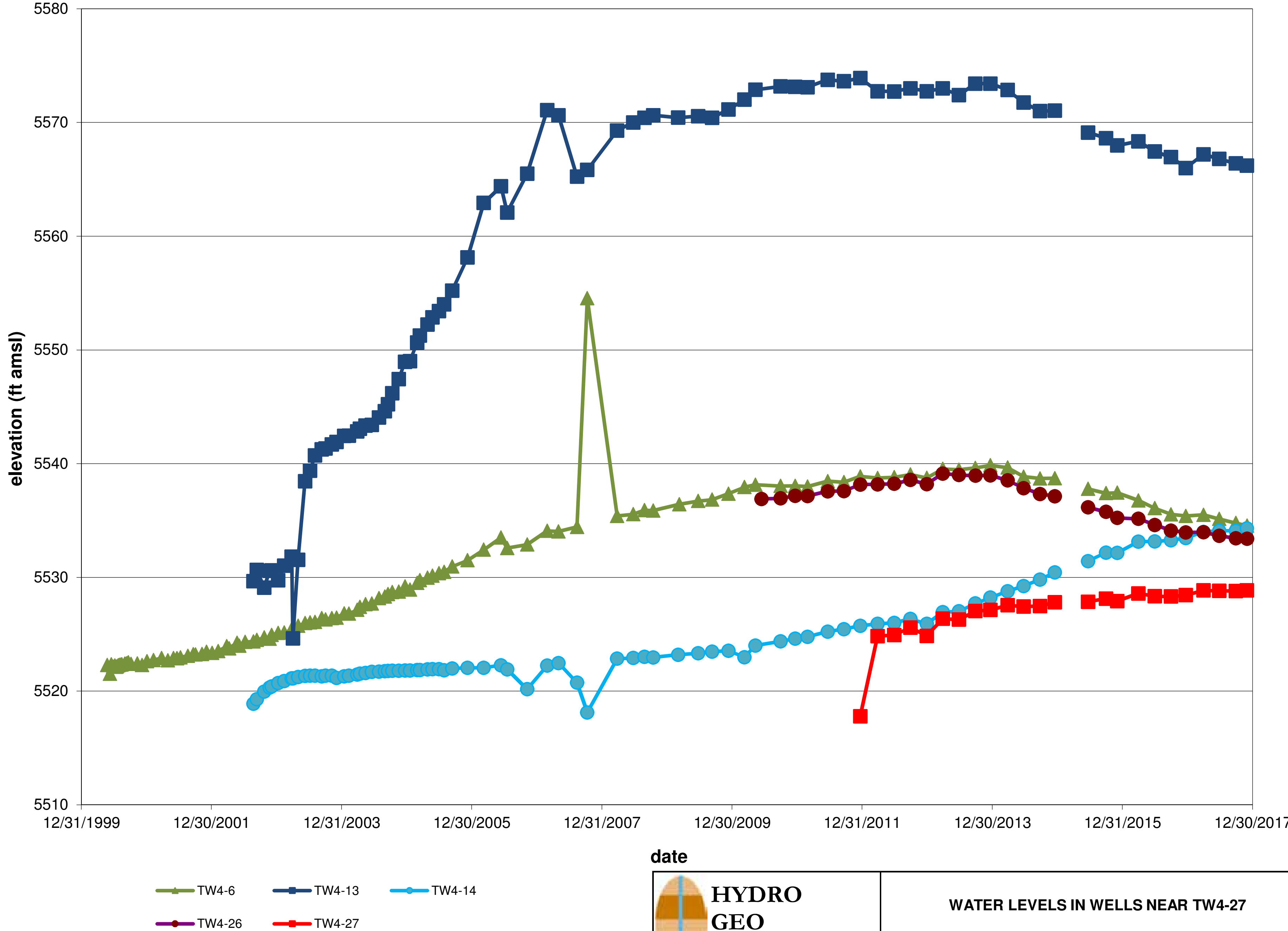
	approximate perched water flow direction
	estimated area having saturated thickness less than 5 feet
5500	4th quarter 2017 kriged water level contour and label in feet amsl
	4th quarter 2017 chloroform plume
	4th quarter 2017 nitrate plume
	estimated dry area
TW4-38	temporary perched monitoring well installed October, 2016
MW-5	perched monitoring well
TW4-12	temporary perched monitoring well
TWN-7	temporary perched nitrate monitoring well
PIEZ-1	perched piezometer
PIEZ-3A	May, 2016 replacement of perched piezometer Piez-03
RUIN SPRING	seep or spring

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

KRIGED 4th QUARTER, 2017 WATER LEVELS SHOWING KRIGED NITRATE AND CHLOROFORM PLUMES AND GENERAL FLOW DIRECTIONS WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/UlvectNChl4Q17.srf	30

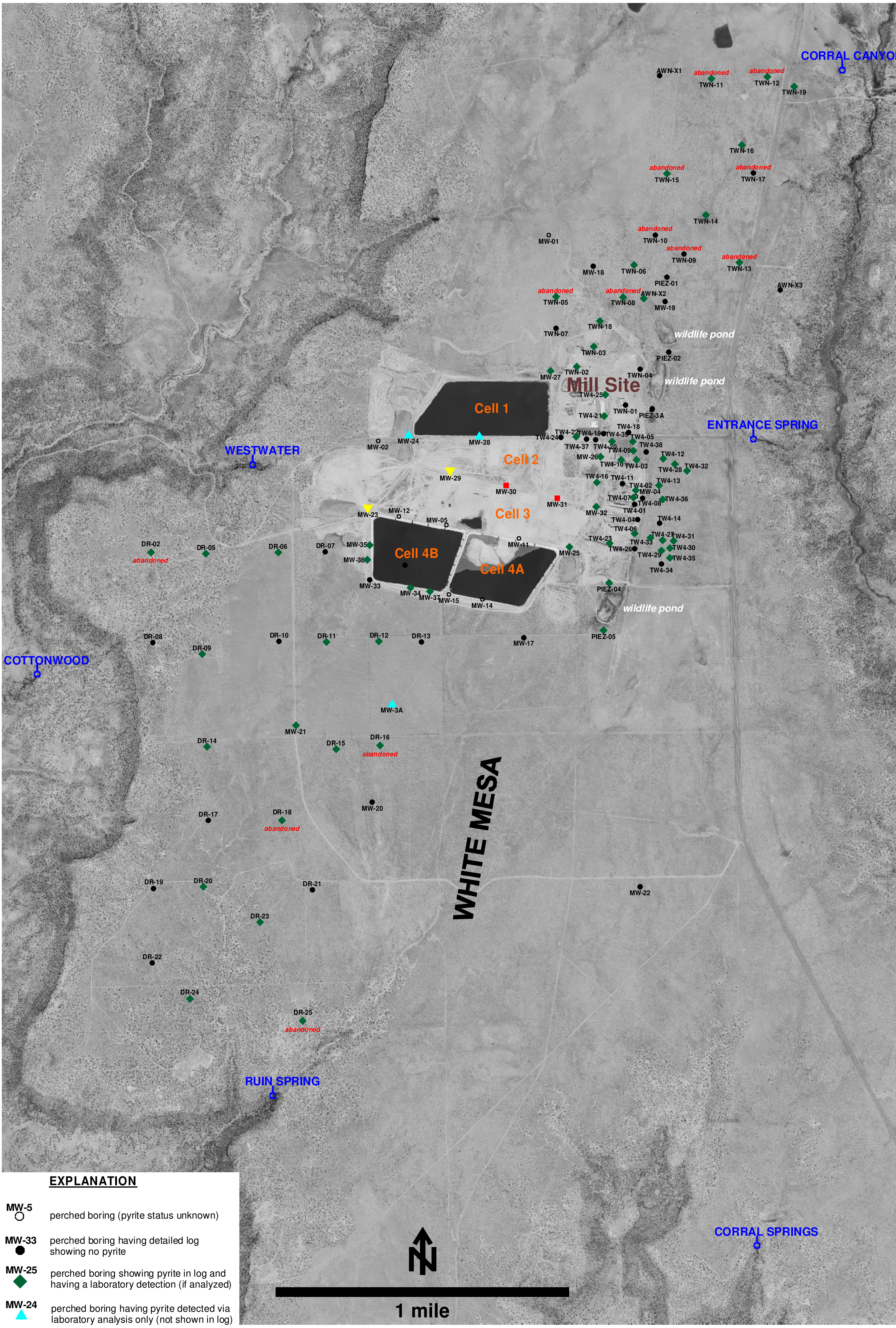


HYDRO GEO CHEM, INC.

WATER LEVELS IN WELLS NEAR TW4-27

Approved	Date	Author	Date	File Name	Figure
SJS		SJS		plot F30	31

H:\718000\hydrpt2018\TW27area_wl_4Q17.xls: plot F31



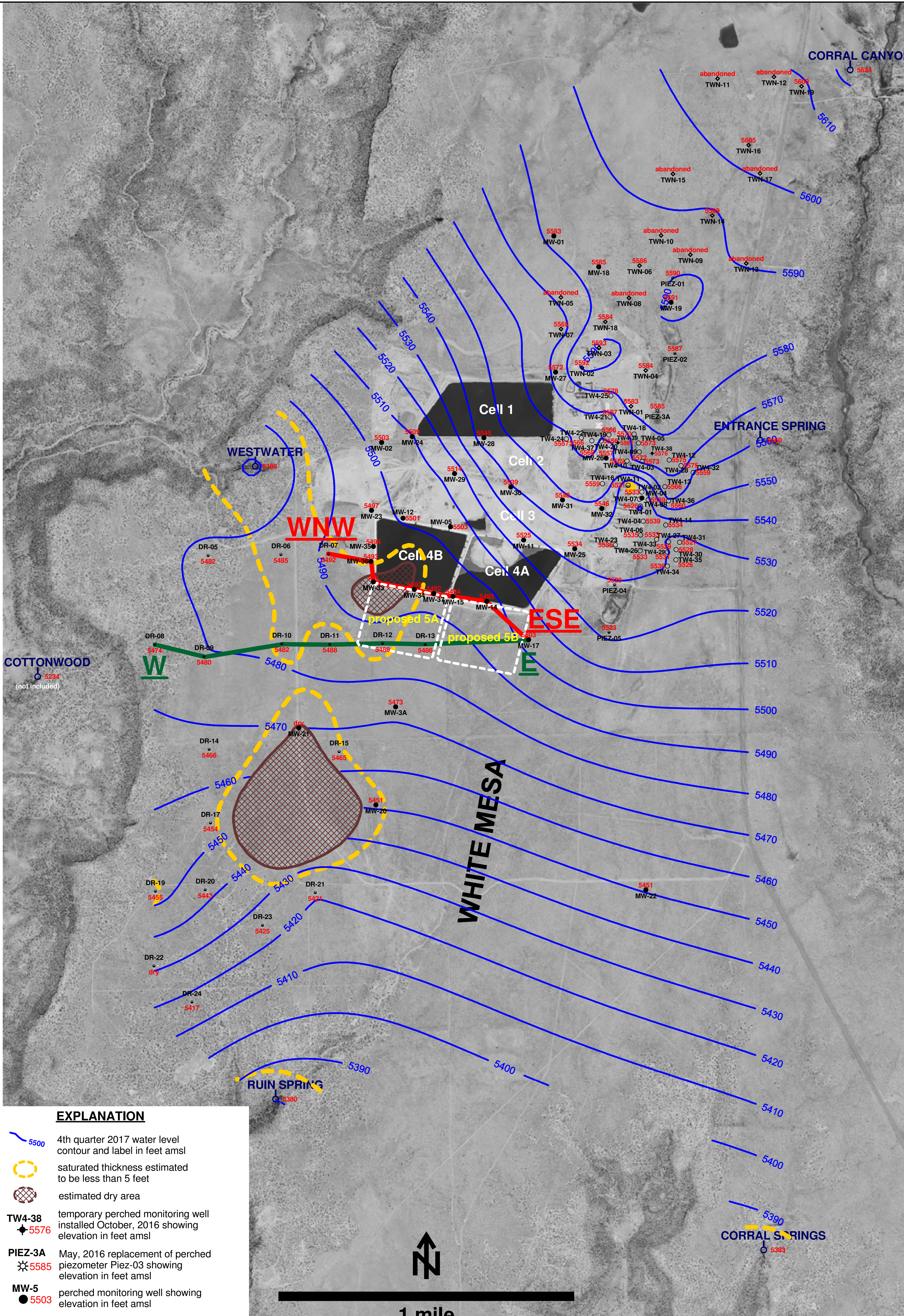
EXPLANATION

MW-5 ○	perched boring (pyrite status unknown)
MW-33 ●	perched boring having detailed log showing no pyrite
MW-25 ◆	perched boring showing pyrite in log and having a laboratory detection (if analyzed)
MW-24 ▲	perched boring having pyrite detected via laboratory analysis only (not shown in log)
MW-29 ▼	perched boring having a possible pyrite detection via laboratory analysis (but not shown in log)
MW-30 ■	perched boring showing pyrite in log and having no laboratory detection
RUIN SPRING	seep or spring

HYDRO GEO CHEM, INC.

WHITE MESA SITE PLAN SHOWING PYRITE OCCURRENCE IN PERCHED BORINGS

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ maps/pyrite_ocuurence17.srf	32



EXPLANATION

5500 — 4th quarter 2017 water level contour and label in feet amsl

saturated thickness estimated to be less than 5 feet

estimated dry area

TW4-38 5576 — temporary perched monitoring well installed October, 2016 showing elevation in feet amsl

PIEZ-3A 5585 — May, 2016 replacement of perched piezometer Piez-03 showing elevation in feet amsl

MW-5 5503 — perched monitoring well showing elevation in feet amsl

TW4-12 5575 — temporary perched monitoring well showing elevation in feet amsl

TWN-7 5565 — temporary perched nitrate monitoring well showing elevation in feet amsl

PIEZ-1 5590 — perched piezometer showing elevation in feet amsl

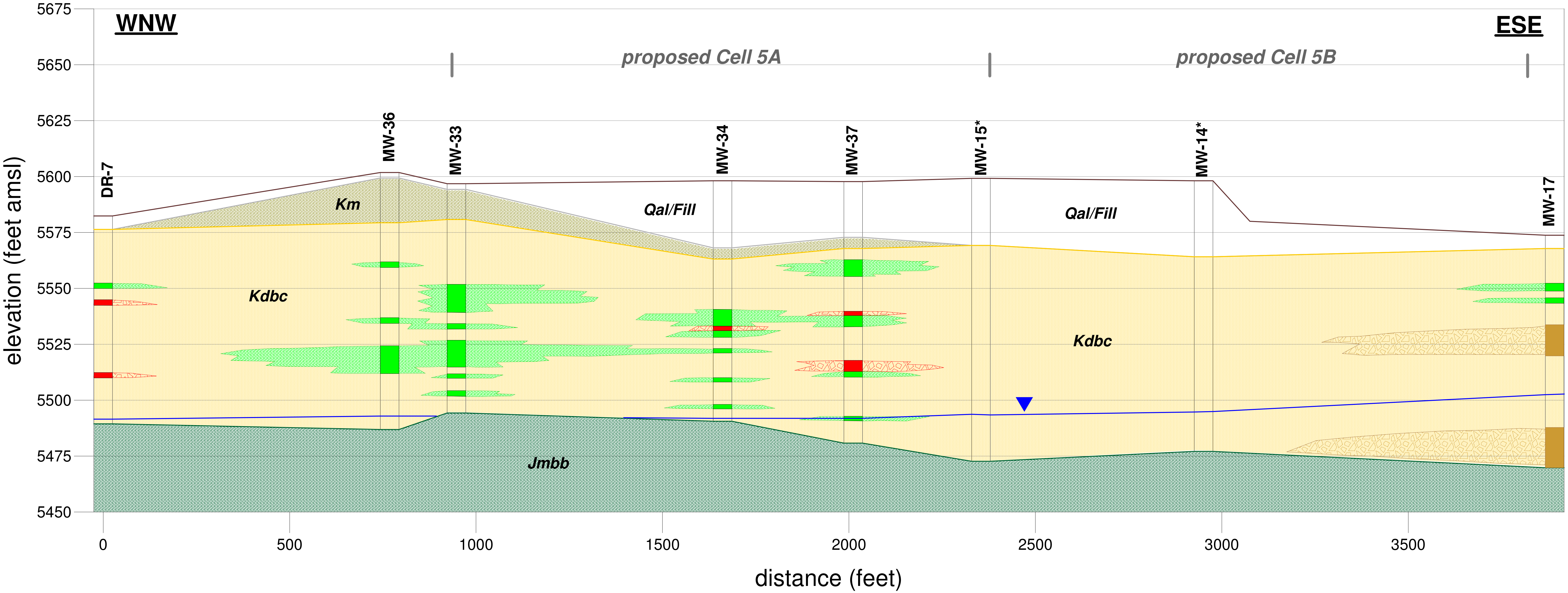
RUIN SPRING 5380 — seep or spring showing elevation in feet amsl

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

PROPOSED CELLS 5A AND 5B (showing kriged Q4 2017 perched water levels and cross sections in proposed cell area) WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/Uwl1217c5a5b.srf	33



EXPLANATION

- Qal/Fill — Alluvium/Fill
- Km — Mancos Shale
- Kdbc — Dakota Sandstone/ Burro Canyon Formation
- Jmbb — Brushy Basin Member of Morrison Formation
- Shale/Shaly Sandstone within Dakota/Burro Canyon
- Conglomerate within Dakota/Burro Canyon
- Conglomeratic Dakota Sandstone/ Burro Canyon Formation
- Piezometric surface

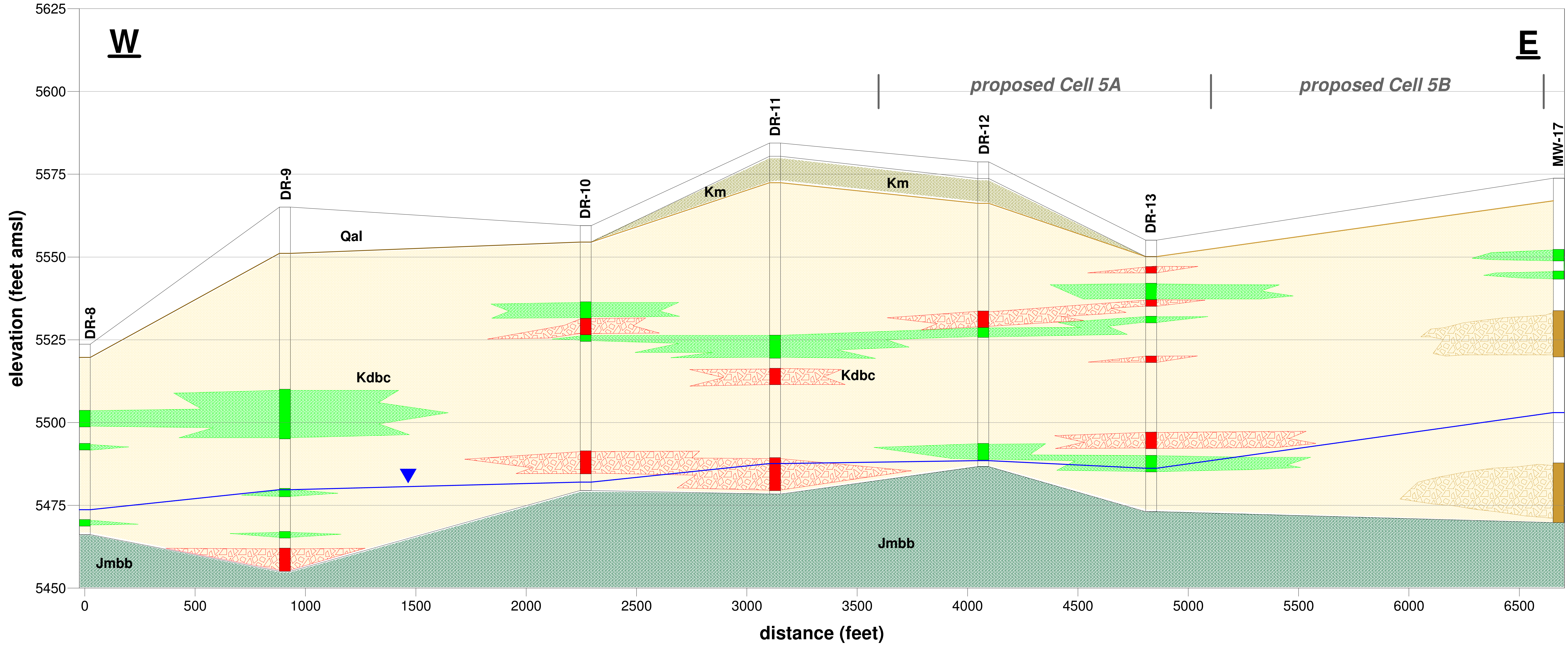
vertical exaggeration = 6:1

* = detailed log unavailable

HYDRO GEO CHEM, INC.

INTERPRETIVE EAST-WEST CROSS SECTION (WNW - ESE) PROPOSED CELL5A/5B AREA

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ xsections/ewxssw3/ew3xsectb_rev.srf	34



vertical exaggeration = 15:1

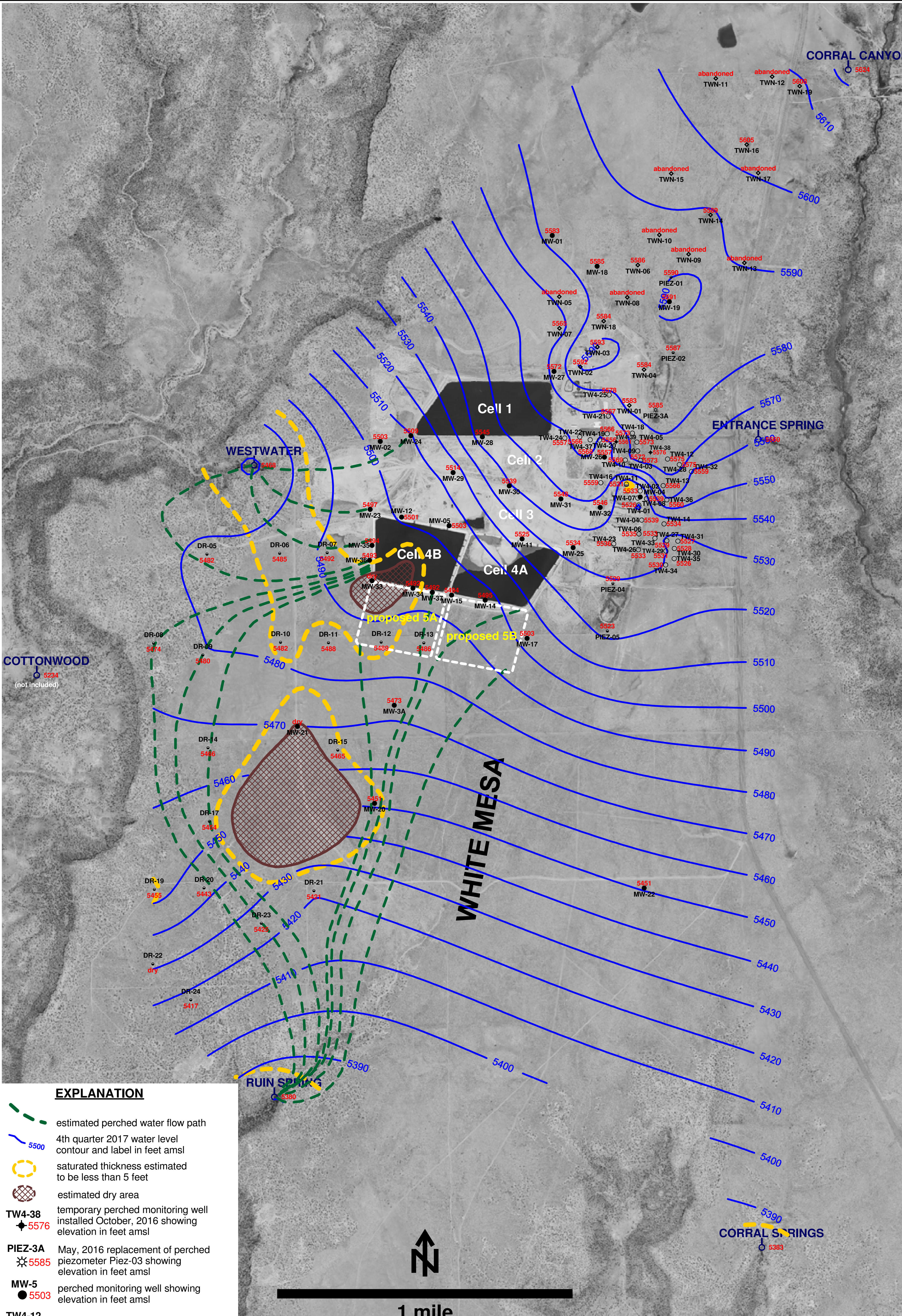
EXPLANATION

Symbol	Description	Symbol	Description
Qal/Fill	Alluvium/Fill		Shale/Shaly Sandstone within Dakota/Burro Canyon
Km	Mancos Shale		Conglomerate within Dakota/Burro Canyon
Kdbc	Dakota Sandstone/ Burro Canyon Formation		Conglomeratic Dakota Sandstone/ Burro Canyon Formation
Jmbb	Brushy Basin Member of Morrison Formation		Piezometric surface

HYDRO GEO CHEM, INC.

INTERPRETIVE EAST-WEST CROSS SECTION (W - E) PROPOSED CELL 5A/5B AREA

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/ xsections/ewxssw3/ewxssw2tb_rev.srf	35



EXPLANATION

estimated perched water flow path

5500 — 4th quarter 2017 water level contour and label in feet amsl

saturated thickness estimated to be less than 5 feet

estimated dry area

TW4-38 5576 — temporary perched monitoring well installed October, 2016 showing elevation in feet amsl

PIEZ-3A 5585 — May, 2016 replacement of perched piezometer Piez-03 showing elevation in feet amsl

MW-5 5503 — perched monitoring well showing elevation in feet amsl

TW4-12 5575 — temporary perched monitoring well showing elevation in feet amsl

TWN-7 5565 — temporary perched nitrate monitoring well showing elevation in feet amsl

PIEZ-1 5590 — perched piezometer showing elevation in feet amsl

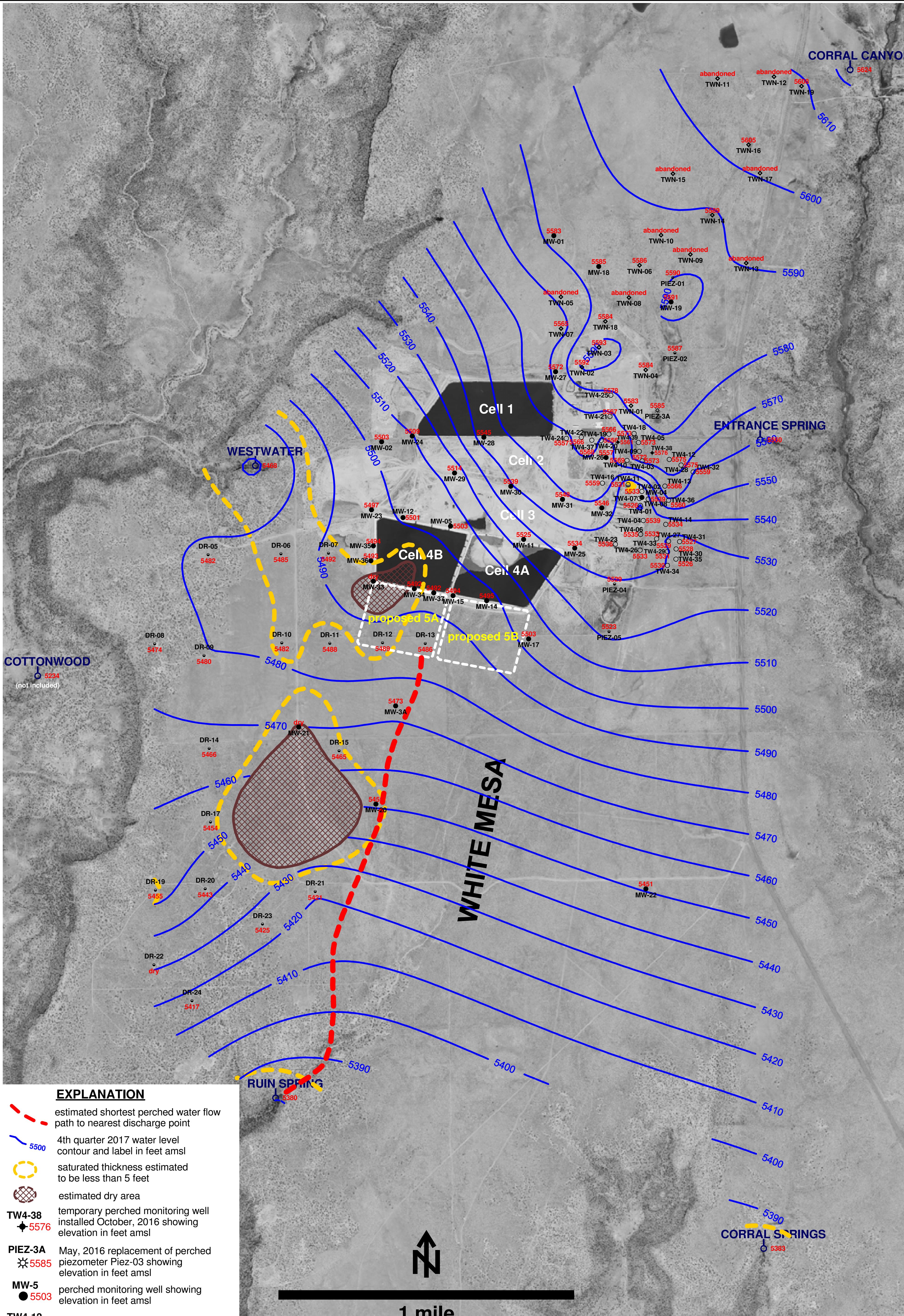
RUIN SPRING 5380 — seep or spring showing elevation in feet amsl

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

PROPOSED LOCATIONS OF CELLS 5A AND 5B (showing kriged Q4 2017 perched water levels and inferred perched water flow paths downgradient of the tailings management system)

APPROVED	DATE	REFERENCE	FIGURE
SJS	6/4/2018	H:/718000/ hydrpt2018/maps/Uwl1217c5a5b_path_rev.srf	36

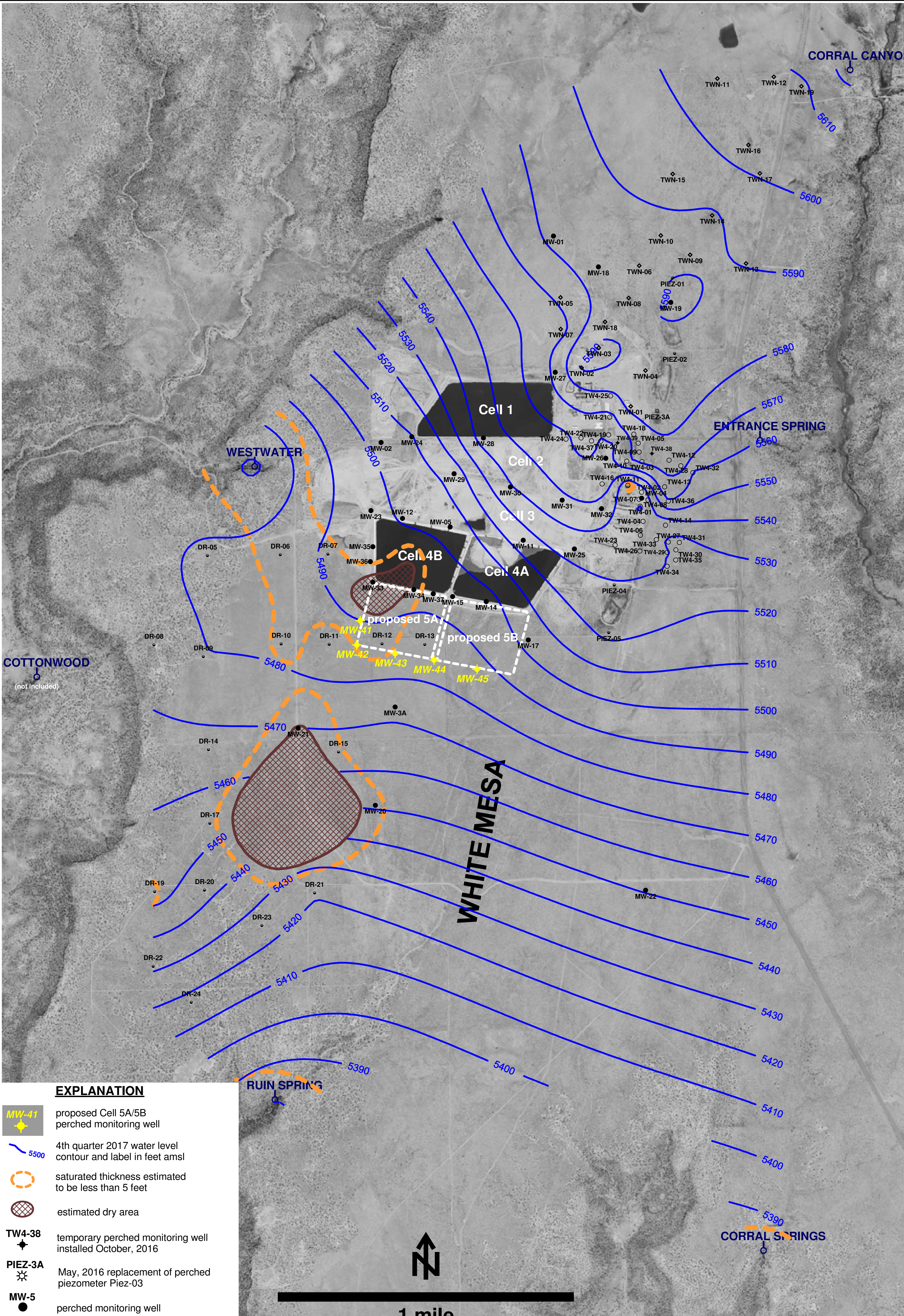


NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

PROPOSED LOCATIONS OF CELLS 5A AND 5B (showing kriged Q4 2017 perched water levels and inferred shortest flow path to closest discharge point) WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/ hydrpt2018/maps/Uwl1217c5a5b_path6B.srf	37



EXPLANATION

MW-41	proposed Cell 5A/5B perched monitoring well
5500	4th quarter 2017 water level contour and label in feet amsl
	saturated thickness estimated to be less than 5 feet
	estimated dry area
TW4-38	temporary perched monitoring well installed October, 2016
PIEZ-3A	May, 2016 replacement of perched piezometer Piez-03
MW-5	perched monitoring well
TW4-12	temporary perched monitoring well
TWN-7	temporary perched nitrate monitoring well
PIEZ-1	perched piezometer
RUIN SPRING	seep or spring

NOTES: MW-4, MW-26, TW4-1, TW4-2, TW4-4, TW4-11, TW4-19, TW4-20, TW4-21, TW4-37 and TW4-39 are chloroform pumping wells; TW4-22, TW4-24, TW4-25 and TWN-2 are nitrate pumping wells; TW4-11 water level is below the base of the Burro Canyon Formation

HYDRO GEO CHEM, INC.

PROPOSED LOCATIONS OF NEW PERCHED WELLS TO MONITOR PROPOSED CELLS 5A AND 5B (showing kriged Q4 2017 perched water levels) WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	5/22/2018	H:/718000/hydrpt2018/maps/UpropwelC5.srf	38

APPENDIX A

LITHOLOGIC LOGS

APPENDIX A.1

DR - SERIES

Date 5 May 2011 Geologist L. Casebolt Drilling Co. Boyles Exploration Inc. Hole No. DR2

Property White Mesa mill Project Cell 4B Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ≈5576

PAGE 1 OF 1

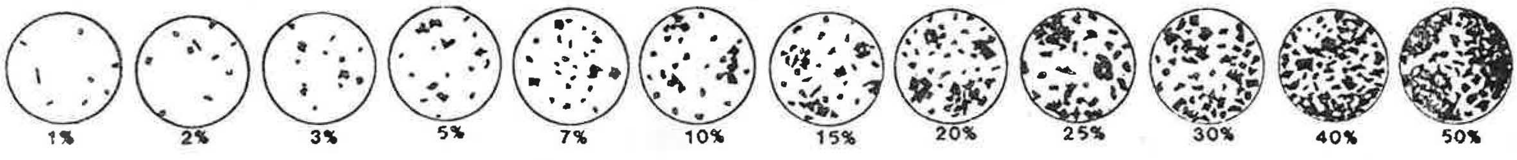
T.D. PROBE ____

T.D. DRILL 95.0

FLUID LEVEL ____

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						sndy mdst	rdbn-ltpktn	f-c	p	a								S			Surface Soil to 2.0' Mancos Shale (unconsolidated)
5.0						sh-qtz ss	ltpktn-	m-c	f	a								VS			Upper Dakota Ct. @ 4.0' (unconsol. to 4.0')
7.5						qtz ss	lt br	m-c	f	a		H						N			wh chert grains
10.0						sh	ywgy											S			
12.5						sh-qtz ss	dk gy	m-c	f	a								M			
15.0						qtz ss	ywtn	m	w	R								N			
17.5						qtz ss	ywtn	m	w	R		L						N			sparce limonite grain coating
20.0						qtz ss	ltgytn	m	w	R								N			gy qtz grains
22.5						qtz ss	ywtn	m-peb	p	a								N			Moist cuttings this morning, dk chert grains + peb.
25.0						qtz ss	ywtn	m-peb	p	a								N			lt-dk chert grains
27.5						qtz ss	lt tn	f-m	w	R								N			
30.0						sh	ywgybl											N			
32.5						sh	ywgybl											N			
35.0						sh	ywgybl											N			
37.5						sh	ywgybl											N			
40.0						qtz ss sltst	lt ywtn	slt-vf	m	r								N			
42.5						qtz ss sltst	lt tn	slt-vf	m	r								N			
45.0						qtz ss sltst	lt tn	slt-vf	m	r								N			
47.5						sltst-sh	lt ywgn											N			
50.0						sh	ltgn-ltpprd											N			
52.5						sltst-qtz ss	lt blgy	slt-m	p	a								N			
55.0						sltst-qtz ss	lt tn	slt-vf	m	r								N			
57.5						qtz ss	lt tn	f	w	r								M			
60.0						qtz ss	lt tn	f	w	r								N			
62.5						sltst-sh	ywgytn											N			
65.0						sh	ltgn-ppbn											N			
67.5						qtz ss	ltgytn	vf-m	m	r			tr	a				N			
70.0						qtz ss	lt tn	m	w	R								N			
72.5						qtz ss	lttn	m	w	R								N			
75.0						qtz/chert ss	gytn	m-peb	p	a								N			abund dk-lt chert grains & pebbles.
77.5						qtz ss cgl	orgy	vc-peb	p	A								N			abund multi colored chert grains
80.0						qtz ss, cgl	orgy	vc-peb	p	A								N			Well began producing approx 3gpm @ 78.0'
82.5						cgl, qtz ss	wh-ltgy	m-peb	p	A	si							N			
85.0						qtz ss	wh-ltgy	m-peb	f	A	si							N			
87.5						qtz ss, sh	wh-gn	m-vc	p	a	Si	L						N			Brushy Basin Ct. @ 87.0' good ct. poss. oil as cement?
90.0						sh	gn-ppbn											N			flow increased to 20 gpm @ 87.0'
92.5						sh	gn-ppbn											N			
95.0						sh	gnppbn											N			T.D. some telltale rd chert grains · 1-2mm
97.5																					
100.0																					(noteable dk bn material (dead oil?) in
102.5																					interstacese of sand grains @ 87.5)
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					Note: this well completed on 6 May 2011

PERCENTAGE COMPOSITION IMAGE



Date 5 May 2011 Geologist L. Casebolt Drilling Co. Boyles Exploration Inc. Hole No. DR5

Property White Mesa Mill Project cell 48 Unit No. ______ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ______ Elev. ≈5560

PAGE 1 OF 1

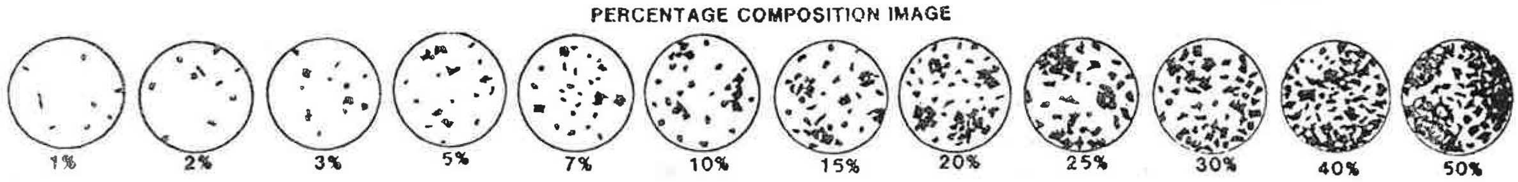
T.D. PROBE ______

T.D. DRILL 100.0

FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React. 10% HCL	Carbon Amount	Carbon Type	Remarks
0–2.5						mdst	rdbn											S			Surface Soil - unconsolidated CL
2.5–5.0						qtz ss, mdst	ywrdbn	m-c	m	a								N			Upper Dakota Ct. @ 3.0'
5.0–7.5						qtz ss	ltorbn	m-c	m	a		L						N			
7.5–10.0						qtz ss	tn	m	w	r								N			
10.0–12.5						qtz ss	tn	m	w	r								N			
12.5–15.0						qtz ss, sh	ltbn-ltgy	f	w	a		L						N			
15.0–17.5						qtz ss	vltbn	f	w	a		L						N			
17.5–20.0						qtz ss	ywgy	vf-c	p	r								N			some chert grains
20.0–22.5						qtz ss	ltgy	m-c	m	R								N			" " "
22.5–25.0						qtz ss	tn	m	w	R								N			
25.0–27.5						qtz ss	ltgy	m-c	m	r								N			
27.5–30.0						sndy sh	vltywgy	f-m	m	r								N			CH
30.0–32.5						sh	ltywgy											N			CH
32.5–35.0						sh	ywgy											N			
35.0–37.5						qtz ss, sh	tn-orgy	f-m	m	r		L						N			
37.5–40.0						qtz ss	tn	m	w	r								N			
40.0–42.5						qtz ss	ltbn	m-c	m	r		L						N			Some chert frags. and grains
42.5–45.0						qtz ss	tn	m	w	r								N			
45.0–47.5						qtz ss	vltbn	m	w	r								N			
47.5–50.0						qtz ss	ltbn	m	w	r								N			
50.0–52.5						qtz ss	lttn	m	w	r								N			
52.5–55.0						qtz ss	ltgytn	m	w	r								N			
55.0–57.5						qtz ss	ltgytn	m	w	a								N			
57.5–60.0						qtz ss	ltgytn	f-m	m	a								N			
60.0–62.5						qtz ss	wh-vdkbn	f-peb	p	a								W			moisture 1st noticed chert pebble frags.
62.5–65.0						qtz ss, sh	wh-vltgn	vf-c	p	a								N			
65.0–67.5						qtz ss	vltgytn	m-peb	p	r								N			abund. chert grains
67.5–70.0						qtz ss	vltgytn	m-c	m	r								N			
70.0–72.5						qtz ss, sh	vltgytn	m-peb	f	r								N			some chert frags + grains
72.5–75.0						qtz ss	vltgytn	m	w	r		L						N			
75.0–77.5						qtz ss	vltgytn	m	w	r								N			
77.5–80.0						qtz ss	ltortn	m	w	r		L						N			very hard drilling
80.0–82.5						qtz ss	lttn	m	w	r		L						N			"
82.5–85.0						qtz ss	lttn	m	w	R								N			"
85.0–87.5						qtz ss	vlttn	m-c	m	a								N			"
87.5–90.0						qtz ss	vlttn	f-m	f	r								N			"
90.0–92.5						qtz ss	vlttn	f-m	f	r								N			"
92.5–95.0						qtz ss, sh	wh-gn	f-m	f	r			tr	A				M			Brushy Basin Ct @ 94.0' good contact
95.0–97.5						sh	gn											N			
97.5–100.0						sh	gn											N			T.D. telltale small red chert grains
100.0–102.5																					
102.5–105.0																					
105.0–107.5																					
107.5–110.0																					
110.0–112.5																					
112.5–115.0																					
115.0–117.5																					
117.5–120.0																					
120.0–122.5																					
122.5–125.0																					

PERCENTAGE COMPOSITION IMAGE



Date 5 May 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Inc. Hole No. DR6

Property White Mesa Mill Project Cell 4B Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ≈5579

PAGE 1 OF 1

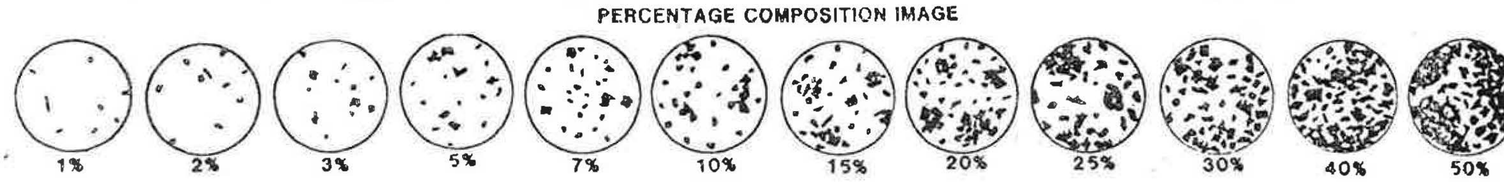
T.D. PROBE ____

T.D. DRILL 100.0

FLUID LEVEL ____

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	React.-10% HCL	Remarks
0–2.5	mdst	rdbn								W	Surface Soil - unconsolidated - CH
2.5–5.0	mdst, sh	rdbn, ltpk								VS	Mancos Shale " CH
5.0–7.5	qtz ss, sh	ltpktn	f-m	m	r		L			VS	Upper Dakota Fm Ct. @ 6.0'
7.5–10.0	qtz ss	tn	m	w	r					N	
10.0–12.5	qtz ss	tn	m-c	m	a		L			N	
12.5–15.0	qtz ss	tn	m	w	a					N	
15.0–17.5	qtz ss	tn	m	w	a					N	
17.5–20.0	qtz ss	tn	m	w	a					N	
20.0–22.5	qtz ss	tn	m-c	m	a		L			N	
22.5–25.0	qtz ss, sh	orbn	m	w	r		L			N	
25.0–27.5	qtz ss	tn	m	w	r					N	
27.5–30.0	qtz ss	tn	m	w	a					N	
30.0–32.5	qtz ss	tn	m	w	a					N	
32.5–35.0	qtz ss	tn	m	w	R					N	
35.0–37.5	qtz ss	tn	m	w	r					N	
37.5–40.0	qtz ss.	tn	m	w	r					N	sparse chert grains
40.0–42.5	qtz ss, sh	tn-vltgn	m-vc	p	a					N	
42.5–45.0	sh, qtz ss	ltywgy	m	w	r					N	CL
45.0–47.5	qtz ss	vlt tn	m	w	r					N	
47.5–50.0	qtz ss	vlt tn	f	w	r					N	
50.0–52.5	qtz ss	vlttn	m-c	m	r					N	
52.5–55.0	qtz ss	lttn	m-vc	f	r		L			N	
55.0–57.5	qtz ss	lttn	m	w	r					N	
57.5–60.0	qtz ss	lttn	f-c	f	r					N	
60.0–62.5	qtz ss	ltpktn	m	w	R					N	
62.5–65.0	qtz ss	vltgy	f-m	f	r					N	
65.0–67.5	qtz ss	vltgy	m	w	R					N	
67.5–70.0	qtz ss	vltgy	m	w	r					N	
70.0–72.5	qtz ss	vltgy	f	w	r					N	
72.5–75.0	qtz ss	vltgy	f	w	r					N	
75.0–77.5	qtz ss	tn	m-vc	m	r					N	chert frag + grains
77.5–80.0	qtz ss	ltgytn	m	w	R					N	
80.0–82.5	qtz ss	ltgytn	m-c	m	r					N	mositure ist noticed @ 80.0'
82.5–85.0	qtz ss	ltgytn	m-c	m	r					N	
85.0–87.5	qtz ss	ltgytn	m-peb	p	a					N	chert pebbles + frags.
87.5–90.0	qtz ss	tn	m-peb	p	a					N	" " "
90.0–92.5	qtz ss	tn	c-peb	p	a					N	" " "
92.5–95.0	qtz ss	ltgytn	c-peb	p	a			tr	C	VS	
95.0–97.5	sh	ppbn-gn								N	Brushy Basin Ct @ 95.0' good contact
97.5–100.0	sh	ppbn-gn								N	T.D.

PERCENTAGE COMPOSITION IMAGE



Date 27 APR 2011 Geologist L. CASEROLT Drilling Co. BAYLES EXPLORATION CO. Hole No. DR7

Property WHITE MESA MILL Project CELL 4B Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County SAN JUAN State UTAH Location ______ Elev. 5594

PAGE 1 OF 1

T.D. PROBE ______

T.D. DRILL 100.0

FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React. 10% HCL	Carbon Amount	Carbon Type	Remarks
0–2.5	mdst	rdbn											N			Surface soil-unconsolidated CH
2.5–5.0	mdst	rdbn											W			Surface soil - unconsolidated CH
5.0–7.5	qtz ss	orbn	m-c	m	a		L						VS			Upper Dakota Ct @ 6.0'
7.5–10.0	qtz ss	ortn	m-c	m	A								N			
10.0–12.5	qtz ss	lt bn	m	w	a								N			
12.5–15.0	qtz ss	lt bn	m	w	a								N			
15.0–17.5	qtz ss	ortn	m-c	m	a								N			
17.5–20.0	qtz ss	tn	m	w	a								N			
20.0–22.5	qtz ss	tn	m	w	r								N			
22.5–25.0	qtz ss	lt bn	m-c	m	r								N			Some chert frags.
25.0–27.5	qtz ss	tn	m	w	r								N			
27.5–30.0	qtz ss	ltgytn	f-m	m	r								N			
30.0–32.5	qtz ss, sh	ltgytn	m	w	r								N			
32.5–35.0	qtz ss	ltgybn	m-c	m	r								N			
35.0–37.5	qtz ss	vltgytn	f	w	R								N			
37.5–40.0	qtz ss, cgl	ltgytn	m-peb	f	r								N			
40.0–42.5	sh, qtz ss	lt ywgy	vf-f	m	r		L						N			CH
42.5–45.0	qtz ss	lt tn	f-m	m	r		L						N			
45.0–47.5	qtz ss	ltpktn	m-c	f	R								N			
47.5–50.0	qtz ss	ltpktn	m-c	f	R								N			
50.0–52.5	qtz ss	ltpktn	m-peb	f	a								N			some multi colored chert grains
52.5–55.0	qtz ss	vltpktn	m	w	R								N			
55.0–57.5	qtz ss	vltpktn	f-m	m	r								N			
57.5–60.0	qtz ss	ltpktn	m-peb	f	a								N			
60.0–62.5	qtz ss	ltgytn	m	w	a								N			
62.5–65.0	qtz ss	ltgytn	m-c	m	a								N			
65.0–67.5	qtz ss	bn	c-vc	m	a								N			abund. chert frags
67.5–70.0	qtz ss	ltgybn	m-vc	m	a								N			
70.0–72.5	qtz ss, cgl	bn	c-peb	m	a								N			
72.5–75.0	qtz ss	gytn	m-c	m	r								N			
75.0–77.5	qtz ss	ltgytn	m	w	r								N			moisture first noted, some chert grains
77.5–80.0	qtz ss	ortn	m-c	m	r								N			
80.0–82.5	qtz ss	orpktn	m	w	R								N			
82.5–85.0	qtz ss	tn	m	w	R								N			
85.0–87.5	qtz ss	lt tn	m	w	R								N			
87.5–90.0	qtz ss	gytn	m	w	R								N			
90.0–92.5	qtz ss	gytn	m-c	m	r								VW			
92.5–95.0	qtz ss, sh, cgl	wh, lt blgn	m-peb	m	r								W			Brushy Basin Fm Ct @ 93.0' chert pebbles.
95.0–97.5	sh	pprdbn-gn											N			mottled frags.
97.5–100.0	sh, qtz ss	gn-vltgy	vf-c	p	r			Tr	A				N			T.D.

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 5 May 2011 Geologist L. Casebolt Drilling Co. Boyles Exploration Inc. Hole No. DR8

Property White Mesa Mill Project Cell 4B Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ≈5537

PAGE 1 OF 1

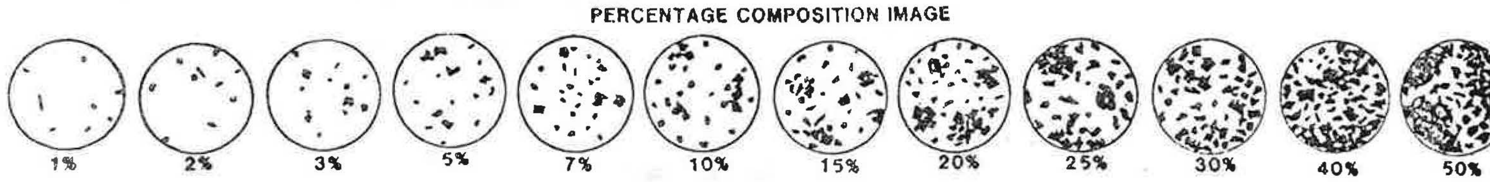
T.D. PROBE ____

T.D. DRILL 70.0

FLUID LEVEL ____

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite: Amount	Pyrite: Habit	Pyrite: Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon: Amount	Carbon: Type	Remarks
0–2.5	Sh, qtz ss	ltywgy	vf	w	r								VS			Mancos Shale - soil was removed during site prep CL
2.5–5.0	sh - qtz ss	ltywgy	vf	w	r								S			upper Dakota Fm Ct @ 4.0' ML
5.0–7.5	qtz ss	tn	f-m	m	a		L						N			
7.5–10.0	qtz ss	tn	f-m	m	a								N			
10.0–12.5	qtz ss	tn	m	w	a								N			
12.5–15.0	qtz ss	tn	m c	m	a								N			
15.0–17.5	qtz ss	pktn	m-c	f	r								N			
17.5–20.0	qtz ss	tn	f-m	f	r								N			
20.0–22.5	sh, qtz ss	ltywgn	f-m	f	r								N			CL
22.5–25.0	qtz ss, sh	ltywgy	f-m	f	r								N			ML
25.0–27.5	qtz ss, sltst	lttn	vf-m	f	r		L						N			
27.5–30.0	qtz ss, sh	lttn	vf-m	f	r		L						N			
30.0–32.5	qtz ss, sh	lttn- ltywgn	m	w	r								N			very hard drilling
32.5–35.0	qtz ss	ltgytn	m-c	m	R		L						N			some dkgy chert grains
35.0–37.5	qtz ss, qtzite	ltgytn	m-vc	f	a								N			abund " " "
37.5–40.0	qtz ss, qtzite	wh	m-vc	f	a								N			very hard drilling
40.0–42.5	qtz ss, qtzite	wh	m-vc	f	a								N			extremely hard drilling
42.5–45.0	qtz ss, qtzite	wh	m-vc	f	a								N			" " "
45.0–47.5	qtz ss, qtzite	wh	m-peb	p	a								N			" " "
47.5–50.0	qtz ss, qtzite	wh-vlttn	m-vc	p	a								N			" " "
50.0–52.5	qtz ss, qtzite	wh-or-dkgy	m peb	p	A								N			" " "
52.5–55.0	sh	ltgybl											N			
55.0–57.5	qtz ss, qtzite	ltgytn	f-m	m	r								W			
57.5–60.0	sh	gygn-pprdbn											N			Brushy Basin Ct @ 57.5' cutting are mottled.
60.0–62.5	sh	gn-pprdbn											N			tale tell rd chert grains
62.5–65.0	sh	gn											N			
65.0–67.5	sh	gn						Tr	A				N			
67.5–70.0	sh	gn											N			TD.

PERCENTAGE COMPOSITION IMAGE



Date 4 May 2011 Geologist L. Casebolt Drilling Co. Boyles Exploration Inc. Hole No. DR9

Property White Mesa Mill Project Cell 4B Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ≈ 5562

PAGE 1 OF 1

T.D. PROBE ____

T.D. DRILL 115.0

FLUID LEVEL ____

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						mdst	rdbn. ltpk											W			Surface soil to 2.0', Mancos Shale to 2.5 CL
5.0						qtz ss, sh	rdbn	f-m	m	r								S			Unconsolidated ML
7.5						qtz ss, sh	rdbn	f	w	r								N			" ML
10.0						qtz ss, sh	rdbn	vf-f	m	r								W			
12.5						qtz ss	rdbn	m	w	r								VS			
15.0						sh, qtz ss	dkgybn	f-m	m	a		L						VS			Upper Dakota Fm Ct @ 14.0'
17.5						qtz ss	tn	m	w	a		L						N			
20.0						qtz ss	tn	m	w	a								N			
22.5						qtz ss	tn	f-m	m	a								N			
25.0						qtz ss	tn	m	w	a								N			
27.5						qtz ss	tn	f	w	r								N			
30.0						qtz ss	tn	m	w	r								N			
32.5						qtz ss	tn	m	w	a								N			
35.0						qtz ss	tn	m	w	a								N			
37.5						qtz ss	tn	m	w	a								N			
40.0						qtz ss	tn	m-c	m	a								N			
42.5						qtz ss	tn	m	w	r								N			
45.0						qtz ss	tn	f	w	r								W			
47.5						qtz ss	orgy	c-vc	p	a								N			abund chert frags
50.0						qtz ss	orgy	c-vc	p	a		L						W			" " "
52.5						qtz ss	tn	m-c	m	a								N			
55.0						qtz ss	tn	m-c	m	a								N			
57.5						sh	ywgy											N			
60.0						qtz ss, sh	ywgy	f	w	r								N			
62.5						qtz ss, sh	gy	f-m	m	r								N			
65.0						qtz ss, sh	gy	f	w	r								N			
67.5						qtz ss, sh	gy	f	w	r								N			
70.0						qtz ss, sh	gy	vf-f	m	r			tr	A				N			
72.5						qtz ss	gy	vf-f	m	r			tr	A				N			
75.0						qtz ss	wh	vf-f	m	r								N			
77.5						qtz ss	lt tn	m	w	r								N			
80.0						qtz ss	lt tn	m	w	a								N			
82.5						qtz ss	lt tn	m	w	a								N			
85.0						qtz ss	ltgytn	m	w	R								N			moisture first noted @ 85.0'
87.5						qtz ss, sh	ltgytn	m	w	R								N			
90.0						qtz ss	lt tn	m-c	m	r								N			
92.5						qtz ss	lt tn	m	w	r								S			
95.0						qtz ss	lt tn	m	w	r								N			
97.5						qtz ss	lt tn	m	w	R								N			
100.0						qtz ss, sh	ltywgy	m	w	R								N			
102.5						qtz ss	wh	m	w	r								N			
105.0						qtz ss, cgl	wh-dkgy	c-peb	p	a			1%	C				N			
107.5						qtz ss, cgl	wh-dkgy	c-peb	p	a			1%	C				VW			
110.0						qtz ss, cgl	dkgy-gn	c-peb	p	a								N			
112.5						sh	gn											N			Brushy Basin Ct @ 110.0
115.0						sh	gn											N			T.D.
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 4 May 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Inc. Hole No. DR 10

Property White Mesa Mill Project cell 4B Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ≈5559

PAGE 1 OF 1

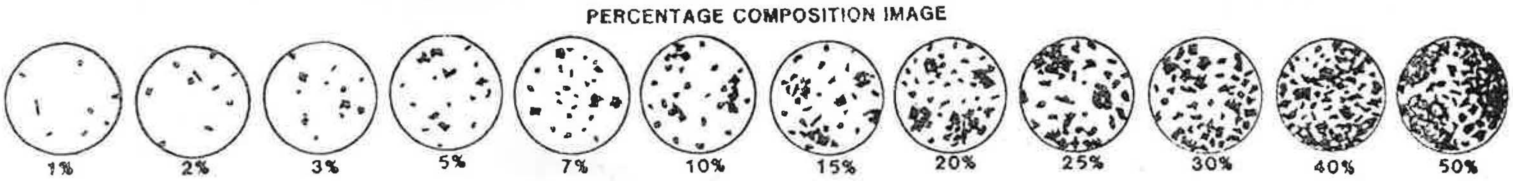
T.D. PROBE ______

T.D. DRILL 90.0

FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						mdst	rdbn											W			Surface Soil . Unconsolidated CH
5.0						mdst	rdbn											W			Surface Soil " CH
7.5						qtz ss	tn	m	w	a		L						N			Upper Dakota Fm Ct @ 5.0'
10.0						qtz ss	tn	m	w	a		L						N			
12.5						qtz ss	tn	f	w	a								N			
15.0						qtz ss	tn	m	w	a								N			
17.5						qtz ss	tn	m-c	m	a								N			some chert frags and grains
20.0						qtz ss	tn	f-m	m	r								N			
22.5						qtz ss	tn	f-m	m	r								N			
25.0						qtz ss, sh	ltywgy	f-m	m	r								N			sandy lean clay CL
27.5						qtz ss, sh	ltgy	f-m	m	r		L						N			" " , CL some chert pebbles.
30.0						qtz ss, cgl sh	dkywgy	f-peb	m	r								N			sandy lean clay CL " " "
32.5						qtz ss, cgl	ywgy	vf-peb	m	r								N			
35.0						qtz ss, sh	ywgy	vf-c	m	r								N			Lean clay CL, some chert grains
37.5						qtz ss	ywtn	f	w	r								N			
40.0						qtz ss	ywtn	f	w	r								N			
42.5						qtz ss	pktn	f	w	r								N			
45.0						qtz ss	ywgy-tn	f-m	m	r		L						N			
47.5						qtz ss	tn	f	w	r		L						N			
50.0						qtz ss	tn	m	w	r								N			
52.5						qtz ss	tn	M	w	r								N			
55.0						qtz ss	ltbn	m-peb	m	r		H						N			abund chert grains
57.5						qtz ss	tn	m	w	R								N			
60.0						qtz ss	tn	m	w	R								N			
62.5						qtz ss	tn	m-c	m	a								N			
65.0						qtz ss	ltortn	m-c	m	a		L						N			
67.5						qtz ss	vltgy	m-c	m	r								N			very hard drilling!
70.0						qtz ss, cgl	ltgybn	m-peb	p	a								N			very abund chert frags + grains
72.5						qtzite, cgl	gytn	m-peb	p	a								N			" " "
75.0						qtzite, cgl	gytn	m-vc	p	a								N			
77.5						qtzite	gytn-wh	m-vc	p	a								N			very abund chert frags + grains
80.0						qtzite	gytn-wh	m-vc	p	a								N			
82.5						sltst, sh	gn											N			Brushy Basin Ct @ 80.0'
85.0						sltst, sh	gn											N			
87.5						sh	gn											N			
90.0						sh	gn											N			T.D.
92.5																					
95.0																					
97.5																					
100.0																					
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



Date 6 May 2011 Geologist L. Casebolt Drilling Co. Boyles Exploration Inc. Hole No. DR 11

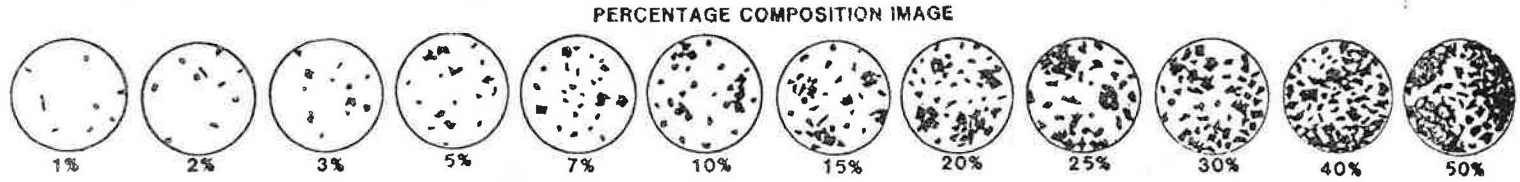
Property White Mesa Mill Project cell 4B Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ≈5582

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 115.0
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5						mdst	rdbn											W			Surface Soil (unconsolidated)
5.0						mdst, sh	rdbn, ltpk											VS			Surface soil (unconsolidated, Mancos Shale @ 4.0'
7.5						sndy sh	rdbn	m	f	r								VS			
10.0						sh, qtz ss	rd bn - lt pk	m	m	r								VS			
12.5						sh, qtz ss	ltpk - vlt tn	m	m	r								VS			Upper Dakota Fm Ct. @ 12.0'
15.0						qtz ss	ltgybn	m-c	m	r								S			
17.5						qtz ss	lt yw	m-vc	f	a	L							N			abund. lt colored chert frags.
20.0						qtz ss	ltgytn	m-c	f	r								N			
22.5						qtz ss	ltgytn	m	w	r								N			
25.0						qtz ss	ltgytn	f-m	w	r								N			
27.5						qtz ss	ltgytn	m	w	R								N			
30.0						qtz ss	ltgytn	c	w	r								N			
32.5						qtz ss	lttn	f	w	r								N			
35.0						qtz ss	lt tn	f-c	p	a								N			some dk chert grains.
37.5						qtz ss	gytn	m-c	m	r								N			abund. dk chert grains
40.0						qtz ss	lt tn	m	w	R								N			
42.5						qtz ss	lt tn	m-c	m	a								N			
45.0						qtz ss	lt tn	m	w	R								N			
47.5						qtz ss	ltgytn	c	w	R								N			
50.0						qtz ss, sh	tn-ltgn	c-peb	p	A								N			multi colored chert frag & grit
52.5						qtz ss	tn	m-vc	m	r								N			" " " " "
55.0						qtz ss	tn	m-c	m	r								N			
57.5						qtz ss, sltst	lt blgy	m-peb	f	a								N			chert pebble frags.
60.0						sltst, qtz ss	lt blgy	f-vc	p	a								N			
62.5						sltst, qtz ss	lt blgy	f-vc	p	a								N			
65.0						qtz ss, sltst	lt blgy - lt tn	m-c	m	a								N			
67.5						qtz ss	tn	m-c	m	a								S			
70.0						qtz ss, cgl	tn bn	m-peb	p	a								M			multi colored chert frags.
72.5						qtz ss, cgl	tn bn	c-peb	p	a								N			
75.0						qtz ss	ltgytn	m-c	m	a								N			
77.5						qtz ss	ltgy tn	m-vc	f	a								N			
80.0						qtz ss	ltgytn	f-m	w	r								N			moisture first noted @ 80.0
82.5						qtz ss	ltgy tn	m-c	w	r								N			
85.0						qtz ss	ltgytn	m	w	R								N			
87.5						qtz ss	ltgytn	f-m	m	r								N			
90.0						qtz ss	ltgytn	f-m	m	r								N			
92.5						qtz ss	gytn	m-peb	f	r								N			
95.0						qtz ss	gytn	c-peb	m	r								N			
97.5						qtz ss, cgl	gytn	c-peb	m	r								N			
100.0						qtz ss, cgl	gytn	m-c	m	r								N			very hard drilling
102.5						qtz ss, cgl	tn bn	m-peb	p	a								N			" " " abund. dkgy chert frags.
105.0						qtz ss, cgl	tn bn	m-peb	p	a			tr					N			" " " gy chert frags.
107.5						qtz ss, sh	wh-gygn	f-peb	p	a								N			Brushy Basin Ct. @ 106.0' good contact chert frags.
110.0						sh	gygn						<1%	A/C				N			some masses of sulfide (pyrite?)
112.5						sh	gygn											N			
115.0						sh	gygn-ppbn											N			T.D. mottled cuttings
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



Date 28 APR 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. DR12

Property White Mesa Mill Project Cell 4B Unit No. ______ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ______ Elev. ≈5584

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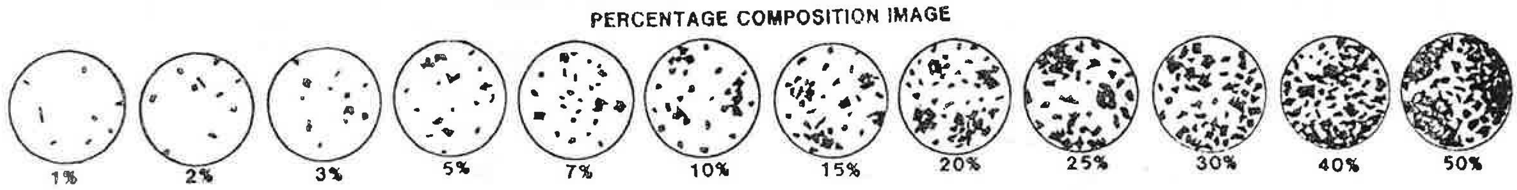
T.D. PROBE ______

T.D. DRILL 100.0

FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						mdst	rdbn											W			Surface Soil unconsolidated fat clay w/sand CH
5.0						mdst	rdbn											VW			Surface Soil " " " " CH
7.5						sh	ltpktn											VS			Manco: Shale Fm. consolidated. Lean clay w/ sand CL
10.0						sh	ltpktn											VS			" "
12.5						sh	ltpktn											S			" "
15.0						qtz ss, sh	lt bn	m	w	r		L						N			Upper Dakota Ct @ 12.5'
17.5						qtz ss	tn	m	w	r		L						N			
20.0						qtz ss	lt or-tn	m	w	r		L						N			
22.5						qtz ss	tn	m	w	a								N			
25.0						qtz ss	tn	m	w	a								N			
27.5						qtz ss	ltgytn	m	w	r								N			some chert grains
30.0						qtz ss	tn	m-c	m	r								N			" " "
32.5						qtz ss	tn	m-c	m	r								N			
35.0						qtz ss	tn	m-c	m	r								N			
37.5						qtz ss	lt ortn	m	w	R		L						N			
40.0						qtz ss	tn	m	w	R								N			
42.5						qtz ss	tn	m-peb	f	a								N			some chert grains
45.0						qtz ss	lt bn	f-peb	p	a								N			" " "
47.5						qtz ss, sh, Cgl	tn-gn	f-peb	p	a								N			" " "
50.0						qtz ss, sh, Cgl	gn-tn	m-peb	p	A								N			" " "
52.5						qtz ss, sh	gn-tn	m-peb	p	a								N			abund. chert frags, grains
55.0						qtz ss	tn	m-peb	p	a		L						N			" " " "
57.5						qtz ss	tn	f-c	p	a		L						N			
60.0						qtz ss	tn	f-c	p	a								N			
62.5						qtz ss	ltgytn	m	w	r								N			
65.0						qtz ss	ltgytn	m	w	r								N			
67.5						qtz ss	ltgytn	m	w	r								N			
70.0						qtz ss	tn	m	w	r								N			
72.5						qtz ss	ltgytn	m	w	r								N			
75.0						qtz ss	lt bn	m	w	a								N			
77.5						qtz ss	ltgytn	m	w	a								N			
80.0						qtz ss	tn	f-m	m	r								N			
82.5						qtz ss	tn	m	w	a								N			
85.0						qtz ss	tn	m-c	m	a			tr	C				N			
87.5						qtz ss, sh	gn-tn	f-c	m	a			tr	C				N			
90.0						qtz ss, sh	wh-ltgn	f-m	m	r			tr	C				N			
92.5						qtz ss, sh	wh-ltgn	f-m	m	r								N			Brushy Basin Ct @ 92.0 ft.
95.0						sh	gn, rdbn											N			
97.5						qtz ss, sh	wh-gn	f-m	m	R								N			
100.0						sh	gn-rdbn											N			T.D. Mottled Frags.
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



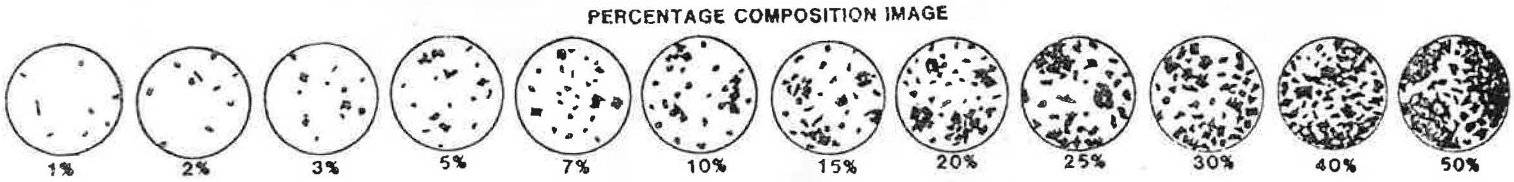
Changed PB Ct. from 82

Date 27 APR 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. DR13
Property White Mesa Mill Project Cell 4B Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. 5575

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 90.0
FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																					
2.5						mdst	rdbn											W			Surface Soil - unconsolidated - lean clay w/sand CL
5.0						mdst	rdbn											S			Surface Soil - unconsolidated - lean clay w/sand CL
7.5						qtz ss	ortn	m-peb	p	A								N			Upper Dakota Ct @ 5.0' abund. chert frags, pebbles,
10.0						qtz ss, cgl	gyortn	m-peb	p	A								N			abundant chert frags & pebbles.
12.5						qtz ss	ortn	m-peb	p	r		L						N			" " " "
15.0						qtz ss, sh	ltgytn	m-peb	p	a								N			Some chert frag & pebbles sandy fat clay CH
17.5						qtz ss, sh	ltgygntn	m-peb	p	a								N			" " " "
20.0						qtz ss, cgl	ltgytn-rd	m-peb	p	a								N			" " " "
22.5						qtz ss	lt tn	m-c	m	a								N			
25.0						qtz ss, sh	lt tn-ltgn	m-vc	f	a								N			
27.5						qtz ss, sh	lttn-ltgygn	m-peb	p	a								N			
30.0						qtz ss	tn	m	w	r								N			
32.5						qtz ss	tn	m	w	a								N			
35.0						qtz ss	lt bn	m-peb	p	a								N			
37.5						qtz ss, cgl	dk bn	m-peb	p	a								W			
40.0						qtz ss	tn	m	w	R								N			
42.5						qtz s	tn	m-peb	p	r								N			
45.0						qtz ss	tn	f-peb	p	a								N			
47.5						qtz ss	tn	m	w	r								N			
50.0						qtz ss	tn	m	w	r								N			
52.5						qtz ss	vlttn	m	w	r								N			
55.0						qtz ss	vlttn	m	w	r								N			
57.5						qtz ss	lt tn	m	w	r								N			
60.0						qtz ss, cgl	gytn	m-peb	p	a		L						N			abund multi colored chert frags & grains
62.5						qtz ss, cgl	ltgytn	m-peb	p	a		L						N			" " " " " "
65.0						qtz ss	lt tn	m	w	r								VS			
67.5						sh, qtz ss	lt blgy	m-peb	p	a								VW			
70.0						qtz ss, sh	wh-blgy	vf-m	f	r								N			
72.5						qtz ss	wh-ltgy	f	w	r								N			
75.0						qtz ss	wh-ltgy	f	w	r								N			
77.5						qtz ss	wh-ltblgn	f	w	r								N			
80.0						qtz ss	wh-ltblgn	f	w	r								N			sparse chert pebble frags.
82.5						sh	gy-rdbn											N			Brushy Basin Fm Ct @ 80.0'
85.0						sh	blgy-rdbn											N			
87.5						sh	blgy-rdbn											N			
90.0						sh	pprdbn-gn											N			TD
92.5																					
95.0																					
97.5																					
100.0																					
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



Date 29 APR 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. DR14

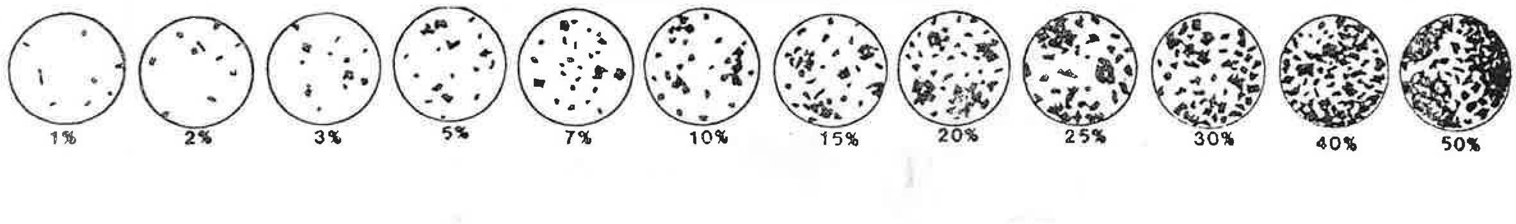
Property White Mesa Mill Project CELL 4B Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ≈ 5546

PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 100.0
FLUID LEVEL ____

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0–2.5						mdst	rdbn											N			Surface Soil.
2.5–5.0						mdst	rdbn											VS			Mancos Shale
5.0–7.5						qtz ss	tn	m	w	a								W			Upper Dakota Fm Ct. @ 5.0'
7.5–10.0						qtz ss	tn	m	w	a								N			
10.0–12.5						qtz ss	lt tn	m	w	a								N			
12.5–15.0						qtz ss	wh-lt tn	m	w	a		L						N			
15.0–17.5						qtz ss	wh-lt tn	m-c	m	a								N			some chert grains
17.5–20.0						qtz ss	tn	f-c	f	a								N			
20.0–22.5						qtz ss, cgl, sh	lt gy	m-peb	f	a								N			abund. dk gy chert frags.
22.5–25.0						qtz ss	tn	m	w	r								N			
25.0–27.5						qtz ss	tn	m-c	m	r								N			
27.5–30.0						qtz ss	tn	m-c	m	r								N			
30.0–32.5						qtz ss	tn	m	w	r								N			
32.5–35.0						qtz ss	tn	f-m	m	r		H						N			
35.0–37.5						qtz ss	tn	m	w	a								N			
37.5–40.0						qtz ss	lt or tn	m	w	r								N			
40.0–42.5						qtz ss	gy tn	m-peb	m	r								N			
42.5–45.0						qtz ss, sh	lt gy tn	f-m	m	r								N			
45.0–47.5						qtz ss	lt gy tn	f-m	m	r			1%	A				N			
47.5–50.0						qtz ss	lt or tn	f	w	r								N			
50.0–52.5						qtz ss sltst	lt gy tn	f-m	m	a								N			
52.5–55.0						qtz ss	lt pk tn	m	w	r		H						N			
55.0–57.5						qtz ss	tn	m	w	r								N			
57.5–60.0						qtz ss	tn	m c	m	r								N			
60.0–62.5						qtz ss	dk gy tn	c-vc	m	a								N			
62.5–65.0						qtz ss	lt gy tn	m	w	a								N			
65.0–67.5						qtz ss	lt gy tn	m	w	r								N			
67.5–70.0						qtz ss	lt tn	m-c	m	r								N			
70.0–72.5						qtz ss	lt tn	m-c	m	r								N			
72.5–75.0						qtz ss	lt tn	m	w	r								N			
75.0–77.5						qtz ss	lt tn	m	w	r								N			
77.5–80.0						qtz ss	lt gy tn	m-c	m	r								N			
80.0–82.5						qtz ss	lt gy bn	m-peb	m	r								N			
82.5–85.0						qtz ss	gy tn	f-m	m	r		L						N			
85.0–87.5						qtz ss	tn	f-m	m	r		L						N			
87.5–90.0						qtz ss	tn	f-m	m	a								N			
90.0–92.5						qtz ss	tn	m	w	r								N			
92.5–95.0						qtz ss, sh	wh-tn, gn	m	w	r		L	tr	c				N			Brushy Basin Fm Ct @ 94.0' good ct.
95.0–97.5						sh	pp bn											N			
97.5–100.0						sh	pp bn-gn											N			T.D.

PERCENTAGE COMPOSITION IMAGE



Date 28 APR 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. DR15

Property White Mesa Mill Project Cell 4B Unit No. ______ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ______ Elev. ≈5571

PAGE 1 OF 1

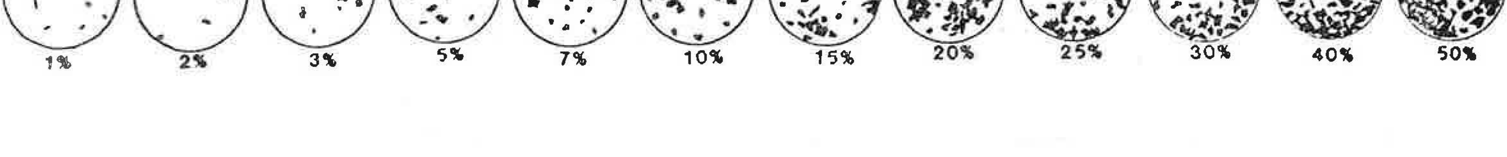
T.D. PROBE ______

T.D. DRILL 100.0 T.D

FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						mdst	rdbn											S			Surface Soil - unconsolidated - sandy lean clay CL
5.0						mdst	rdbn											S			Surface Soil - unconsolidated " " " CL
7.5						sh	ltpktn											VS			mancos sh sandy fat clay CH
10.0						sndy sh	ywgy	f-m	f	a								S			mancos sh
12.5						qtzss, sh	vltbn	f	w	r								W			Upper Dakota Ct. @ 11.0'
15.0						qtz ss	ltywbn	vf-f	m	r								N			
17.5						qtzss	ltywbn	f-m	m	r		L						N			
20.0						qtzss	gytn	f	w	r								N			
22.5						qtzss	ltywbn	f	w	r		L						N			
25.0						qtzss	lttn	m	w	r								N			
27.5						qtzss	tn	m	w	r								N			
30.0						qtz ss	tn	m-c	m	r								N			some chert frags. and grains
32.5						qtzss	ltortn	f-m	m	r		L						N			
35.0						qtz ss	tn	f	w	r								N			
37.5						qtzss	tn	m	w	a								N			
40.0						qtz ss	tn	m-c	m	a								N			
42.5						qtz ss	tn	m-c	m	r								N			
45.0						qtz ss	tn	m-c	m	r								N			
47.5						qtz ss	tn	m-c	m	r								N			some chert frags and grains
50.0						qtz ss, sh	ltbn, gn	m-peb	m	r								N			some gn shale frags.
52.5						sh	ywgygn											N			
55.0						sh, qtzss, cgl	ltgygn	m-peb	p	a								N			abund chert frags and grains.
57.5						qtz ss	tn	m-vc	p	a								N			" " " " "
60.0						qtz ss	tn	m	w	r								N			
62.5						qtz ss	tn	m	w	R		L						N			
65.0						qtz ss	ltortn	m	w	R		L						N			
67.5						qtz ss	ltortn	m-vc	m	r		L						N			abund chert frags and grains
70.0						qtz ss, cgl	dkgyortn	m-peb	f	r								N			50% chert frags, grains, and pebbles.
72.5						qtz ss	lttn	m-vc	f	a								N			some " " "
75.0						qtz ss	vlttn	m	w	r								N			
77.5						qtz ss	ltgytn	m-peb	m	a								N			10% chert frags, grains.
80.0						qtz ss, cgl	gy-dkgy	m-peb	m	a								N			50% chert frags, grains and pebbles.
82.5						qtz ss	tn	m	w	R								N			
85.0						qtz ss	tn-gy	m-peb	f	a								N			some chert
87.5						qtz ss, cgl	gy	m-peb	f	a								N			60% chert frags, grains and pebbles.
90.0						qtz ss, cgl	gy	m-peb	f	a								N			note: some material is a qtzite - hard drilling!
92.5						qtz ss	ltpktn	m	w	r								N			qtzite - hard drilling.
95.0						qtz ss	lttn-wh	m	w	r								N			
97.5						qtz ss, sh, cgl	gn-wh	m-peb	p	a			Tr.	C				N			Brushy Basin Ct @ 96.0 pyrite assoc. w/qtz.
100.0						sh,	gn											N			T.D
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



Date 28 APR 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. DR16

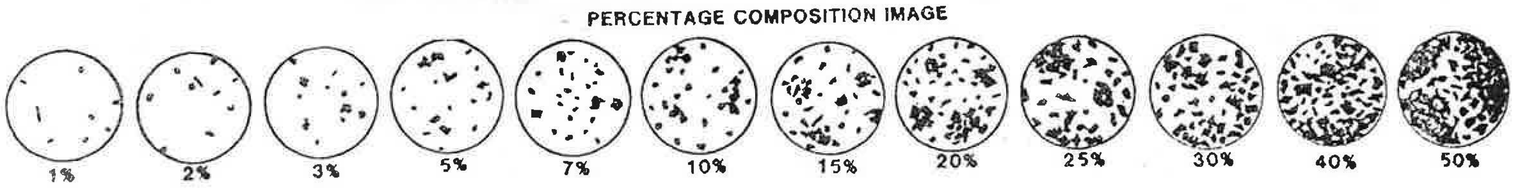
Property White Mesa Mill Project Cell 4B Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ≈ 5555

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 105.0
FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0–2.5						mdst	rdbn											W			Surface Soil-unconsolidated-sandy lean clay CL
2.5–5.0						mdst	rdbn											W			Surface Soil-unconsolidated-sandy lean clay CL
5.0–7.5						mdst, lmy sh	rdbn-pktn											VS			Manco Shale @ 6.0 ft.
7.5–10.0						lmy sh-qtz ss	pktn-wh	m	w	r								VS			Mancos Shale ss is qtzitic
10.0–12.5						qtz ss	ortn	m	w	r		V						S			Upper Dakota Fm Ct @ 9.5'
12.5–15.0						qtz ss	tn	m	w	R								N			
15.0–17.5						qtz ss	tn	f-m	m	r								N			
17.5–20.0						qtz ss	tn	f-m	m	r								N			
20.0–22.5						qtz ss	tn	f	w	r								N			
22.5–25.0						qtz ss	tn	m	w	R								N			
25.0–27.5						qtz ss	tn	vf-f	m	R								N			
27.5–30.0						qtz ss	tn	m	w	R								N			
30.0–32.5						qtz ss	tn	m	w	R								N			
32.5–35.0						qtz ss	tn	vf	w	R								N			
35.0–37.5						qtz ss	ltgytn	m-c	m	a								N			
37.5–40.0						qtz ss	tn	m	w	a								N			
40.0–42.5						qtz ss	tn	m	w	a								N			
42.5–45.0						qtz ss	tn	m-pel	p	a								N			
45.0–47.5						sh-qtz ss	[illegible]	m-vc	p	a								N			
47.5–50.0						qtz ss, sh	ywgy-tn	m-pel	p	a								N			abund, multi colored chert frags, grains & pebbles
50.0–52.5						qtz ss	gytn	m-[illegible]	p	a								N			" " " " " " "
52.5–55.0						qtz ss	ltortn	m-c	m	a		L						N			
55.0–57.5						qtz ss	ltortn	m-c	m	a		L						N			
57.5–60.0						qtz ss	tn	m	w	r								N			
60.0–62.5						qtz ss	tn	m	w	r								N			
62.5–65.0						qtz ss, sh	ltgytn	m c	m	a								N			
65.0–67.5						qtz ss	ltgytn	m c	m	r								N			
67.5–70.0						qtz ss	tn	f-m	m	r								N			
70.0–72.5						qtz ss	tn	m-vc	p	a								N			chert grains
72.5–75.0						qtz ss	ltortn	m-c	m	r								N			
75.0–77.5						qtz ss, cgl	ltbn	m-[illegible]	p	a								N			50% chert grains [illegible]
77.5–80.0						qtz ss	ltgytn	m-vc	p	a								N			
80.0–82.5						qtz ss	ltgytn	m-vc	p	a								N			
82.5–85.0						qtz ss	ltgytn	m-vc	p	a								N			
85.0–87.5						qtz ss, cgl	gybn	m-[illegible]	p	a								N			50%+ chert grains, fragments & grains
87.5–90.0						qtz ss	tn	m	w	r								N			
90.0–92.5						qtz ss, cgl	gybn	m-pel	p	a								N			50%+ chert grains, frags. & grains
92.5–95.0						qtz ss, cgl	gybn	m-pel	p	a								N			75% chert grains, frags & grains
95.0–97.5						qtz ss	tn	m	w	r								N			
97.5–100.0						qtz ss	tn-gn	m-c	m	a			tr	C				W			Brushy Basin Ct @ 100.0, pyrite assoc. w/qtz
100.0–102.5						sh	gn-vltgn											N			
102.5–105.0						sh	gn-[illegible]											N			telltale small red chert grains T.D.
105.0–107.5																					
107.5–110.0																					
110.0–112.5																					
112.5–115.0																					
115.0–117.5																					
117.5–120.0																					
120.0–122.5																					
122.5–125.0																					

PERCENTAGE COMPOSITION IMAGE

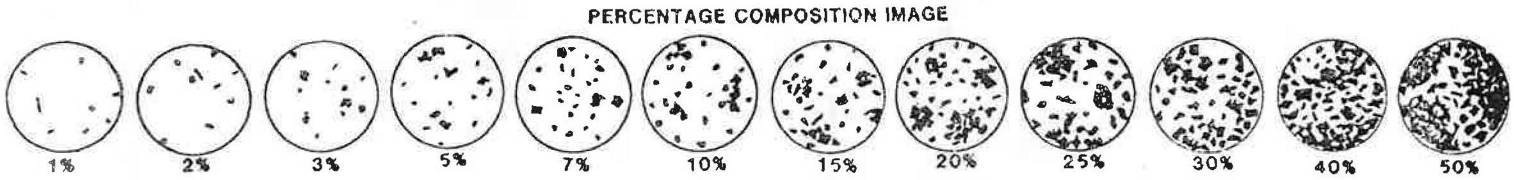


Date 29 APR 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. DR17
Property White Mesa Mill Project CELL 4B Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 85.0
FLUID LEVEL ____

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0–2.5						mdst	rdbn											N			Surface Soil - unconsolidated - lean sandy clay CL
2.5–5.0						mdst	rdbn											W			Surface Soil - unconsolidated - lean sandy clay CL
5.0–7.5						qtz ss	ortn	m	w	r		L						N			Upper Dakota Fm Ct @ 5.0'
7.5–10.0						qtz ss	tn	m-c	m	r								N			
10.0–12.5						qtz ss	tn	m	w	r								N			
12.5–15.0						qtz ss	ltgytn	m	w	R								N			
15.0–17.5						qtz ss	ltgytn	m-c	m	r								N			Some dk chert frags.
17.5–20.0						qtz ss	ltgytn	f-c	f	a								N			
20.0–22.5						qtz ss	tn	m	w	a								N			
22.5–25.0						qtz ss	tn	m-c	m	a								N			
25.0–27.5						qtz ss, sh	vlttn	f-vc	p	a								N			
27.5–30.0						cgl, qtz ss	tn-dkgybn	m-peb	p	a								N			dkgy chert pebbles + frags, 75%
30.0–32.5						sh, qtz ss	ltgygntn	m-vc	f	a								N			
32.5–35.0						sndy sltst	ltortn	vf-m	f	a								N			
35.0–37.5						sndy sh	ltgytn	vf-m	p	a								N			
37.5–40.0						sndy sh	ltgytn	vf-f	f	a								N			
40.0–42.5						sndy sh, ss	ltgy-ltortn	vf-f	f	a								N			
42.5–45.0						qtz ss	tn	m-c	m	r								N			
45.0–47.5						qtz ss	vltgy	vf-f	m	r								N			
47.5–50.0						qtz ss, sltst	vltgy	vf-m	f	r								N			
50.0–52.5						qtz ss	tn	f-c	f	a								N			
52.5–55.0						qtz ss	tn	f-m	m	a								N			
55.0–57.5						qtz ss	lttn	m-peb	p	a								N			Some light colored chert frags. and pebbles
57.5–60.0						qtz ss, cgl	ltgytn	m-peb	p	a								N			" " " " " " "
60.0–62.5						qtz ss	ltgytn	m-vc	p	a								N			
62.5–65.0						qtz ss	ltgytn	f-m	m	a								N			
65.0–67.5						qtz ss	tn	f-m	w	r								N			
67.5–70.0						qtz ss	tn	f-m	w	r								W			Brushy Basin Ct @ 70.0'
70.0–72.5						sh cgl	gn	peb										N			some dk chert pebbles.
72.5–75.0						sh cgl	gn	peb										N			" " " " tell tale red chert frags.
75.0–77.5						sh	gn											N			
77.5–80.0						sh	gn											N			red chert frags.
80.0–82.5						sh	gn-ltgy											N			
82.5–85.0						sh	gn						tr	A				N			T.D. red chert frags, pyrite as small aggre.
85.0–87.5																					
87.5–90.0																					
90.0–92.5																					
92.5–95.0																					
95.0–97.5																					
97.5–100.0																					
100.0–102.5																					
102.5–105.0																					
105.0–107.5																					
107.5–110.0																					
110.0–112.5																					
112.5–115.0																					
115.0–117.5																					
117.5–120.0																					
120.0–122.5																					
122.5–125.0																					

PERCENTAGE COMPOSITION IMAGE



Date 4 May 2011 Geologist L. Casebolt Drilling Co. Boyles Exploration Inc. Hole No. DR 18

Property White Mesa Mill Project Cell 4B Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ≈ 5536

PAGE 1 OF 1

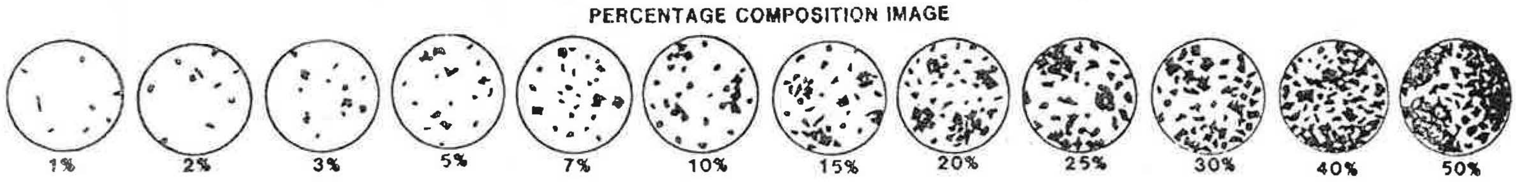
T.D. PROBE ______

T.D. DRILL 70.0

FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite: Amount	Pyrite: Habit	Pyrite: Alter.	Metallic	Non-Metallic	React.-10% HCl	Carbon: Amount	Carbon: Type	Remarks
0–2.5	mdst	rdbn											W			Surface Soil: unconsolidated - sndy slt ML
2.5–5.0	mdst	rdbn											m			Surface soil: unconsolidated - sndy slt ML
5.0–7.5	qtz ss	bn	m-vc	p	A								N			Upper Dakota Fm Ct. @ 5.0' wh-gy chert frags.
7.5–10.0	qtz ss	wh-gybn	m-vc	p	A								N			abund chert frags.
10.0–12.5	cgl, qtz ss	gybn	m-peb	p	a								N			75% multi colored chert frags. & grains
12.5–15.0	qtz ss	dkgy	m	w	a								N			
15.0–17.5	qtz ss	tn	f	w	r								N			
17.5–20.0	qtz ss	lt ortn	m	w	r								N			
20.0–22.5	qtz ss	tn	m-c	m	r								N			
22.5–25.0	qtz ss	tn	m-vc	f	r								N			
25.0–27.5	cgl, qtz ss	gytnbn	m-peb	p	a								N			
27.5–30.0	qtz ss	tn	m	w	R								N			moisture first noticed @ 30.0'
30.0–32.5	qtz ss	tn	m	w	R								N			
32.5–35.0	qtz ss	tn	m c	m	R								N			
35.0–37.5	qtz ss	tn	m c	m	R								N			
37.5–40.0	qtz ss	lt orbn	m-vc	f	r								N			abund chert frags. & grains
40.0–42.5	qtz ss	vltgytn	m	w	a								N			
42.5–45.0	qtz ss	vltgytn	m-c	m	a								N			
45.0–47.5	qtz ss, qtzite	wh	m-c	m	a		L						N			very hard drilling some small chert grains
47.5–50.0	qtz ss, qtzite	wh	m-c	m	a		L						N			" " "
50.0–52.5	qtzite	wh-vlttn	m-vc	p	a								N			" " "
52.5–55.0	qtzite	wh-vlttn	m-vc	p	a								N			" " "
55.0–57.5	qtzite, sh	rdgybn-ltgn	m-peb	p	A			tr					N			Brushy Basin Ct. @ 57.0' chert breccia.
57.5–60.0	sh	ywgygn					H						N			
60.0–62.5	sh	blgy					L						N			some chert grains
62.5–65.0	sh	blgy											N			telltale red chert grains
65.0–67.5	sh	blgy											N			
67.5–70.0	sh	blgy											N			T.D.
72.5																
75.0																
77.5																
80.0																
82.5																
85.0																
87.5																
90.0																
92.5																
95.0																
97.5																
100.0																
102.5																
105.0																
107.5																
110.0																
112.5																
115.0																
117.5																
120.0																
122.5																
125.0																

PERCENTAGE COMPOSITION IMAGE



Date 3 May 2011 Geologist L. Casebolt Drilling Co. Boyles Exploration Inc. Hole No. DR19

Property White Mesa Mill Project Cell 4B Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ≈ 5513

PAGE 1 OF 1

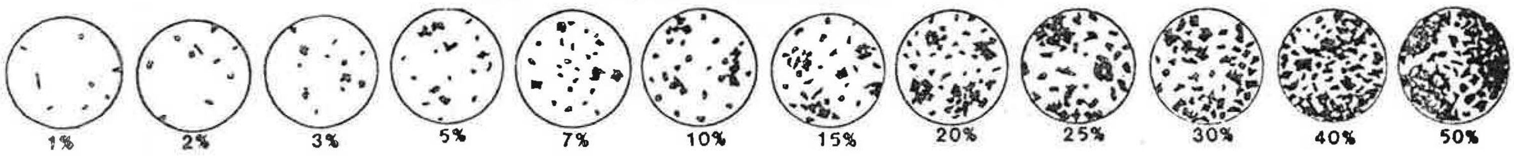
T.D. PROBE ____

T.D. DRILL 75.0

FLUID LEVEL ____

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
2.5						mdst	rdbn											N			Surface soil-unconsolidated
5.0						mdst	rdbn											S			Surface soil-unconsolidated
7.5						sndysltst	rdbn-pk	vf-f	m	r								VS			mancos Sh @ 6.0'
10.0						sndysltst	rdbn-pk	vf-m	f	r								VS			" "
12.5						qtz ss	yutn	f-m	m	r								N			Upper Dakota Fm Ct @ 10.0'
15.0						qtz ss	lt or bn	m	w	a		L						N			
17.5						qtz ss, sh	gytn-vdkgy	m-c	m	a								N			
20.0						qtz ss	ltgytn	m	w	a								N			sparse gy chert grains
22.5						qtz ss	tn	m	w	r		L						N			" " " "
25.0						qtz ss, cgl, qtzite	gy-wh	m-peb	f	r								N			25% lt-dkgy chert pebbles & frags.
27.5						qtz ss	wh-gybn	m-peb	f	a								N			abund chert frags. & pebbles.
30.0						qtz ss	ltgytn	m	w	r								N			
32.5						qtz ss, sh	wh-ltgytn	m-peb	m	a								N			
35.0						qtz ss	ltgytn	m-vc	f	a								N			
37.5						qtz ss	ltgytn	m-c	m	a								N			
40.0						qtz ss	vltgytn	m	w	r								N			
42.5						qtz ss	vltgytn	f-m	m	r								N			
45.0						qtz ss	vltgytn	f	w	r								N			
47.5						qtz ss	vltgytn	m	w	r								N			
50.0						qtz ss	lt pk tn	m-vc	m	r		H						N			abund chert frags.
52.5						qtz ss	ltgytn	m-c	f	a								N			
55.0						qtz ss	ltgytn	m-c	f	a								N			
57.5						qtz ss	wh-ltgytn	m-vc	f	a								N			
60.0						qtz ss, cgl	dkgytn	c-peb	p	a								N			50% lt & dk gy chert pebbles & frags.
62.5						qtz ss	tn-dkgy	m-peb	p	a								N			
65.0						cgl, qtz ss	tn bn	c-peb	p	a								N			75% multicolored chert pebbles & frags.
67.5						sh, qtz ss	bn-gy	m-c	m	r								N			Brushy Basin Ct @ 66.0'
70.0						sh	ltgygn											N			
72.5						sndy sh	blgn											N			
75.0						sh	blgn											N			T.D. some red chert grains
77.5																					
80.0																					
82.5																					
85.0																					
87.5																					
90.0																					
92.5																					
95.0																					
97.5																					
100.0																					
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



Date 2 MAY 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Inc. Hole No. DR 20

Property White Mesa Mill Project Cell 4B Unit No. ______ Sec. ______ Twp. ______ Rge. ______

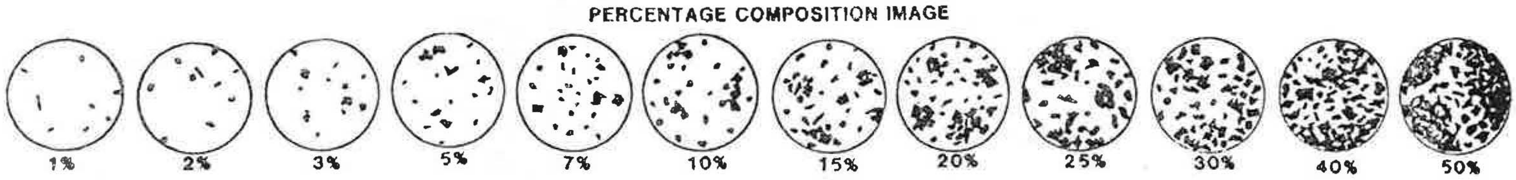
County San Juan State Utah Location ______ Elev. ≈5499

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL ______
FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Iron Oxide	Pyrite Amount	React.-10% HCL	Remarks
2.5	mdst	rdbn						N	Surface soil-unconsolidated sndy lean clay CL
5.0	mdst	rdbn						N	Surface soil-unconsolidated-sndy lean clay CL
7.5	qtzss, sh	pktn	m-peb			L		VS	upper Dakota Fm Ct. @ 6.0' some chert frags.
10.0	qtzss	ltrdbn	m-c	m	r	H		N	
12.5	qtzss	vltgytn	m-c	m	a			N	
15.0	qtzss	vltgytn	m	w	a			N	
17.5	qtzss	ltgytn	m	w	a			N	
20.0	qtzss	tn	m	w	a			N	
22.5	qtzss	tn	m-c	m	a			N	
25.0	qtzss	lttn	f	w	a			N	
27.5	qtzss	tn	m-c	m	a			N	some chert frags
30.0	qtzss	ltgy	m-c	m	a	H		N	" " "
32.5	qtzss	ltgytn	m-c	m	a			N	
35.0	qtzss-sh	ywgnbn	f-m	m	r	L		N	
37.5	sndy sh	ltblgy	m	w	r			N	sparse chert grains
40.0	sndy sh	ltblgy	f-m	m	r			N	
42.5	sh	ltblgy						N	
45.0	sh	blgy-bn						N	sparse chert frags.
47.5	qtzss, sh	gybn	vf-m	f	a			N	
50.0	sh, qtzite	gybn	vf-m	f	a			N	
52.5	sndy sh	gygn	m-peb	f	a			N	sparse chert pebbles & grains
55.0	sh, qtzss	ltgngy	m	w	a	L		N	
57.5	sndy sh	ltgytn	f-m	m	r		tr		
60.0	qtzss, sh	ywgybn	f-m	m	r			N	
62.5	sndy sh	ltblgy	f-m	m	r			N	
65.0	sh	gygn						N	sparse red-bn chert frags.
67.5	sh	gygn						N	
70.0	qtzite, sh	wh-gy	f-m	m	r			N	some red-bn chert grains & frags.
72.5	qtzss, sh	wh-gy	f-c	p	a			N	
75.0	qtzss, sh	wh-gygn	f-m	m	a			N	Brushy Basin Ct @ 73.0' abund. rd-gy chert pebbles
77.5	sh	gygn						N	
80.0	sh	gygn-ppbn						N	mottled shale frags.
82.5	sh	gygn						N	
85.0	qtzss, sh	wh-gygn	m-c	m	a			N	micaceous ss, (muscovite?)
87.5	sndy sh	gy-gygn	f-m	m	r			N	
90.0	sh	ltgy					tr	N	T.D.

Other column headings (no entries): Sample Taken, Graphic Log, Alteration, Gamma Anomaly, Breccia Pipe, Cement Matrix, Habit, Alter., Metallic, Non-Metallic, Carbon Amount, Type. Depth scale continues blank to 125.0.

PERCENTAGE COMPOSITION IMAGE

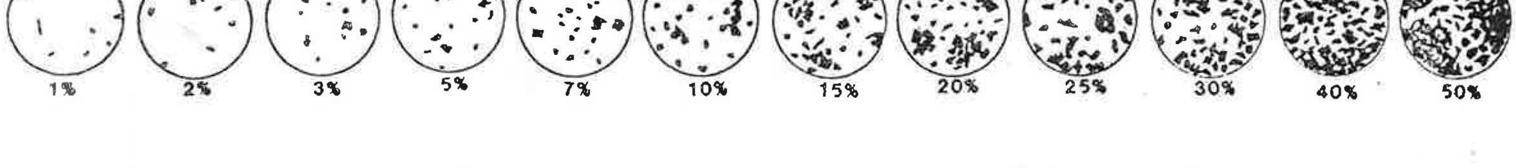


Date 2 May 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Inc Hole No. DR 21
Property White Mesa Mill Project Cell 4B Unit No. ___ Sec. ___ Twp. ___ Rge. ___
County San Juan State Utah Location ___ Elev. ≈ 5530

PAGE 1 OF 1
T.D. PROBE ___
T.D. DRILL ___
FLUID LEVEL ___

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React. - 10% HCL	Carbon Amount	Carbon Type	Remarks
2.5						mdst	rdbn											W			Surface soil - unconsolidated - sndy lean clay CL
5.0						mdst	rdbn											S			Surface soil - unconsolidated - sndy lean clay CL
7.5						sndysh	rdbn-ltpk	m	w	a								VS			Mancos shale @ 8.0'
10.0						sh	pktn											VS			
12.5						sh	ywgy											VS			
15.0						sh	ywgy											M			
17.5						sh	ywgy											M			
20.0						sndysh	ywgy	f	w	a								M			
22.5						sndy sh	ywgy	m	w	a		L						VW			
25.0						sndy sh, ss	tn	f-m	m	a								VW			Upper Dakota Fm Ct @ 24.0'
27.5						qtz ss	tn	m	w	a								N			
30.0						qtz ss	tn	m	w	a								N			
32.5						qtz ss	tn	m	w	a								N			
35.0						qtz ss	tn	f-m	m	a								N			
37.5						qtz ss	tn	m	w	a								N			
40.0						qtz ss	tn	f	w	a								N			
42.5						qtz ss	tn	m	w	a								N			
45.0						qtz ss, sh	dkbn	m	w	a		L						N			
47.5						qtz ss	tn	m-c	m	a								N			
50.0						qtz ss	gytn	m-vc	p	a								N			abund multicolored chert frags.
52.5						qtz ss	tn	m-vc	p	a								N			" " " " "
55.0						qtz ss	tn	m-c	f	a								N			" " " " "
57.5						sh	ltgy-gybn											N			chert pebbles & frags
60.0						sh	ltgy											N			
62.5						sndy sh	vltgytn	vf-m	f	a								N			
65.0						qtz ss	tn	m	w	a								N			
67.5						qtz ss	tn	m-c	m	a								N			
70.0						qtz ss	tn	c	w	r								N			
72.5						qtz ss, cgl	ltgytn	m-peb	f	r								N			
75.0						qtz ss	ltgytn	c	w	r								N			some gy chert grains
77.5						qtz ss	tn	c	w	r								N			
80.0						qtz ss	tn	m-c	m	a								N			
82.5						qtz ss	tn	m	w	r								N			
85.0						qtz ss	tn	f-m	m	r								N			
87.5						qtz ss	ltpktn	vf	w	r								N			
90.0						qtz ss	tn	f-m	m	r								N			
92.5						qtz ss	tn	m	w	r								N			
95.0						qtz ss, cgl	tn	m-peb	f	a								N			some gy chert frags.
97.5						qtz ss	wh-vlttn	m-vc	m	a								N			abund. wh-lt colored qtzite & chert frags.
100.0						qtz ss	wh-vlttn	m-vc	m	a								N			" " " " " "
102.5						qtz ss	wh-tn	m-peb	f	a								N			" " " " " "
105.0						qtz ss	wh-tn	m-peb	f	a								N			hard drilling, abund rusting steel frags.
107.5						qtz ss, qtzite	wh-tn	m-peb	f	a								N			" " " " " "
110.0						qtz ss, qtzite	wh-tn	m-peb	f	a								N			50% of grains are chert
112.5						qtz ss, cgl	gytn	m-peb	f	a								N			
115.0						qtz ss, cgl - sltysh	ywtn-gygn	m-peb	f	a		L						N			Brushy Basin Ct. @ 114.0
117.5						slty sh	gn-ppbn											N			
120.0						sltysh	gn-ppbn											N			T.D.
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 3 May 2011 Geologist L. Casebolt Drilling Co. Boyles Exploration Inc. Hole No. DR 22

Property White mesa mill Project Cell 4B Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. 5488

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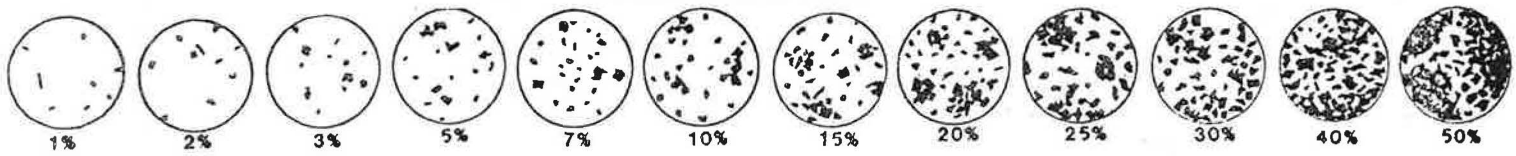
T.D. PROBE ____

T.D. DRILL 85.0

FLUID LEVEL ____

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE: AMOUNT	PYRITE: HABIT	PYRITE: ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON: AMOUNT	CARBON: TYPE	REMARKS
0																					
2.5						mdst	rdbn											W			Surface Soil - unconsolidated - sndy lean clay CL
5.0						mdst	rdbn											W			Surface Soil - unconsolidated - sndy lean clay CL
7.5						qtz ss	ltgytn											N			Upper Dakota Ct @ 5.0'
10.0						qtz ss cgl	ltgytn	m-peb	f	r								N			abund gray chert frags.
12.5						qtz ss,	ltgytn	m	w	r								N			
15.0						qtz ss, sh	wh-ltgytn	m-c	m	r								N			
17.5						qtz ss	wh-ltgytn	m-vc	m	r								N			some chert frags.
20.0						qtz ss	ltgytn	m-c	m	r								N			
22.5						qtz ss, cgl	gytn	m-peb	f	a								N			50% chert grains & frags.
25.0						qtz ss, cgl	gytn	m-peb	f	a								N			" " " "
27.5						qtz ss,	tn	m	w	a								N			
30.0						qtz ss cgl	gytn	m-peb	f	a								N			abund light colored chert grains.
32.5						qtz ss	ltgytn	m-c	m	R								N			
35.0						qtz ss	ltgytn	m	w	R								N			
37.5						qtz ss	ltgytn	m	w	r								N			
40.0						qtz ss	ltgytn	m-c	m	a								N			
42.5						qtz ss	ltgytn	m	w	r								N			
45.0						qtz ss	ltgytn	m-c	m	r								N			
47.5						qtz ss	ltgytn	m	w	r								N			
50.0						qtz ss	ltgytn	m-c	m	r								N			
52.5						qtz ss	ltgytn	m-c	m	a								N			
55.0						qtz ss	ltgy	m-c	m	a								N			
57.5						qtz ss	ltgy	m-c	m	a								M			
60.0						sh	ltgy-ltgn											N			Brushy Basin Ct @ 57.5' some chert Grains
62.5						sh	wh-ltgygn											N			
65.0						sh	gybn											N			some red chert grains
67.5						sh	gn-ppbn											N			Extremely hard drilling (chert) from 67.5
70.0						sh, qtz	ortn-gn											N			To 72.5' chert pebbles & frags.
72.5						sh, qtzite	wh-ltgn	m-peb										N			
75.0						sh	blgy											N			red chert frags.
77.5						sh	blgy	peb										N			" " " & pebbles
80.0						sh	blgy											N			
82.5						sh, qtz ss	blgy	f-m	m	a		tr	C					N			
85.0						qtz ss, sh	ltgy	vf-m	f	a								N			TD
87.5																					
90.0																					
92.5																					
95.0																					
97.5																					
100.0																					
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



Date 4 May 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. DR 23

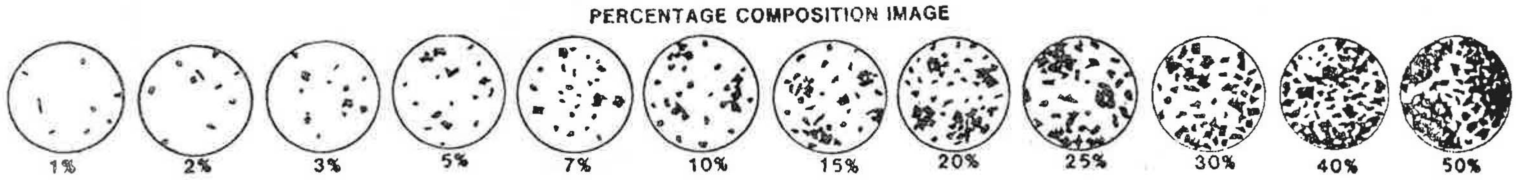
Property White Mesa Mill Project Cell 4B Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ≈ 5491

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 85.0
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0						mdst	rdbn											S			Surface soil. Mancos Shale @ 2.0'-unconsolidated
2.5						sndysh	rdbn-ltpktn	vf-f	w	r								VS			Mancos Sh
5.0						sndysh, qtzss	pktn-ywbn	f-m	m	r								VS			Upper Dakota Ct @ 7.0'
7.5						qtz ss	wh-ywtn	m-c	m	r		L						N			
10.0						qtz ss	tn	m-c	m	r		L						N			
12.5						qtz ss	tn	m-c	m	a								N			
15.0						qtz ss	tn	f-m	m	a								N			
17.5						qtz ss	tn	m	w	a		L						N			
20.0						qtz ss	tn	m	w	r								N			
22.5						qtz ss	tn	m-c	m	a								N			
25.0						qtz ss	lt	m-c	m	r								N			
27.5						qtz ss	ltgytn	m	w	R								N			
30.0						qtz ss	ltgytn	m	w	r								N			
32.5						qtz ss	ltgytn	m	w	r								N			
35.0						qtz ss	ltgytn	m-c	m	r								N			
37.5						qtz ss	ltgytn	m-c	m	a								N			
40.0						qtz ss, cgl	gytn-dkgy	m-peb	f	a								N			30% chert pebbles & grains
42.5						qtz ss	gytn	m-c	m	r								N			
45.0						qtz ss	gytn	m-c	m	r								N			Some chert frags.
47.5						qtz ss	gytn	m-c	m	r								N			
50.0						qtz ss	vltgy	vf-m	f	r								N			
52.5						qtz ss	wh-ortn	f-m	m	r		L						N			
55.0						qtz ss	wh	f	w	a								N			
57.5						qtz ss	wh	m	w	r								N			
60.0						qtz ss	vltgy	m	w	r								N			
62.5						qtz ss	vltgy	m	w	r								N			
65.0						qtz ss	vltgy	m	w	r								N			quite moist @ 67.5
67.5						qtz ss	vltgy	m	w	r								N			
70.0						qtz ss	vltgy	m-c	m	r								N			Some gy chert grains & frags.
72.5						qtz ss, sh	ywbn-tnbn	m-c	m	r		L						N			
75.0						qtz ss, sh	wh-tn-gn	m-peb	p	a			tr	c				N			Brushy Basin Ct @ 77.0' good contact
77.5						sh	gygn											N			some red chert grains
80.0						sh	gygn											N			
82.5						sh	gn											N			T.D.
85.0																					
87.5																					
90.0																					
92.5																					
95.0																					
97.5																					
100.0																					
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



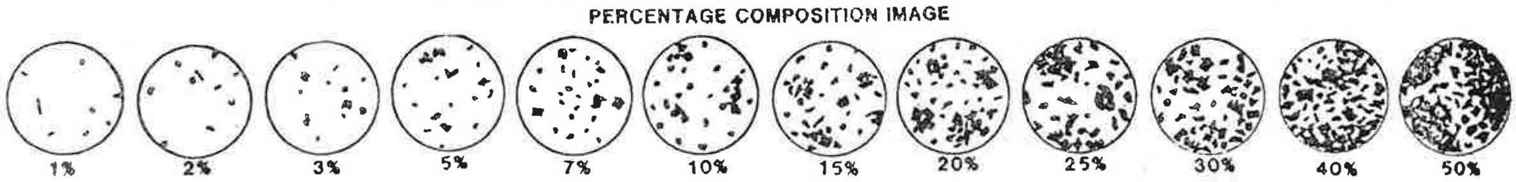
Date 3 MAY 2011 Geologist L. Casebolt Drilling Co. Byles Exploration Inc. Hole No. DR 24
Property White Mesa Mill Project Cell 4B Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ≈5469

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 80.0'
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React. 10% HCL	Carbon Amount	Carbon Type	Remarks
0 – 2.5						mdst	rdbn											W			Surface soil - unconsolidated - sndy lean clay - CL
2.5 – 5.0						mdst	rdbn											W			Surface soil - unconsolidated - sndy lean clay - CL
5.0 – 7.5						sndy sh	pktn	c-vc	p	r								VS			Mancos Sh
7.5 – 10.0						qtz ss	gytn	m-peb	f	r								N			Upper Dakota Fm Ct @ 7.5' chert pebbles + grains
10.0 – 12.5						qtz ss	gytn	m-vc	f	a								N			light colored chert frags. + grains
12.5 – 15.0						qtz ss	gytn	m-peb	f	a								N			" " " " "
15.0 – 17.5						qtz ss	ltgytn	f-m	m	r								N			
17.5 – 20.0						qtz ss	ltgytn	m-c	m	a								N			
20.0 – 22.5						qtz ss	ltgytn	m	w	r								N			
22.5 – 25.0						qtz ss	ltgytn	m	w	r								N			
25.0 – 27.5						qtz ss	gytn	m-c	m	R								N			
27.5 – 30.0						qtz ss	ywgytn	m-vc	f	a								N			abund white chert frags.
30.0 – 32.5						qtz ss	ltgytn	m-c	m	r								N			
32.5 – 35.0						qtz ss	ltgytn	m	w	r								N			moisture 1st noticed 35.0'
35.0 – 37.5						qtz ss	ltgytn	m	w	r								N			
37.5 – 40.0						qtz ss	ltgytn	m	w	r								N			
40.0 – 42.5						qtz ss	ltgytn	f	w	r								N			
42.5 – 45.0						qtz ss	ltgytn	f-m	m	r								N			
45.0 – 47.5						qtz ss	gytn	f-c	f	a								N			
47.5 – 50.0						qtz ss	ltywtn	m-vc	f	a		L						N			
50.0 – 52.5						qtz ss	ywgytn	m-peb	f	a		L						N			abund light colored chert pebbles + grains
52.5 – 55.0						qtz ss, cgl	orgytn	m-peb	p	a		L						N			30% " " " " "
55.0 – 57.5						qtz ss	ywgytn	m-vc	f	a								VS			
57.5 – 60.0						qtz ss	gy	f-c	f	a			tr.					VS			
60.0 – 62.5						sh	gn											N			Brushy Basin Ct @ 60.0' some ppbn chert pebbles.
62.5 – 65.0						sh	gn						tr					N			some ppbn-red chert frags.
65.0 – 67.5						sh	gygn											N			
67.5 – 70.0						sh	gygn-ppbn											N			some mottled cuttings
70.0 – 72.5						sh	gn											N			
72.5 – 75.0						sh	gn											N			some red chert grains
75.0 – 77.5						sh	gn											N			
77.5 – 80.0						sh	gygn											N			T.D.

Depth scale continues (blank): 82.5, 85.0, 87.5, 90.0, 92.5, 95.0, 97.5, 100.0, 102.5, 105.0, 107.5, 110.0, 112.5, 115.0, 117.5, 120.0, 122.5, 125.0

PERCENTAGE COMPOSITION IMAGE

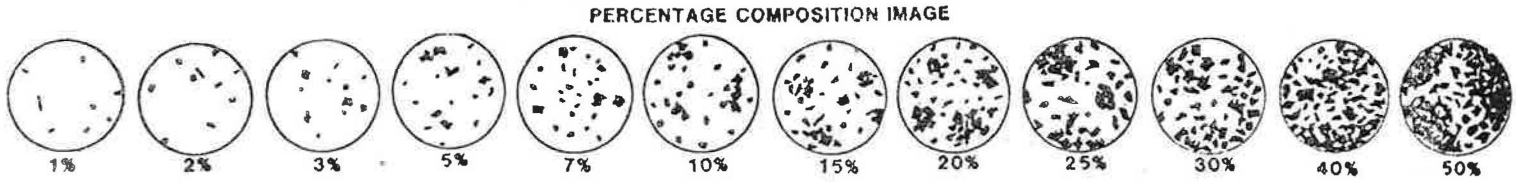


Date 2 May 2011 Geologist L. Casebolt Drilling Co. Boyles Exploration, Inc. Hole No. DR 25
Property White Mesa Mill Project Cell 4B Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ≃ 5462

PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 80.0
FLUID LEVEL ____

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0–2.5						qtz ss, mdst	lt or bn	m-c	m	a		L						VW			Surface soil to 1 foot. Upper Dakota Fm Ct @ 1.0'
2.5–5.0						qtz ss	orgybn	c-vc	m	a		L						N			30% chert frags.
5.0–7.5						qtz ss	tn	m-c	m	a								N			20% " "
7.5–10.0						qtz ss	ortn	m-c	m	a								N			Moisture First noted @ 7.5' 30% chert.
10.0–12.5						qtz ss, sh, cgl	gwtn	m-peb	p	a								N			
12.5–15.0						qtz ss	tn	m-c	m	r								N			30% chert grains
15.0–17.5						qtz ss, cgl	orbn	c-peb	p	a								N			80%+ " " & pebbles
17.5–20.0						qtz ss, cgl	orbn	c-peb	p	a		L						N			90%+ " " "
20.0–22.5						qtz ss, cgl	orgybn	c-peb	p	a		L						N			90%+ " " "
22.5–25.0						qtz ss, cgl	orgybn	c-peb	p	a		L						N			90%+ " " "
25.0–27.5						qtz ss, cgl	gybn	c-peb	p	a		L						N			90%+ " " "
27.5–30.0						qtz ss, cgl	orgybn	c-peb	p	a								N			90%+ " " "
30.0–32.5						qtz ss, cgl	orbn	c-peb	p	a								N			70%+ " " "
32.5–35.0						qtz ss, cgl	gybn	c-peb	p	a								N			90%+ " " "
35.0–37.5						qtz ss	tn	m	w	R								N			
37.5–40.0						qtz ss	lt ortn	f-m	m	r		L						N			
40.0–42.5						qtz ss	tn	f-m	m	r								N			
42.5–45.0						qtz ss	tn	m	w	r								N			
45.0–47.5						qtz ss	tn	f-m	m	r								N			Some chert frags.
47.5–50.0						qtz ss	tn	m	w	R								N			
50.0–52.5						qtz ss	tn	m-c	f	a								VW			some gy chert frags & grains
52.5–55.0						qtz ss	ltgytn	m-vc	f	a								N			abund. " " " "
55.0–57.5						qtz ss, cgl	ltgytn	m-peb	p	a								N			30% wh-gy chert pebbles & frags.
57.5–60.0						qtz ss	lt tn	m-peb	p	a			Tr.	A				N			some " " " " "
60.0–62.5						qtz ss	lt tn	m	w	R								N			
62.5–65.0						qtz ss, cgl	ortn	m-peb	p	a								N			40% multi colored chert pebbles, frags, & grains
65.0–67.5						qtz ss, cgl	gytn	m-peb	p	a								N			80% " " " " " "
67.5–70.0						qtz ss	vltgy	m-c	f	a								N			
70.0–72.5						qtz ss	vltgy	m	w	r								N			
72.5–75.0						qtz ss	vltgy	f-m	m	r								N			Well began producing water @ 72.5'
75.0–77.5						qtz ss, cgl, sh	gwtn-blgn	m-peb	p	a			1%	C				N			Brushy Basin Ct. @ 76.0' (good contact)
77.5–80.0						sh	blgn						Tr.	A				N			T.D. some ppbn chert pebbles
82.5																					
85.0																					
87.5																					
90.0																					
92.5																					
95.0																					
97.5																					
100.0																					
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



APPENDIX A.2

MW - SERIES

Umetco Minerals Corporation

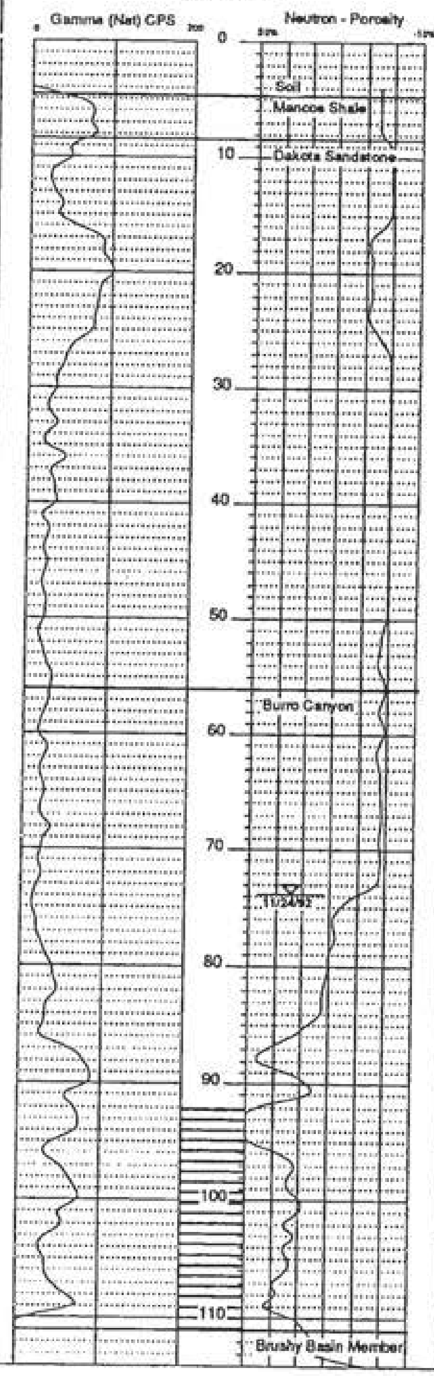
Location: San Juan County, Utah | Date: 11/24/92

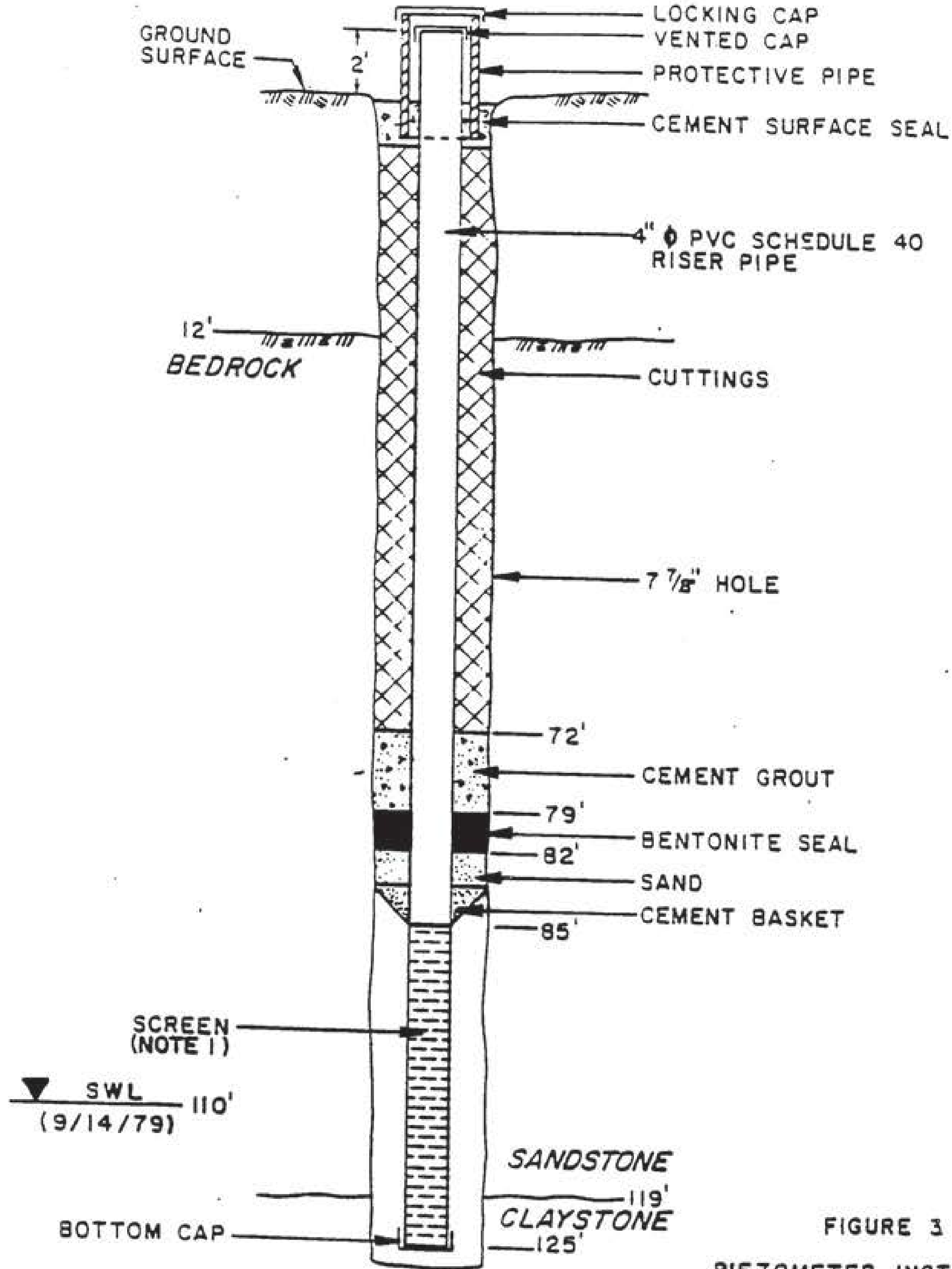
Gamma (Nat) - Neutron Porosity

Gd. Elev. 5642.2

T.D. 114

WMMW-1





NOT TO SCALE

NOTE 1: SCREEN CONSISTS OF COMMERCIALLY SLOTTED PIPE WITH 0.045 IN. WIDE SLOTS, 3 ROWS AND 40-42/SLOTS/ROW/FT. PIPE.

FIGURE 3

PIEZOMETER INSTALLATION
WELL NO. 2
CONSTRUCTION DETAILS

PREPARED FOR

ENERGY FUELS NUCLEAR, INC.
DENVER, COLORADO

BY	B. 9-27-79	CI APPROVED BY	ED CE MJT	D 11/12/79	DF NUMBER	IG RM10-682-A3

REVISED 20-82 20 2/22/82

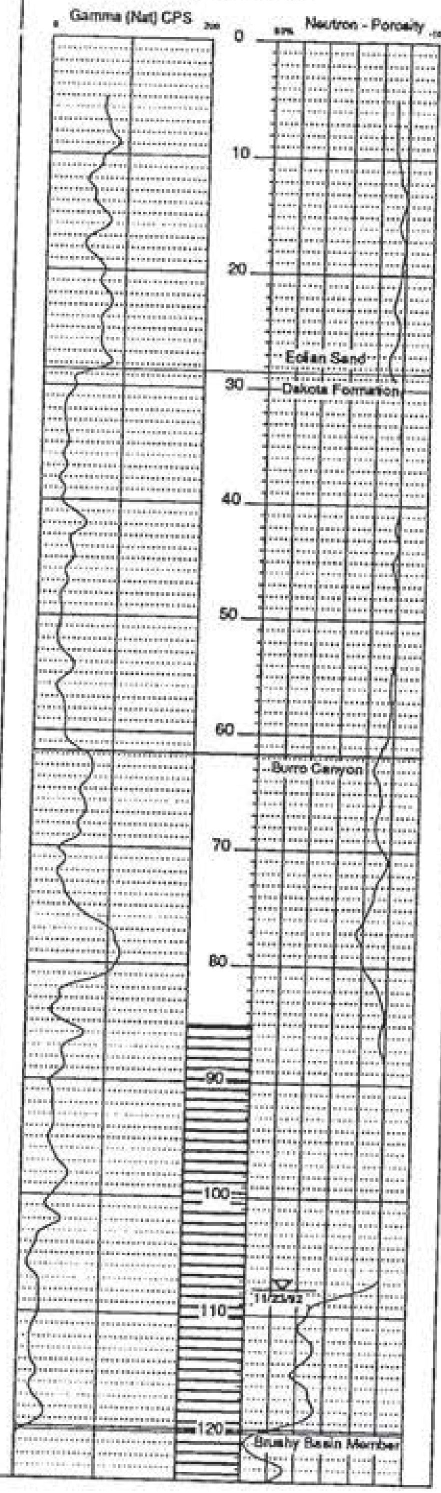
Umetco Minerals Corporation

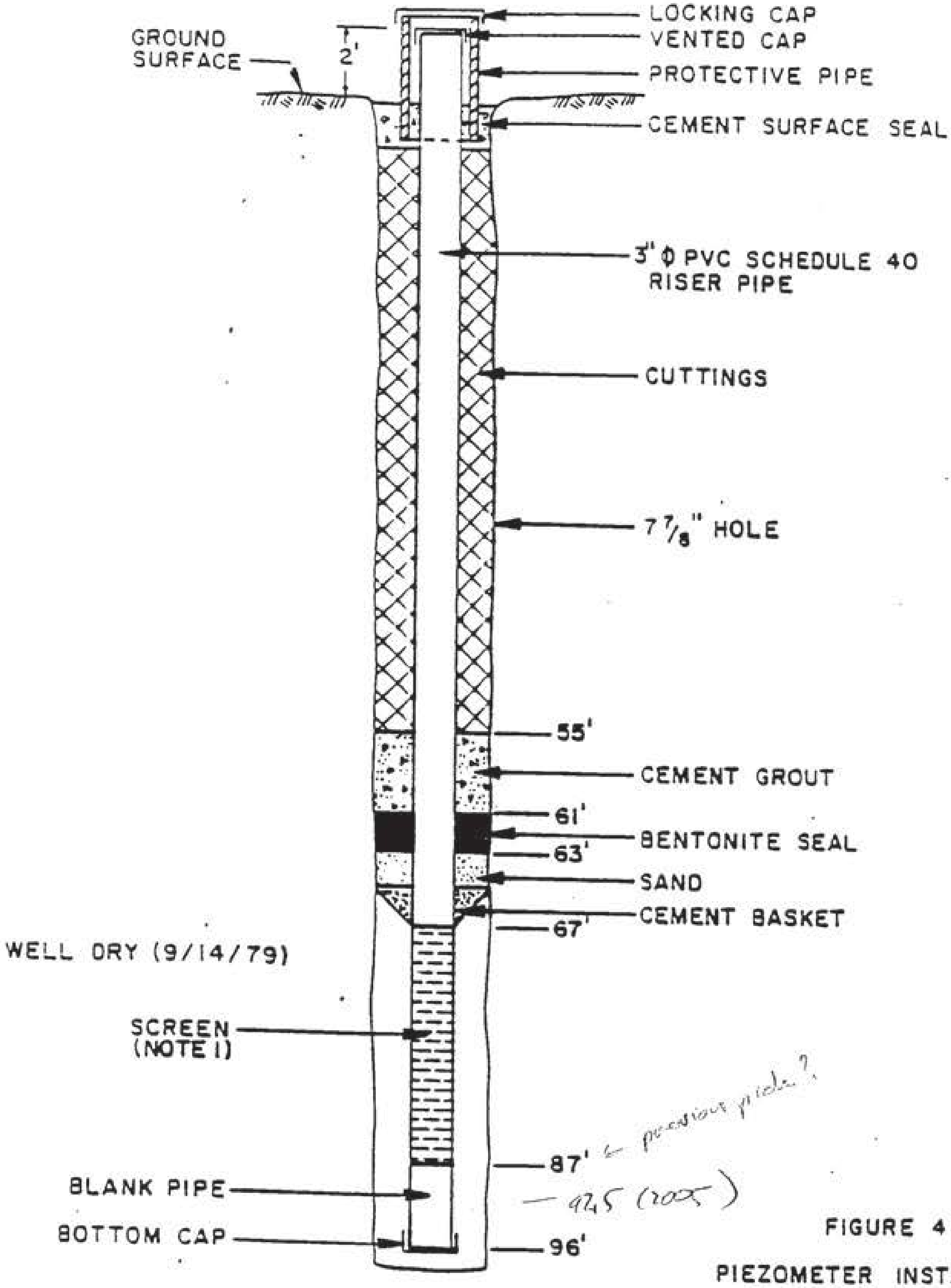
Location: Montrose County   Date: 11/23/92

Gamma (Nat) - Neutron Porosity

Gd. Elev. 5611.6
T.D. 124

WMMW-2





NOT TO SCALE

FIGURE 4

PIEZOMETER INSTALLATION
WELL NO. 3
CONSTRUCTION DETAILS

PREPARED FOR

ENERGY FUELS NUCLEAR, INC.
DENVER, COLORADO

NOTE 1: SCREEN CONSISTS OF COMMERCIALLY SLOTTED PIPE WITH 0.045 IN. WIDE SLOTS, 3 ROWS AND 40-42/SLOTS/ROW/FT. PIPE.

BY B.K. 9-28-79 APPROVED BY WJS 10/2-1979 DRAWING NUMBER

Date 4-19-05 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. MW-3A

Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1

T.D. PROBE ______

T.D. DRILL 95.0

FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Iron Oxide	React.-10% HCL	Remarks
2.5	Sndy sh	rdbn	vf-m	p			VS	Surface soil/Shale
5.0	Sndy sh	rdbn-tn	vf-m	p			VS	
7.5	Ss-sltst	rdbn	vf-f	m			VS	
10.0	qtz ss	vltgy-wh	f	w	sa		W	Upper Dakota Fm Ct @ approx 7.5 ft.
12.5	qtz ss	lttn	f	w	sr		N	
15.0	qtz ss	ltgytn	f-cr	p	sr		N	sparse pk-wh chert grains
17.5	qtz ss	ltgytn	f-m	p	sr		N	
20.0	qtz ss	ltgytn	f-m	p	sr		N	
22.5	qtz ss	ltgytn	f	w	sr		N	
25.0	qtz ss	lttn	f-m	p	sr		N	sparse multicolor chert grains
27.5	qtz ss	lttn	f-m	w	sr		N	
30.0	qtz ss	tn	m-vcr	p	sa		N	abnt. multicolor chert grains
[illegible]	qtz ss-peb	tn	m-vcr	p	a		N	congl. zone abnt chert frags.
35.0	qtz ss-sh	tn-blgy	m-cr	p	sr		N	blgy shale frags
37.5	qtz ss, sh, l	blgy-tn	m-vcr	p	sa		N	blgy shale frags, chert frags, congl. zone
40.0	qtz ss	tn	vf-vcr	p	sa		N	chert frags
42.5	qtz ss	tn	m-vcr	p	sr		N	
45.0	qtz ss, cgl	tn	f-vcr	p	sr		N	congl. zone
47.5	qtz ss, cgl	tn	f-vcr	p	sr		N	congl. zone
50.0	qtz ss	tn	m-vcr	p	sr		N	
52.5	cgl, qtz ss	dkgytn	cr-vcr	p	a		N	cgl. zone abnt. chert frags
55.0	qtz ss	tn	f-m	p	sr		N	
57.5	qtz ss, sh	vltgy	vf	w	r		N	sparse blgy sh
60.0	sltst, ss, cgl	ltblgy	f-peb	p	sa		N	cgl. zone, sparse chert frags
62.5	qtz ss	lttn	f-cr	p	sr		N	some chert frags
65.0	qtz ss	ltgytn	f-vcr	m	r		N	" " "
67.5	qtz ss	ltgytn	f-vcr	m	r		N	" " "
70.0	qtz ss	ltgytn	f-vcr	p	sr		N	qtz ss, begin coring
72.5	qtz ss	dkgybn	m-vcr	f	sr	LT	N	abnt. chert frags
75.0	qtz ss	dkgybn	m-vcr	f	sr	LT	N	
77.5	qtz ss	ltgy	vf-m	p	sa		N	abnt. wh chert grains
80.0	qtz ss	ltgy	vf-cr	p	sa		N	
82.5	qtz ss	ltgy	f-cr	p	sr		N	
85	qtz ss	ltgy	f-m	f	sr		N	
87.5	qtz ss	ltgy	m-vcr	p	sa		VW	25% chert frags, trace blgy sh
90.0	qtz ss	gytn	vcr-peb	p	sa		VW	
92.5	cgl, qtz ss	gytn	vcr-peb	p	sa		N	Upper Brushy Basin Mbr. Ct @ 92.5 ft (from core)
95.0	sh, cgl	gybl-bn	cr-peb	p	sa		N	95.0 T.D.

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Core Log of Well No. MW-3A

Cored Interval 70.0 ft. to 95.0 ft. T.D.

Depth	Description
70.0 - 74.0	Core barrel blocked, 75% core recovery, quartz sandstone, very light tan - white, med. to very coarse grained, chert pebble zone at 71.3 ft., sparse chert grains, calcareous cement at 72.3 - 73.0 ft., abund. hematite/limonite disseminated at 73.2 - 73.8 ft., possible replacement of earlier pyrite.
74.0 - 80.0	Core recovery 67%, quartz sandstone from 76.0 ft.-77.5 ft., white, medium grained, sub rounded, 77.5 ft. - 78.4 ft., quartz sandstone, very light tan, fine to medium grained, sub rounded, 78.4 ft. - 80.0 ft., quartz sandstone, very light tan, fine to medium grained, sub rounded, clay cement.
80.0 - 85.2	Quartz sandstone fine grained subrounded to rounded clay cement (non calcareous) occasional chert pebble, grit size zone from 82.5 - 82.8 and from 84.5 - 84.9 ft..
85.0 - 87.5	No core recovery.
87.5 - 90.0	Quartz sandstone / grit, calcareous cement white to light gray green, coarser zones contain light green shale fragments and chert pebbles, green clay gall noted from 88.0 - 88.2 ft., conglomerate from 89.5 - 90.0 feet.
90.0 - 95.0	Core recovery 97%, quartz sandstone / conglomerate, light gray green, contains abundant chert pebbles and grit, zone from 90.0 - 92.5 ft. contains numerous low angle partings due to friable character of the core, no weathered or mineralized surfaces noted. Upper Brushy Basin contact at 92.5 ft.. Conglomerate in direct contact with undisturbed green shale below. End of Core

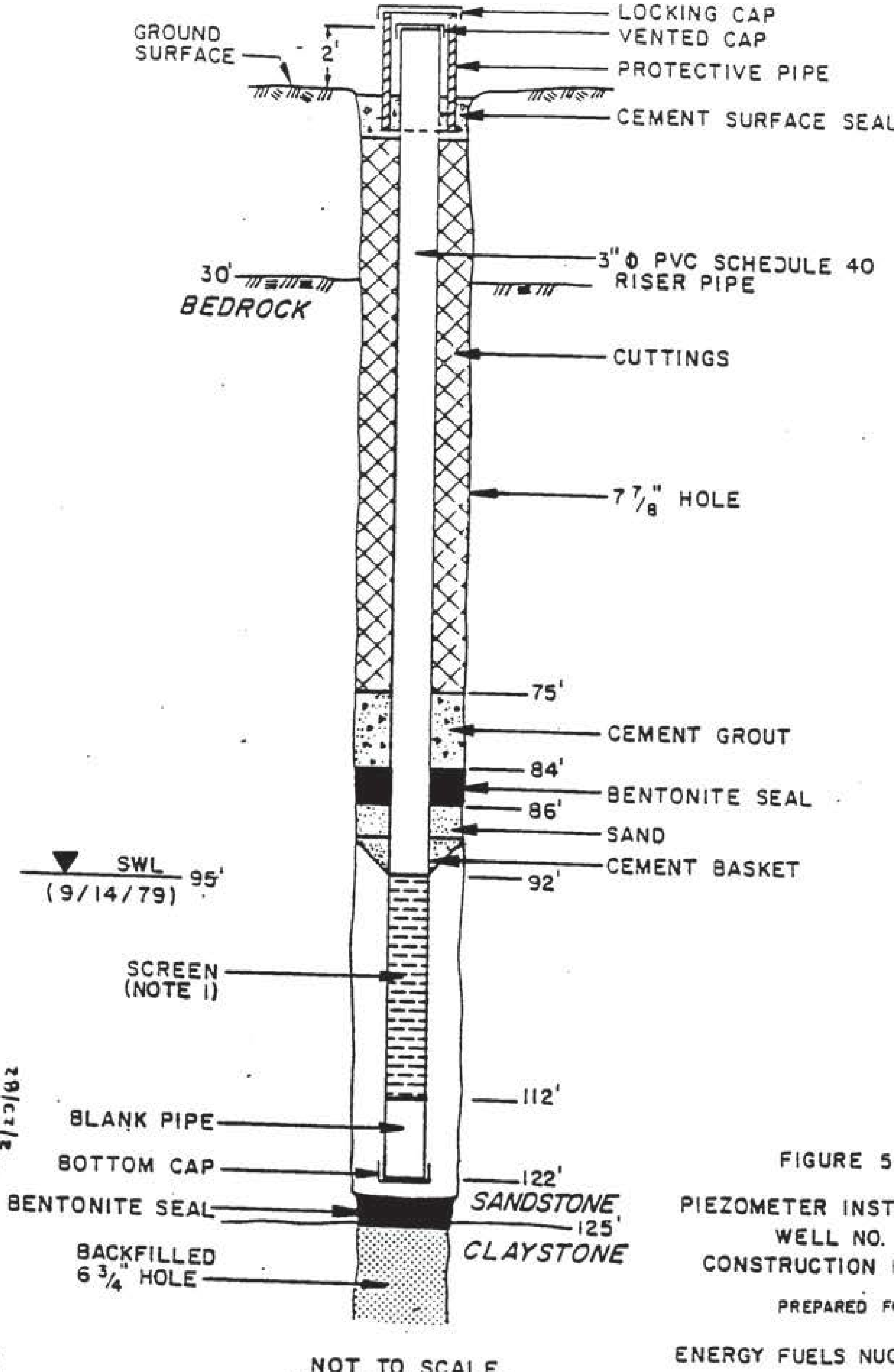


FIGURE 5

PIEZOMETER INSTALLATION
WELL NO. 4
CONSTRUCTION DETAILS

PREPARED FOR

ENERGY FUELS NUCLEAR, INC.
DENVER, COLORADO

NOTE I: SCREEN CONSISTS OF COMMERCIALLY SLOTTED PIPE WITH 0.045 IN. WIDE SLOTS, 3 ROWS AND 40-42/SLOTS/ ROW/FT. PIPE

REVISION: REVISED 2-20-82 CEO 2/22/82

DRAWN BY B.K.H. 9-28-79 CHECKED BY CEO 10/29/79 APPROVED BY DRAWING NUMBER 682

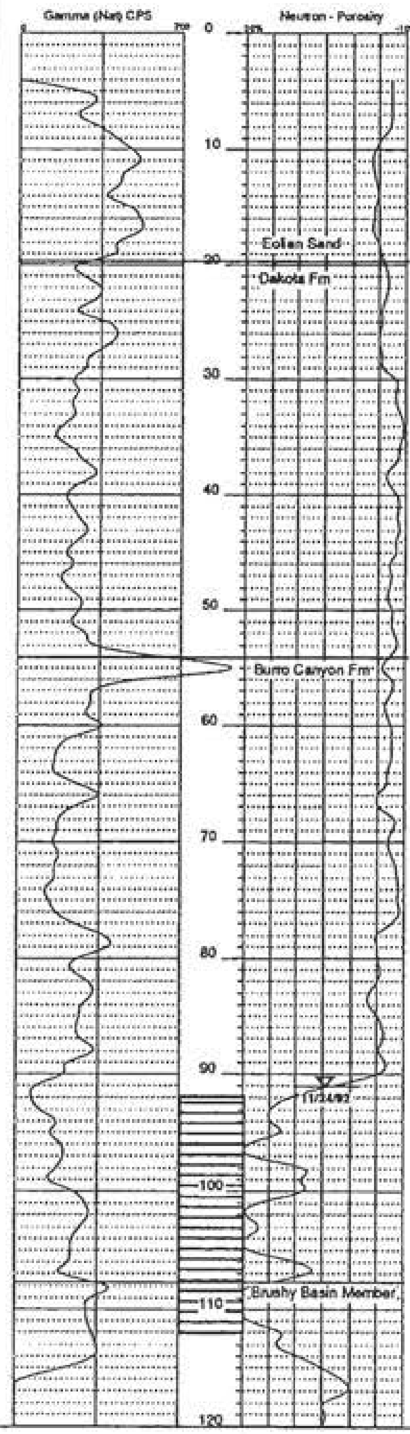
Umetco Minerals Corporation

Location: San Juan County, Utah   Date: 11/24/92

Gamma (Nat) - Neutron Porosity

Gd. Elev. 5621
T.D. 120

WMMW-4



Core Log of Well No. MW4-A

Depth	Description
92.5 - 96.6	Top of core Quartz sandstone, fine grained, tan, well sorted, limonite coating on near horizontal partings, possible bedding planes, approx 2 - 3 inches apart. (oxidized), redox boundary at 96.6 feet.
96.6 - 100.0	Very fine grained quartz sandstone / siltstone, very light gray-green, shale parting at 97.4 feet, pyritic dendrite at 99.8 feet.
100.0 - 100.8	100.0 feet, upper contact, Brushy Basin Fm., low angle, quartz sandstone with limonite / hematite stain.
100.8 - 101.0	Silty shale, gray/green.
101.0 - 102.1	Silty shale, red/brown.
102.1 - 102.5	Siltstone / shale, purple-red, purple-gray green.
102.5 - 104.0	Sandy shale, purple-red to gray-green, near horizontal clay parting at 103.0 feet and at 104.0 feet.
104.0 - 106.5	Quartz sandstone, light green, fine to medium grained,sub-rounded, clay parting at 105.5 feet.
106.5 - 107.0	Quartz sandstone, very light gray-green, numerous pyrite blebs.
107.0 - 108.0	Quartz sandstone / conglomerate, white, fine to very coarse grained, with chert pebbles and fragments. Sharp basal contact.
108.0 - 112.7	Silty shale, gray-green, mottled, shale partings at 108.2, 108.8, 109.3, 109.6, 110.0, 110.2, 110.8, 111.0, 112.0 feet.
112.7 - 116.7	Quartz sandstone, gray, fine grained, some horizontal shale partings.
116.7 - 121.3	Quartz sandstone, light gray-green, mottled, with light gray bleached spots.
121.3 - 125.0	Shale, mottled, red-purple-brown to green. End of core.

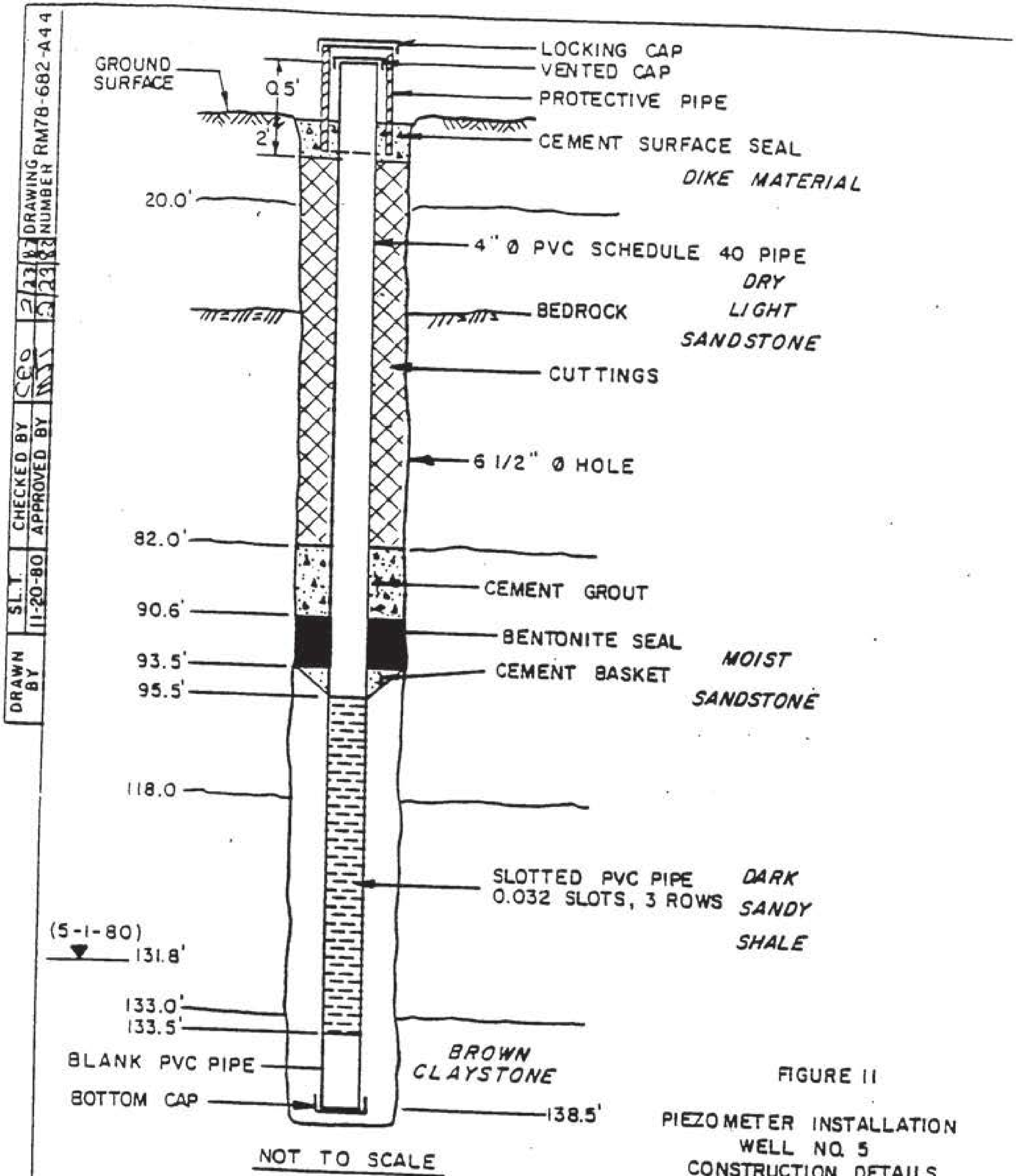


FIGURE II

PIEZOMETER INSTALLATION
WELL NO. 5
CONSTRUCTION DETAILS

PREPARED FOR

ENERGY FUELS NUCLEAR, INC.
DENVER, COLORADO

D'APPOLONIA

Umetco Minerals Corporation

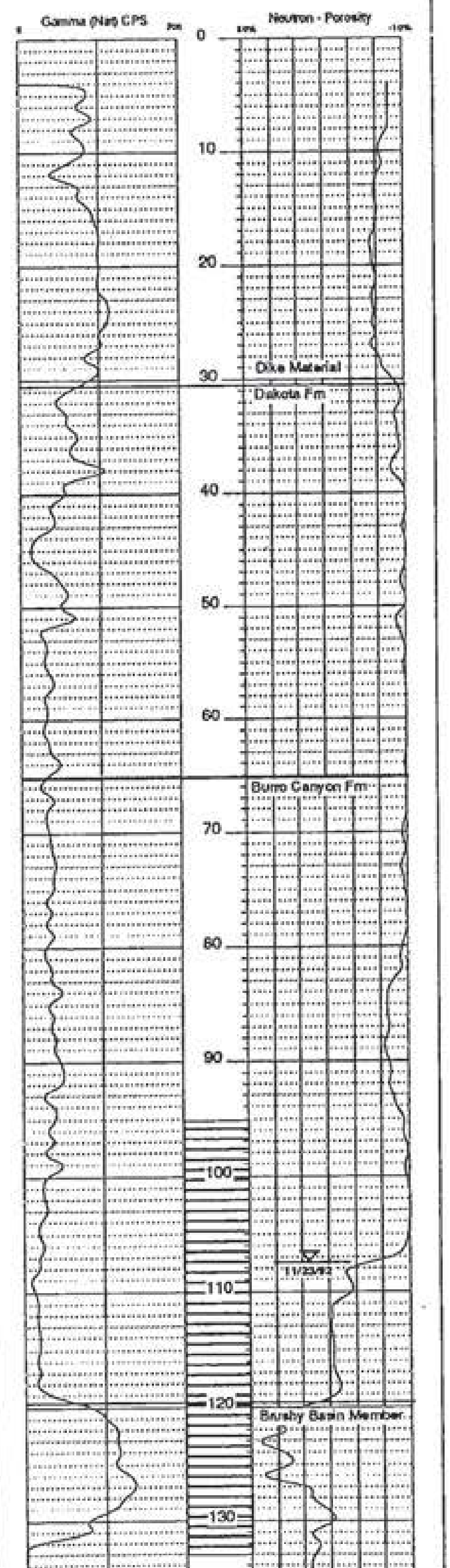
Location: San Juan County, Utah Date: 11/23/92

Gamma (Nat) - Neutron Porosity

Gd. Elev. 5606.9

T.D. 136

WMMW-5



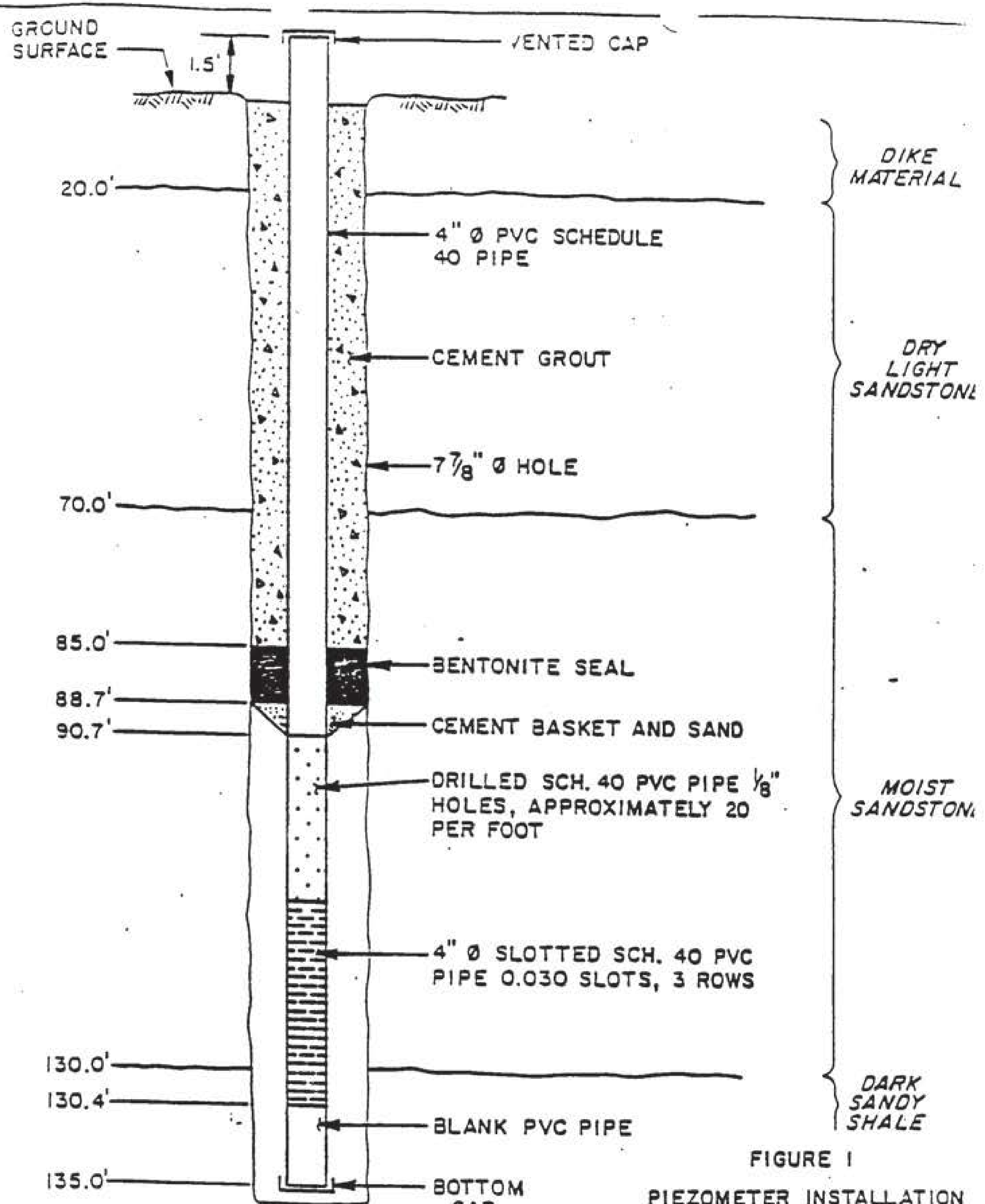


FIGURE I

PIEZOMETER INSTALLATION
WELL NO. 11
CONSTRUCTION DETAILS

PREPARED FOR

ENERGY FUELS NUCLEAR, IN
DENVER, COLORADO

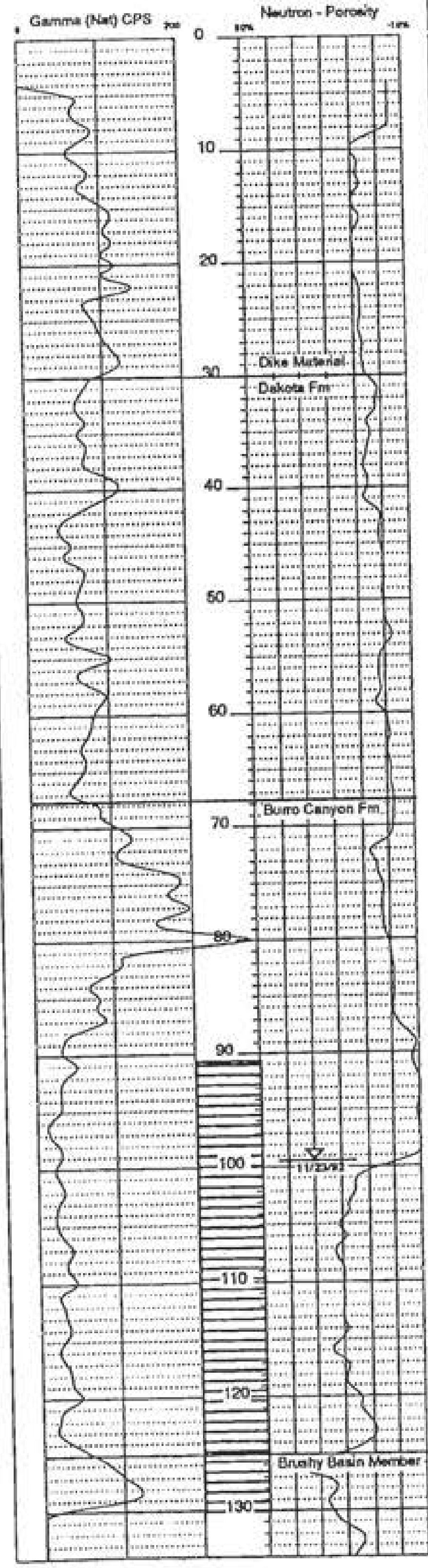
Umetco Minerals Corporation

Location: San Juan County, Utah   Date: 11/23/92

Gamma (Net) - Neutron Porosity

Gd. Elev. 5606.8
T.D. 134

WMMW-11



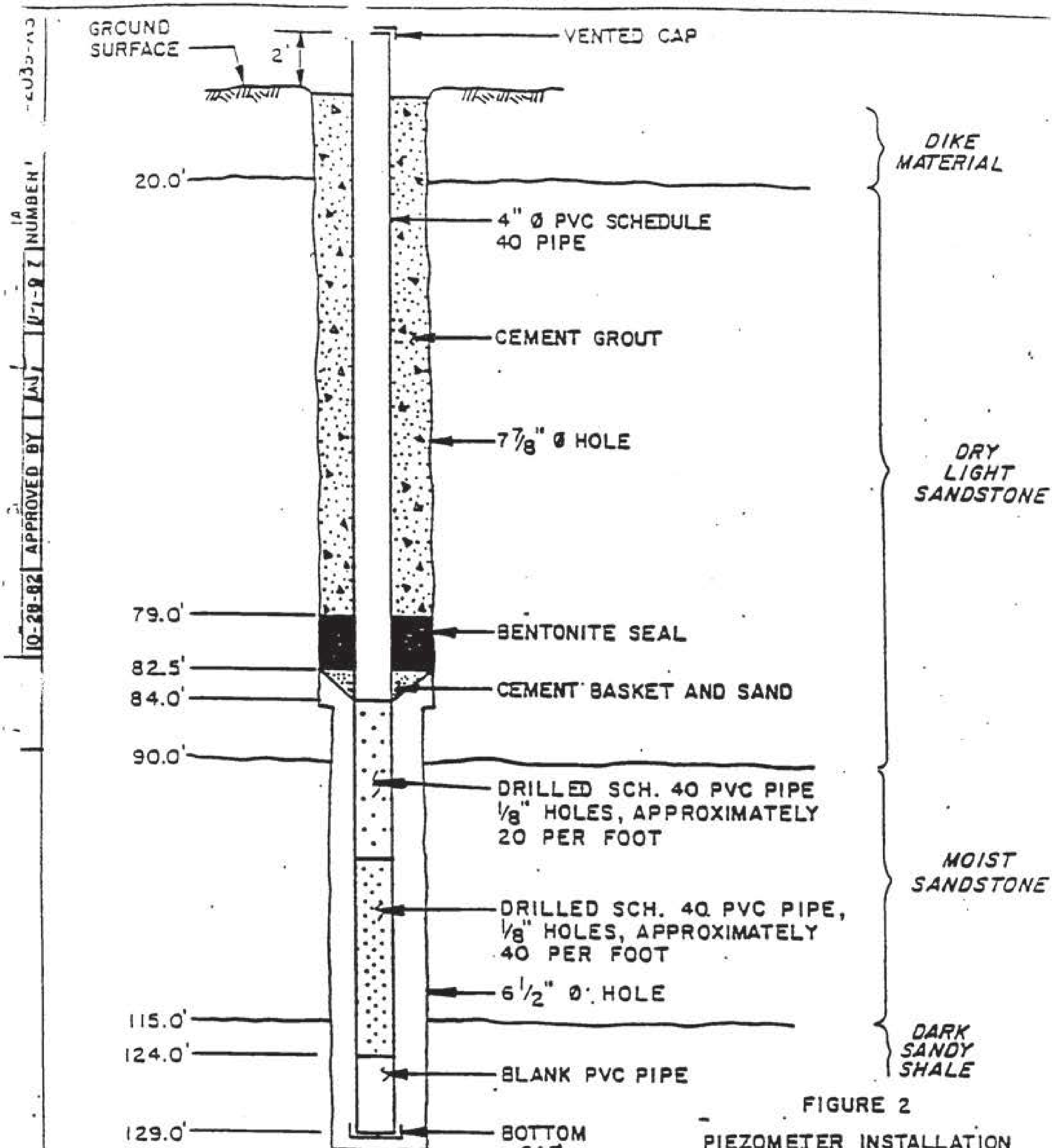


FIGURE 2

PIEZOMETER INSTALLATION
WELL NO. 12
CONSTRUCTION DETAILS

PREPARED FOR

ENERGY FUELS NUCLEAR, INC.
DENVER, COLORADO

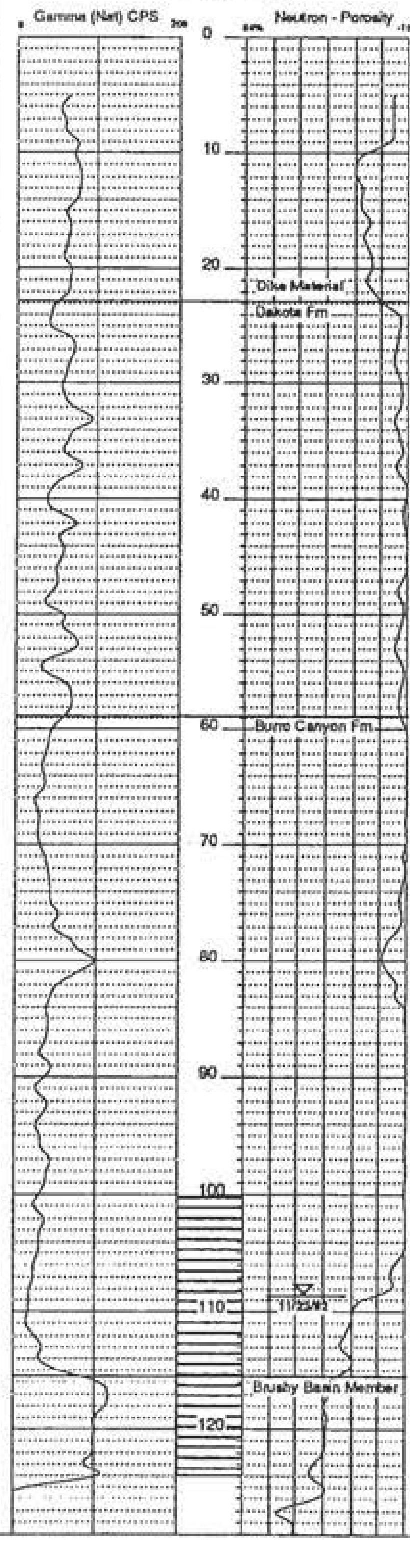
Umetco Minerals Corporation

Location: San Juan County, Utah Date: 11/23/92

Gamma (Nat) - Neutron Porosity

Gd. Elev. 5408.5
T.D. 129

WMMW-12



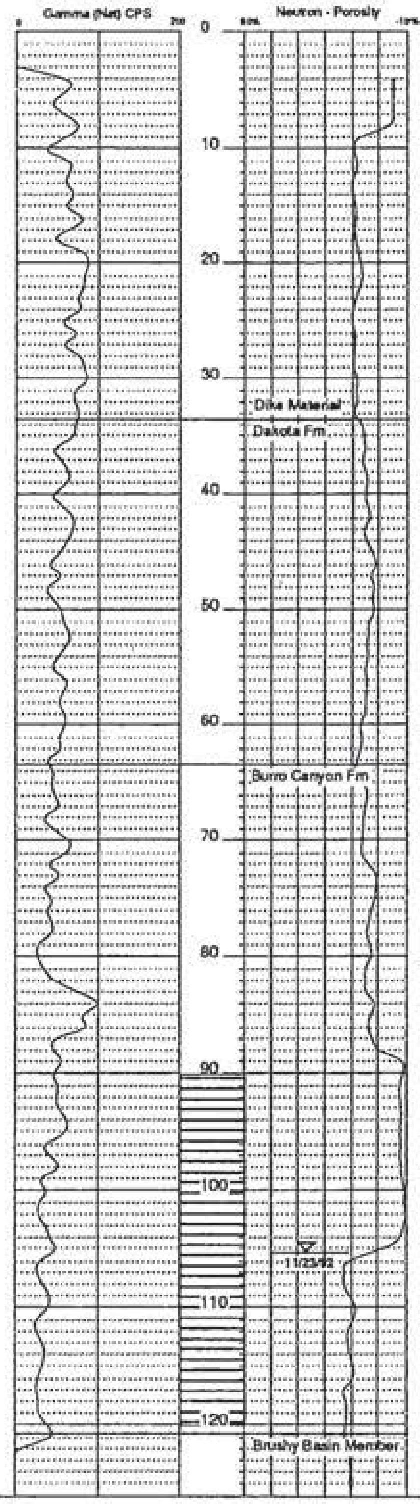
Umetco Minerals Corporation

Location: San Juan County, Utah Date: 11/23/92

Gamma (Nat) - Neutron Porosity

Gd. Elev. 5596
T.D. 127

WMMW-14



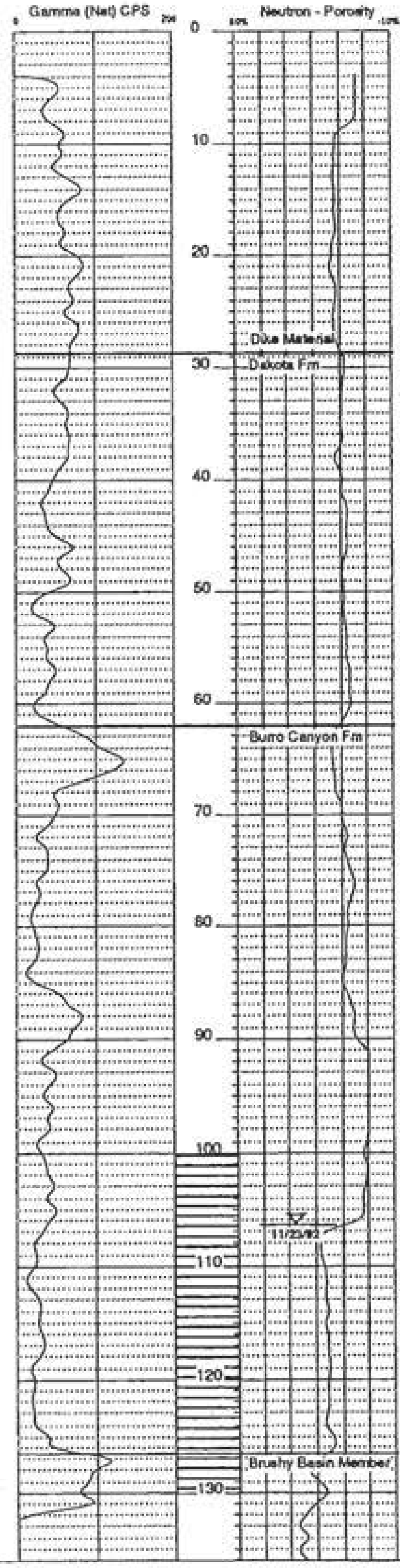
Umetco Minerals Corporation

Location: San Juan County, Utah Date: 11/23/92

Gamma (Net) - Neutron Porosity

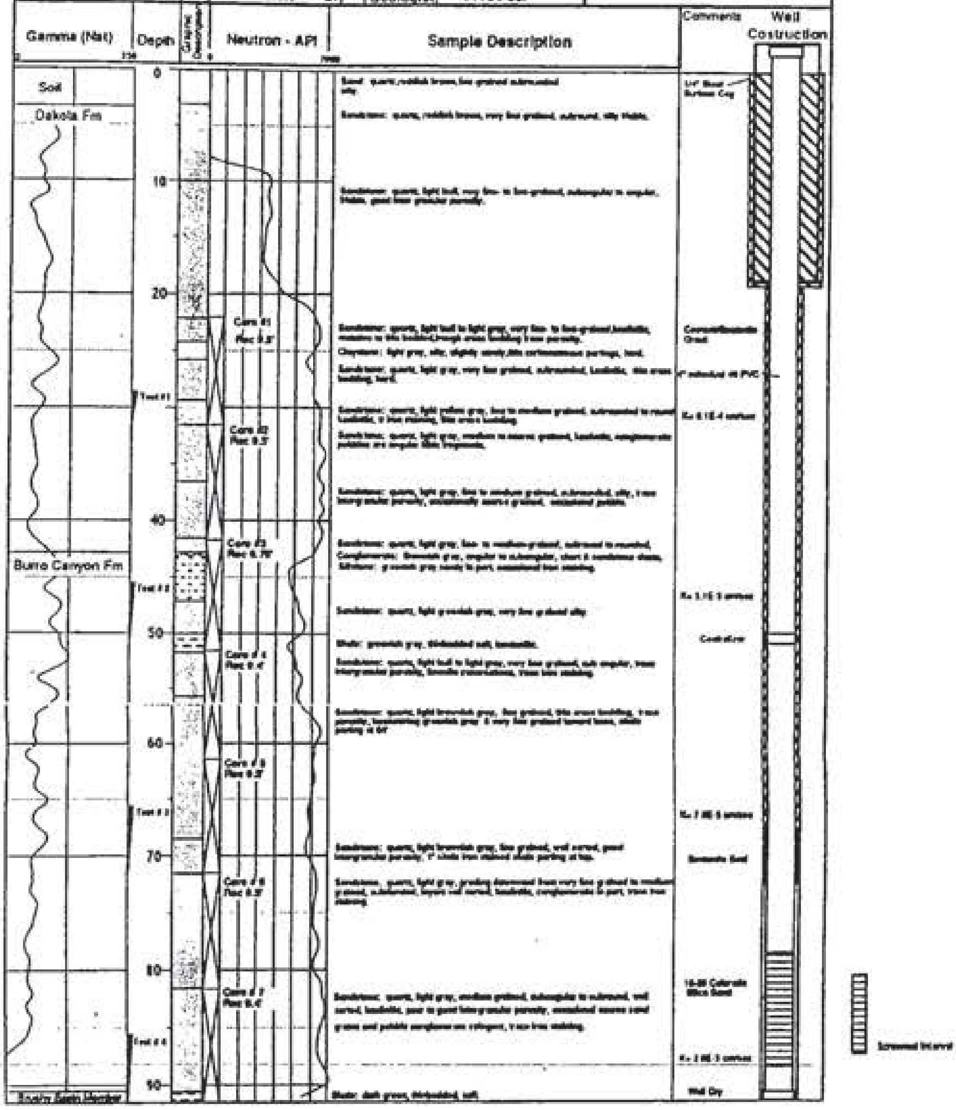
Gd. Elev. 5596.8
T.D. 136

WMMW-15



PEEL Environmental Services

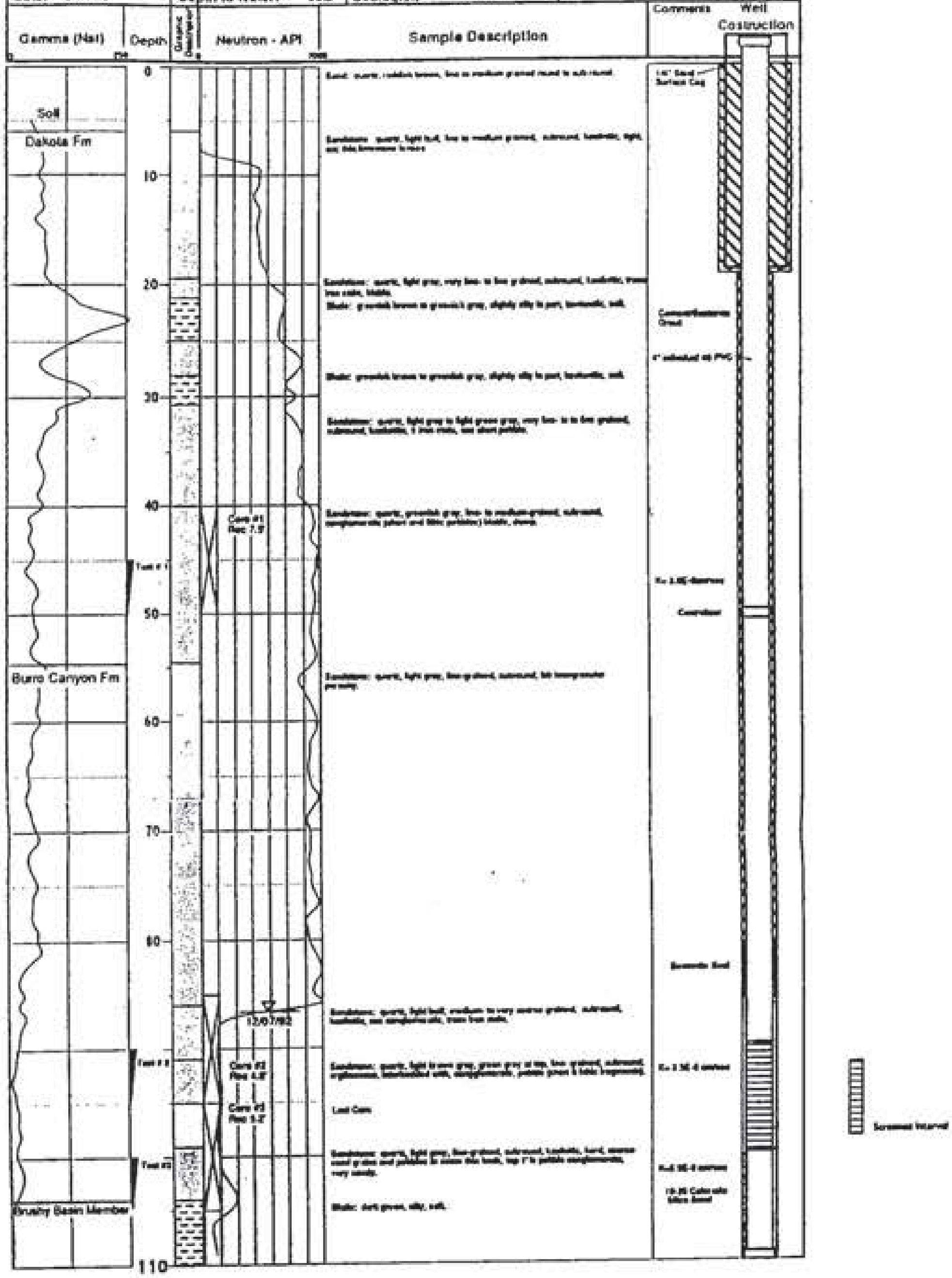
Project: White Mesa	Surface Elev. 5588.18	T. D. = 91.5	Bore Hole No.: WMMW-16
Date: 12/07/92	Depth to Water: Dry	Geologist: F. A. Peel	UMETCO Minerals Corporation



PEEL Environmental Services

Project: White Mesa	Surface Elev. 5575.06	T. D. = 110'	UMETCO Minerals Corporation
Date: 12/07/92	Depth to Water: 86.5'	Geologist: F. A. Peel	

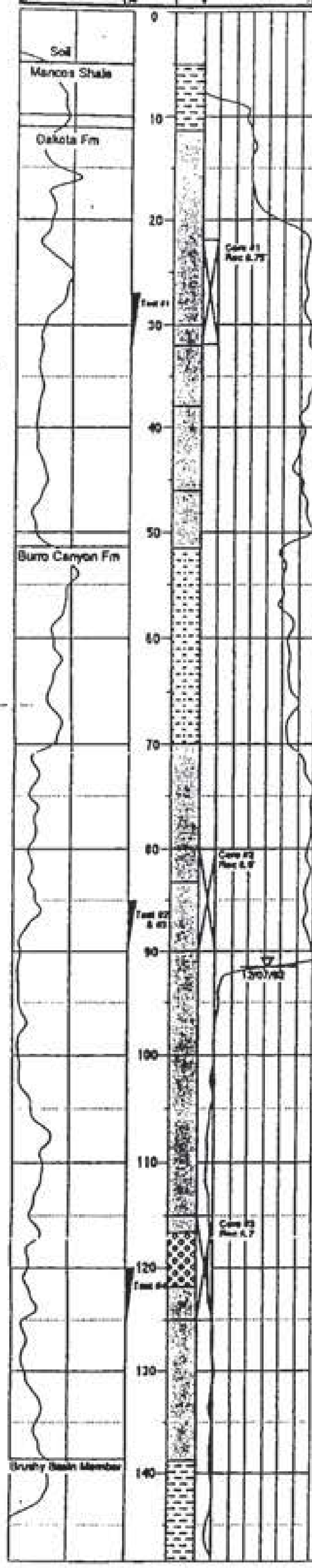
Bore Hole No.: WMMW-17



PEEL Environmental Services

Project: White Mesa	Surface Elev. 5657.58	T. D. : 148.5'	Bore Hole No. : WMMW-18
Date: 12/07/92	Depth to Water: 92'	Geologist: F. A. Peel	UMETCO Minerals Corporation

Gamma (Nat) | Neutron - API | Sample Description | Comments | Well Construction



Sand: quartz, red brown, silty.

Shale: black, platy, hard.

Sandstone: quartz, light buff to light gray, subround, kaolinitic, trace iron staining >>> less toward base, Occ lithic pebble, occ thin shale parting.

Sandstone: as above >>> very conglomeratic in part, pebble size chert and lithic fragments.
Sandstone: quartz, buff, fine-grained, subrounded, slightly argillaceous, kaolinitic, trace iron staining.

Sandstone: quartz, light yellow gray, fine-grained, subangular, iron staining.

Sandstone: as above >>> very fine-grained.

Siltstone: light greenish gray, argillaceous, platy.

Sandstone: quartz, light gray, very fine-grained, subangular, trace kaolinite.

Sandstone: quartz, light gray, very fine- to medium-grained, subangular, occ pebble.

Sandstone: as above interbedded with Conglomerate, pebble [illegible], light gray, sandy in part.

Sandstone: as above.

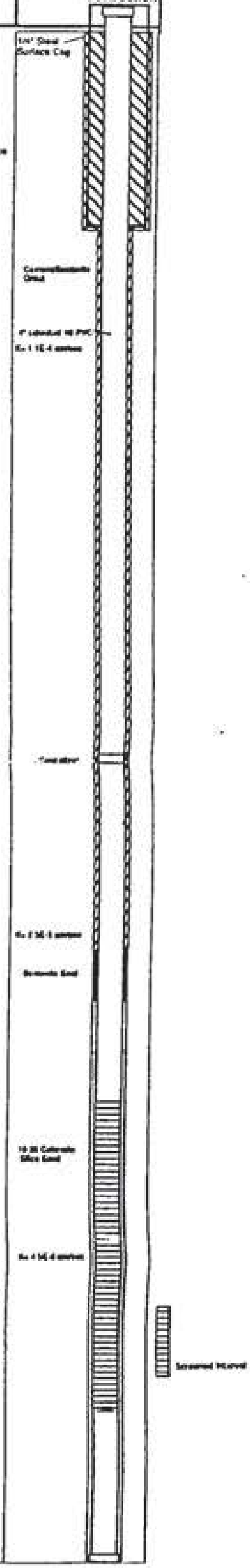
Sandstone: quartz, greenish gray, fine-grained, subangular, to subround, kaolinitic, friable, interbedded with occasional thin shale layer reddish brown, soft.

Sandstone: quartz, light green to greenish gray, very fine- to fine-grained, subround, argillaceous.
Conglomerate: pebble, lithic fragments, very friable, sandy to very sandy in part.

Sandstone: quartz, light green, very fine-grained, argillaceous with thin red and green shale stringers.

Sandstone: as above.

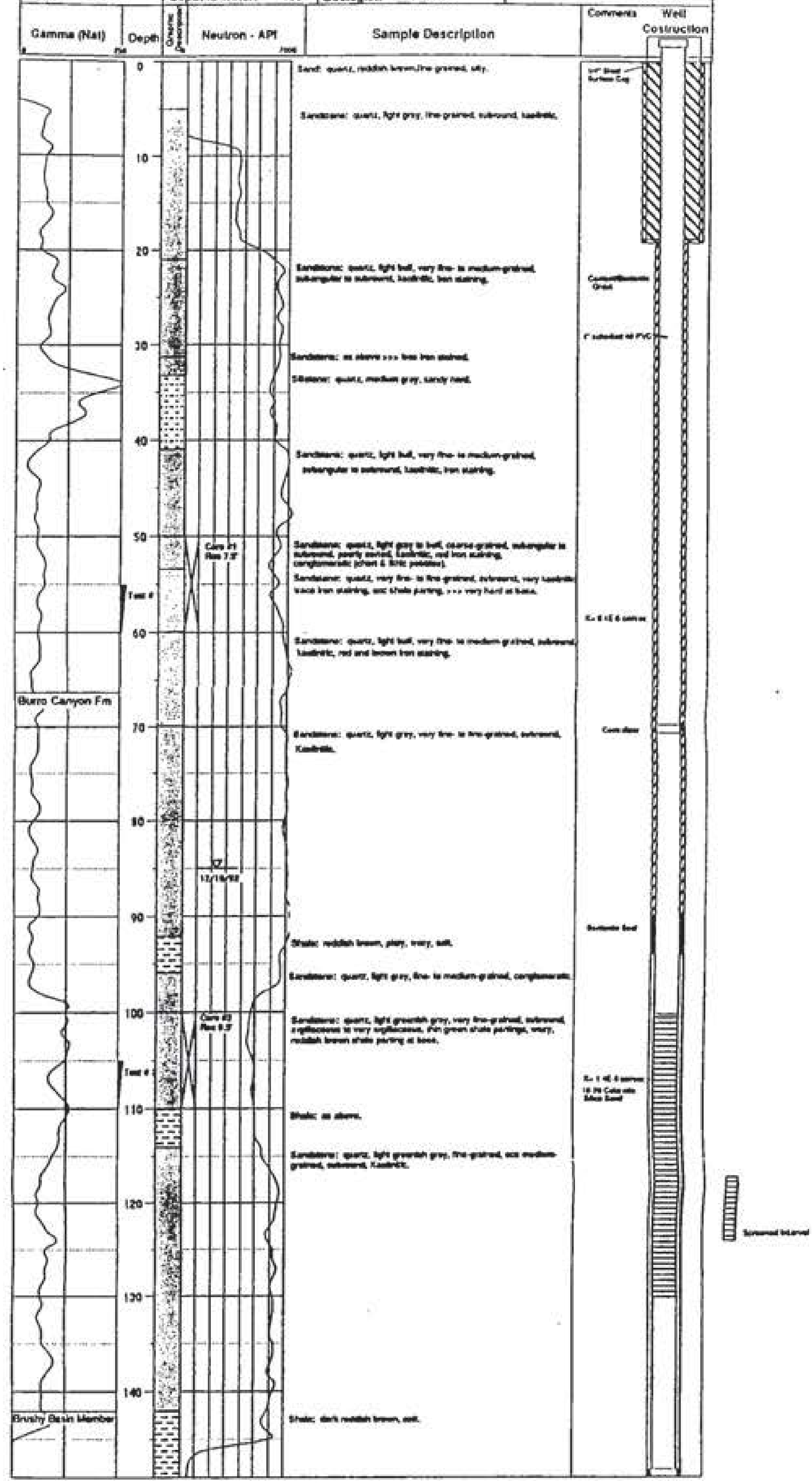
Shale: reddish brown platy, soft.



PEEL Environmental Services

Bore Hole No.: WMMW-19

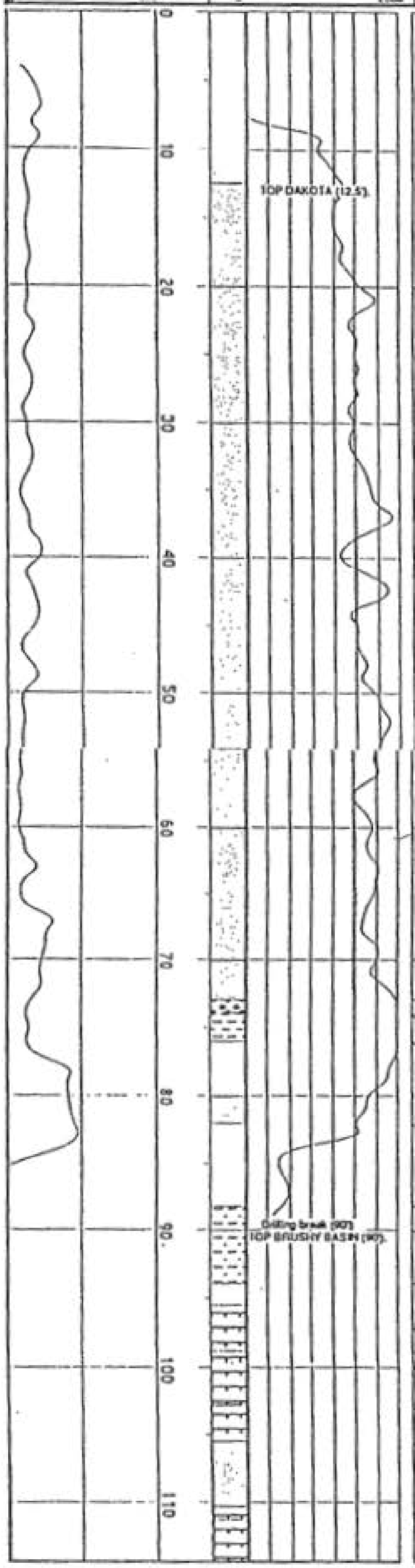
Project: White Mesa	Surface Elev. 5655.05	T. D. = 149	UMETCO Minerals Corporation
Date: 12/07/92	Depth to Water: 150	Geologist: F. A. Peel	



PEEL Environmental Services
Arvada, CO (303)422-5116

Bore Hole No. : WMMW-20			
Project: White Mesa	Surface Elev. 5538 Est	T. D. = 114.5	PBTD = 90'
Date: 8/4/94	Depth to Water: 86.4	Geologist: C. Bilgood	

Gamma (Nat) 0–250	Neutron - API 0–2000	Sample Description



Sample Description

Sand: quartz, reddish brown, silty, argillaceous, aeolian.

Sandstone: quartz, light gray to buff, very fine- to fine grained, argillaceous, subangular, soft.

Sandstone: quartz, light gray, fine- to medium grained, argillaceous, soft, trace iron staining, trace pinpoint porosity.

Sandstone: as above, conglomeratic in part with dark gray chert clasts.

Sandstone: quartz, light gray, argillaceous, fine- to medium grained, firm.

Sandstone: as above, conglomeratic in part, dark gray and white chert clasts.

Sandstone: as above, becoming less argillaceous, light brown gray, medium grained, well sorted, fair intergranular porosity.

Sandstone: quartz, light gray, medium-grained, occasionally coarse-grained, subangular to subrounded becoming very argillaceous, shale clasts from 72.0 to 72.9'.

Conglomerate: lithic, pebble, shale and chert clasts, very sandy, poorly sorted, subrounded.

Shale: olive green, waxy, soft, top 0.2' blocky, sandy.

Missing Core

Sandstone: quartz, dark reddish green to gray, fine-grained, very argillaceous, subrounded, scattered iron staining, massive, hard, tight, becoming dark reddish gray, thin bedded and platy at base.

Missing Core

Siltstone: dark reddish brown, sandy in part, argillaceous, thin stringers of dark red brown silty shale at top.

Siltstone: green, waxy, brittle, occasional vertical tension joints, silty in part, iron staining along 2" near vertical fractures.

Missing Core

Claystone: dark greenish gray with reddish cast, poorly developed horizontal plating, waxy, filled vertical joints, becoming lighter in color at base.

Claystone: light green gray, silty to sandy, hard to very hard.

Claystone: red, silty to sandy, hard, mottled green top and bottom, poorly developed horizontal plating.

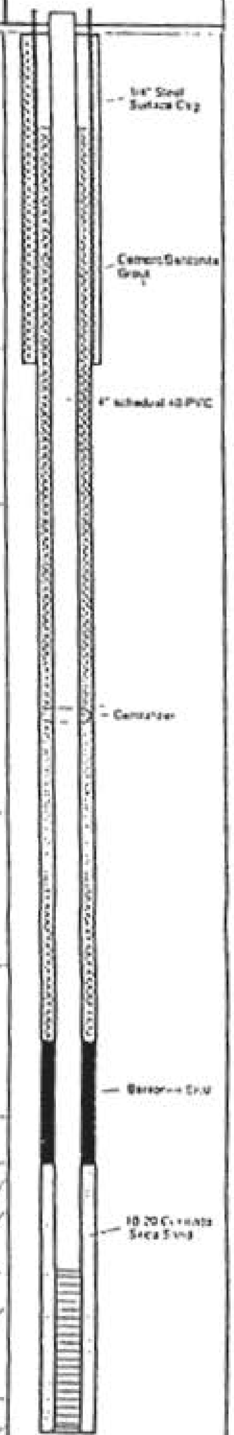
Claystone: dark reddish purple with occasional green tinge, blocky, 2" vertical fracture at base filled with white clay.

Claystone: earthy red, poorly developed horizontal plating, some thin vertical 2" to 4" hairline fractures filled and altered to light green in color.

Sandstone: quartz, light gray green, very fine- to medium grained, very argillaceous, subangular, silty, poorly sorted in part grading downward into light green gray siltstone and light green gray shale, very hard and tight, very argillaceous and sandy.

Claystone: dark red brown, massive, hard.

Claystone: light gray green, poorly developed horizontal plating, hard, sharp contact with overlying red shale.

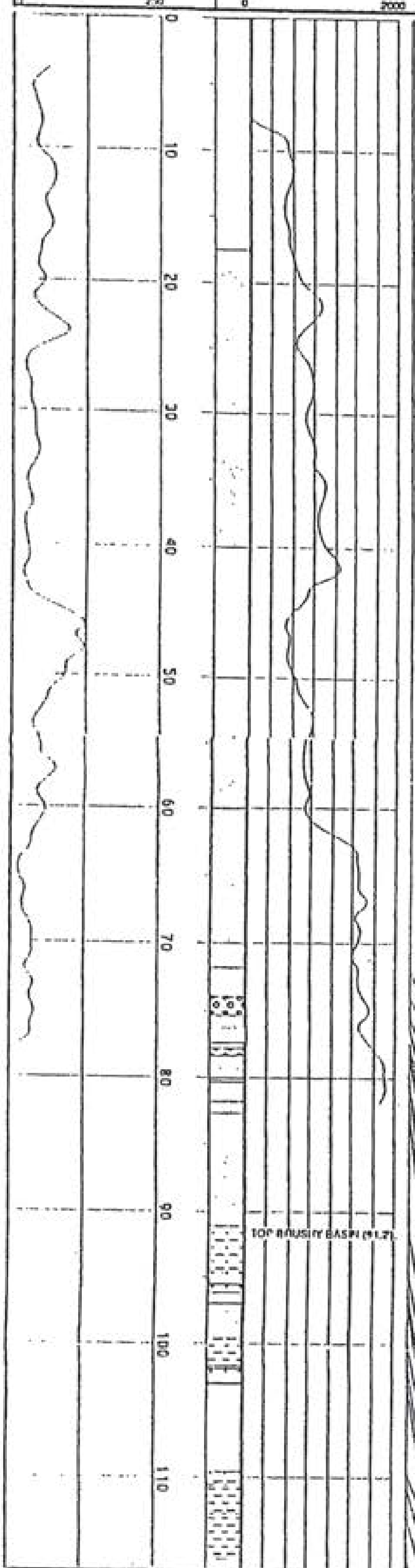


PEEL Environmental Services
Arvada, CO (303)422-5116

Bore Hole No. : WMMW-21

Project: White Mesa	Surface Elev. 5558 Est.	T. D. = 117.0'	PBTD = 90.0'
Date: 8/12/94	Depth to Water: Dry	Geologist: C. Bilgood	

Gamma (Nat) 0 – 250 | Neutron - API 0 – 2000 | Sample Description



Sample Description

Sand: aeolian sand, quartz, reddish brown.

Sandstone: quartz, light gray, fine- grained, angular to subangular to rounded, well sorted, argillaceous, some light tan to gray poorly sorted fine- to medium grained sandstone.

Sandstone: quartz, light tan, fine- to medium grained, argillaceous, limonitic staining, abundant chert fragments (probable conglomerate).

Sandstone: quartz, light tan, fine- to medium-grained, friable, well sorted, olive green soft claystone clasts.

Sandstone: quartz, light gray to greenish gray, fine- to medium grained, sub angular to subrounded, poorly sorted, argillaceous, abundant varicolored chert fragments, conglomeratic in part, pyritic.

Sandstone: quartz, gray to light gray, fine- to medium grained, subrounded, argillaceous, well sorted, abundant pyrite and pyrite crystals probably developed along fractures.

Missing Core

Sandstone: quartz, light gray, medium-grained, subrounded, very argillaceous, conglomeratic, chert fragments, angular to subangular, occasional subrounded pebble, black chert fragments.

Missing Core

Conglomerate: black pebble, chert, very sandy, quartz, medium-grained, subrounded, very argillaceous.

Sandstone: quartz, conglomeratic grading downward to sandy conglomerate.

Missing core

Conglomerate: chert pebble, argillaceous, sandy, hard, tight.

Sandstone: quartz, light gray, fine- to medium grained, subangular to subrounded, conglomeratic, argillaceous, hard, tight.

Sandstone: quartz, light gray, fine- to medium grained, rounded to subrounded, slightly conglomeratic, very hard and tight, well sorted, siliceous cement, no visible porosity.

Sandstone: as above with large vertical fractures filled with pyrite.

Sandstone: quartz, light gray, fine- to medium-grained, subrounded to rounded, very hard and tight, siliceous cement, no visible porosity.

Sandstone: quartz, light gray, very fine- to medium-grained, poorly sorted, conglomeratic, siliceous cement, parting along bedding planes, numerous vertical or near vertical fractures filled with pyrite, very hard and tight, no visible porosity.

Siltstone: very light gray green, pyritic, near vertical fractures, some horizontal bedding parting, hard, becoming more Shaley at base.

Claystone: light gray green, sandy, near vertical fractures, pyritic, blocky in part.

Missing Core

Sandstone: quartz, light gray green, very fine-grained, vertical fractures, occasional small chert pebbles, some horizontal parting.

Shale: gray green, slightly sandy, bedding plane and vertical tension fractures

Claystone: gray green, waxy, soft.

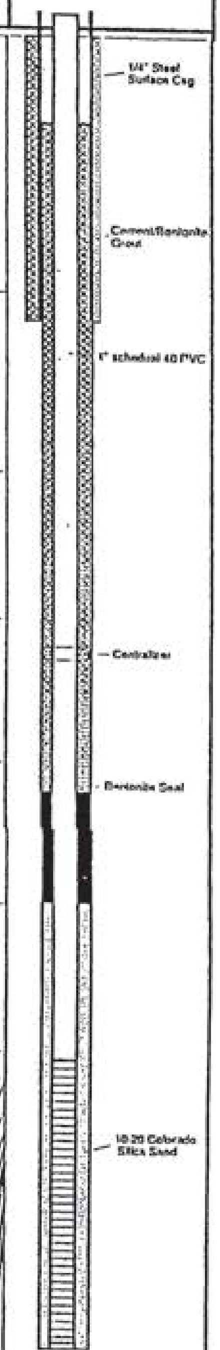
Missing Core

Siltstone: Light gray green with very fine-grained sandstone stringers, chert fragments, argillaceous, very sandy.

Shale: brownish grey, becoming grey green, soft very platy, random tension fracturing.

Shale: light greenish gray to green gray, very sandy, very silty, tension fracturing, trace soft, red shale at base.

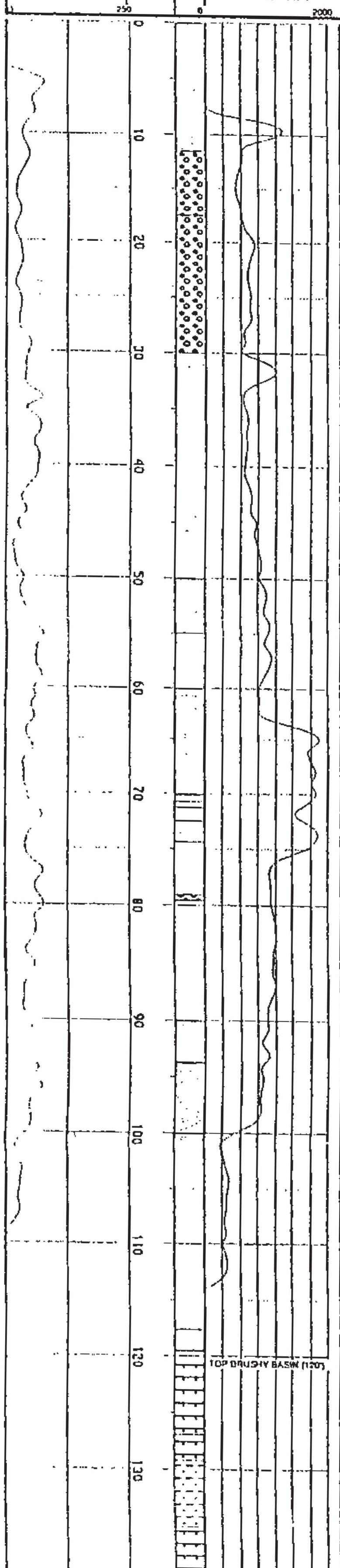
Missing Core



PEEL Environmental Services
Arvada, CO (303)423-5116

Bore Hole No.:	WMMW-22

Project: White Mesa	Surface Elev. 5516 Est	T. D. = 140'	PBTD = 120'
Date: 8/4/94	Depth to Water: 76	Geologist: C. Bilgood	



Sample Description

Sandstone: aeolian sand, quartz, reddish brown.

Conglomerate: chert, light gray to dark gray, occasional translucent, interbedded with light gray quartz sandstone, rounded, thin bedded.

Conglomerate: sandstone and conglomerate as above.

Sandstone: quartz, white to very light gray, fine- to medium-grained, argillaceous

Sandstone: quartz, white to very light tan, fine-grained, well cemented, hard, tight

Sandstone as above, very hard, siliceous cement

Sandstone as above with trace light gray chert fragments, trace iron staining

Sandstone: quartz, light gray to light tan, very fine-grained, subangular, chert clasts to 1/2", siliceous cement, well cemented, hard, iron staining, occasionally light green in color.

Sandstone: as above with increase in chert clasts.

Missing Core

Sandstone: quartz, light tan to light gray, fine- to medium-grained, subangular to subrounded, siliceous cement, tight, becoming very conglomeratic at base, hard, well cemented.

Sandstone: as above becoming conglomeratic at base. Conglomerate pebbles sub angular to subround, varicolored

Missing Core

Conglomerate: varicolored as above, chert and claystone fragments.

Sandstone: quartz, very light gray, very fine-grained, argillaceous, subrounded, occasional rock clasts, trace intergranular porosity, some horizontal bedding parting, some cross bedding

Missing Core

Sandstone: quartz, light gray to light green gray, fine- to very coarse-grained, subangular to rounded, poorly sorted, large 1" green gray claystone clasts, fair to good intergranular porosity, very friable.

Sandstone: quartz, very light gray, fine- to medium-grained, subangular to subrounded, very friable, good intergranular porosity, massive, well sorted.

Sandstone: quartz, light green gray, fine grained, argillaceous, rounded, fair intergranular porosity, friable

Missing Core

Sandstone: quartz, light green gray, fine- to coarse-grained, argillaceous at base, conglomeratic, varicolored, with green claystone, chert and other lithic fragments

Claystone: green, waxy

Missing Core

Claystone: red brown, mottled green, some horizontal parting

Claystone: gray green to bright green, some red mottling and banding

Siltstone: light gray green, hard, very argillaceous, slightly sandy, lower 1' grading into light green claystone.

Claystone: light gray mottled, with red brown claystone, hard, some platyness, some 3" to 10" vertical fractures, some sealed, some [illegible] staining

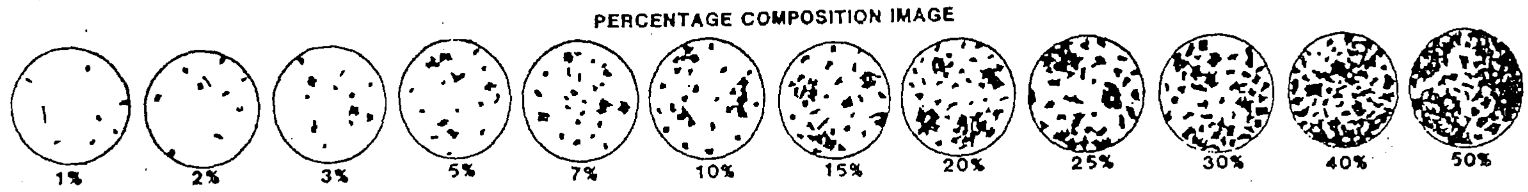
Date 4-4-05 Geologist L Casebolt Drilling Co. Bayles Exploration Hole No. MW-23
Property White Mesa Project MW-23 Unit No. ____ Sec. 32 Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ≈5608

PAGE 1 OF 2
T.D. PROBE ____
T.D. DRILL 132
FLUID LEVEL ____

REMARKS drilled with foam & air

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																					
2.5						sltst	ltrd bn											m			Surface soil.
5.0						sndy sltst	ltrd bn											VS			
7.5						sndy sltst	ltrd bn											S			
10.0						qtz ss, sltst	lt pk bn											VS			
12.5						sltst, sh	lt pk bn											VS			
15.0						slty sh	lt pk bn											VS			
17.5						slty sh	lt pk tn											S			
20.0						sndy sh	lt pk tn											VS			
22.5						qtz ss, sltst	lt bn	f-m	p	sa								VS			Upper Dakota Fm. ct @ approx 21.0 ft
25.0						qtz ss	ltgy bn	f	f	sa								VS			
27.5						qtz ss	ltgy bn	f-m	f	sa		1						S			
-						qtz ss, sh	gy bn	vf-m	f	sa		1						VS			
32.5						qtz ss	ltgy bn	m-cr	p	sa								S			
35.0						qtz ss	lt or bn	m-vcr	p	sa								m			
37.5						qtz ss	lt pk bn	m-cr	p	sa		1						S			
40.0						qtz ss	lt pk bn	m-cr	p	sa		1						M			
42.5						qtz ss	tn	m-vcr	p	a		1						M			abnt. light colored chert frags
45.0						qtz ss	tn	m-cr	f	sa		1						m			" light-dk chert frags.
47.5						qtz ss	tn	m-cr	f	sa		1						M			
50.0						qtz ss	tn	m-cr	f	sa		1						m			
52.5						qtz ss	lt tn	vf-f	w	sa								S			very clean sand.
55.0						qtz ss	lt tn	vf-m	w	sa								m			sparse chert fragments
57.5						qtz ss	lt gy tn	f	w	sa								W			
60.0						qtz ss	lt gy tn	f	w	sr								VW			
62.5						qtz ss	lt tn	f-m	w	sr								N			
65.0						qtz ss	lt tn	f-m	w	sr								N			
67.5						qtz ss	lt tn.	m-vcr	f	sa								N			abunt. light colored chert grains
70.0						qtz ss	lt tn	f-vcr	f	sa								N			
72.5						qtz ss	lt tn	f-m	f	sa								N			
75.0						qtz ss	lt gy tn	f-m	f	sa								N			
77.5						qtz ss	lt gy tn	f-m	f	sa								N			
80.0						qtz ss	lt gy tn	m	w	sr								M			
82						qtz ss	lt gy	m	w	sr								N			
85.0						qtz ss	lt gy bn	f-m	f	sr								N			
87.5						qtz-ss	lt gy bn	m	w	sr								N			
90.0						qtz ss	lt gy bn	m	w	sa								N			
92.5						qtz ss	lt bn	m-cr	f	sa								N			abunt. light colored chert grains
95.0						qtz ss	lt bn	m	f	sa								N			
97.5						qtz ss	tn	f	w	sr								N			
00.0						qtz ss	yw tn	m	w	sr								N			
102.5						qtz ss	yw tn	f-m	f	sr								N			
05.0						qtz ss	yw tn	f	w	sr								N			
107.5						qtz ss	yewtn.	vf-f	f	sr								N			
10.0						qtz ss	yw tn	f	w	sr								N			
12.5																					
15																					
17.5																					
20.0																					
22.5																					
25.0																					

PERCENTAGE COMPOSITION IMAGE



Date 4-4-05 Geologist L. Casebolt Drilling Co. Bayles Exploration Hole No. MW-23
Property White Mesa Mill Project MW-23 Unit No. ____ Sec. 32 Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 2 OF 2
T.D. PROBE ____
T.D. DRILL 132
FLUID LEVEL ____

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
125.0																					
127.5																					Upper Brushy Basin Mbr. ct @ approx 126.8'
130.0																					(from core log - no cuttings below 110.0')
132.0																					

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Core Log of Well No. MW-23

Cored Interval 49.0 ft. to 132.0 ft. T.D.

Depth	Description
49.0 - 59.5	Core recovery 100%, 49.0 - 59.5 ft., quartz sandstone, fine - medium grained, tan, non calcareous cement, cross-bedded, very uniform, most partings occur along cross beds and are mechanical (broken during drilling), no mineralized or weathered surfaces.
59.5 - 70.0	Core recovery 95%, 59.5 - 61.5 ft., quartz sandstone, fine - medium grained, tan, non calcareous, cross-bedded as above, lower contact is 45 degree angle erosional surface. 61.5 - 64.0 ft., quartz sandstone, very light gray, medium grained, very clean sandstone, no mineralized partings, grades downward into conglomerate. 64.0 - 69.5 ft., quartz sandstone, medium - grit sized grains, very coarse chert pebble conglomerate from 67.0 - 69.5 ft.. 69.5 - 70.0 ft., quartz sandstone, medium - coarse grained, very light gray.
70.0 - 80.0	Core recovery 90%, 70.0 - 70.5 ft., no core recovered, 70.5 - 73.5 ft., siltstone, very light gray- green, soft core, low angle parting with limonite at 73.0 ft.. 73.5 - 80.0 ft., quartz sandstone, light gray-tan to light pink-tan, limonite stained low angle parting at 73.7 ft., grit zone at 75.0 ft., and from 75.5 - 76.5 ft., small limonite blebs after sulfides at 77.5 - 78.0 ft., some manganese dendrites from 78.5 - 79.5 ft., calcareous zone from 78.5 to 79.5 ft..
80.0 - 90.0	Core recovery 87%, 80.0 - 84.5 ft., quartz sandstone, light gray-tan, fine - medium grained, non calcareous cement, no mineralized partings. 84.5 - 85.7 ft., quartz sandstone, pink-tan to yellow orange, medium - grit sized grains, abundant disseminated limonite at 85.5 - 85.7 ft.. 85.7 - 87.0 ft., core not recovered. 87.0 - 89.0 ft., quartz sandstone, pink-tan, medium - grit sized grains. 89.0 - 90.0 ft., quartz sandstone / gritstone, some disseminated limonite.
90.0 - 100.0	Core recovery 40%, 90.0 - 96.0 ft., no core recovered. 96.0 - 100.0 ft., quartz sandstone / gritstone, medium - very coarse, light tan - yellow-orange, abundant disseminated limonite from 97.8 - 98.2 and from 99.5 - 100.0 ft., mechanical partings along un-mineralized bedding planes, non calcareous.
100.0 - 110.0	Core recovery 100%, 100.0 - 102.3 ft., quartz sandstone, fine - medium grained, light yellow-orange to pink-tan, abundant limonite from 100.0 - 101.0, hematite from 101.5 - 102.3. 102.3 - 105.5 ft., quartz sandstone, fine - medium grained, light gray,

Core log of well MW- 23 Cont.

	unmineralized mechanical partings. 105.5 - 106.0 ft., disseminated limonite zone, yellow-orange. 106.0 - 110.0 ft., quartz sandstone, fine - coarse grained, light gray to orange-yellow.
11.0 - 120.0	Core recovery 100%, 110.0 - 111.2 ft., no core recovered. 111.2 - 113.5 ft., quartz sandstone / conglomerate, fine - grit size grains, light gray to light gray-green, green clay blebs plus dark chert fragments and pebbles. 113.5 - 114.5 ft., quartz sandstone / gritstone, abundant hematite mineralization, yellow-orange. 114.5 - 120.0 ft., quartz sandstone / gritstone, cross-bedded, gray-tan, chert fragments and pebbles at 115.0 - 116.5, 117.5 - 118.5, and 119.0 - 120.0 ft., non calcareous.
120.0 - 130.0	Core recovery 91%, 120.0 - 120.9.0 ft., no core recovered. 120.9 - 126.8 ft., quartz sandstone / gritstone, gray-tan to dark gray, dark gray chert fragments and pebbles, no mineralized partings observed, calcareous zone from 124.2 - 126.8 ft., upper Brushy Basin Mbr. contact at 126.8 ft. 126.8 - 129.7 ft., shale, green. 129.7 - 129.8 ft., gritstone as above.
130.0 - 132.0	Core recovery 100%, shale, green, non calcareous, T.D.

Date 4-7-05 Geologist L. Casebolt Drilling Co. Bayles Exploration Hole No. MW-24
Property White Mesa Mill Project ______ Unit No. ______ Sec. 32 Twp. 37S Rge. ______
County San Juan State Utah Location ______ Elev. ≈5620

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 120 ft.
FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																
2.5	sltysh	orbn											S			
5.0	sltysh	wh-ltorbn											VS			
7.5	sltysh	ltrdbn											VS			
10.0	sltysh	lttn-ltrdbn											VS			
12.5	sltysh	ltpk-wh											VS			
15.0	sltysh, qtzss	ltorbn	f-cr	p	a								m			Upper contact Dakota Fm. @ approx 13.0 ft.
17.5	qtz ss	tn	m	w	sr		L						N			
20.0	sh	ltpogy											N			
22.5	qtz ss	ltgytn	vf-f	f	sa		L						N			Note coring began @ 20.0'
25.0	qtz ss, sh	ltgytn-wh	f-m	f	sa								N			
27.5	qtz ss, sh	ltgytn-wh	vf-m	p	sa								N			
30.0	qtz ss	lttn	vf-f	f	sa								N			
3-	qtz ss	ltgy	vf	w	sa								N			
3.	qtz ss	ltgy	vf-f	f	sa								N			
37.5	qtz ss	ltgy	f-m	f	sr								VW			
40.0	qtz ss	ltgy	f-cr	f	sr								VW			
42.5	qtz ss	ltgy	m	w	sr								N			
45.0	qtz ss	ltgy	m-cr	f	sr								N			
47.5	qtz ss	ltgy	m-cr	f	sr								N			
50.0	qtz ss	ltgy	m	w	r								N			
52.5	qtz ss	ltgytn	m-cr	f	sr								N			
55.0	qtz ss	ltorbn	m-cr	f	sa								N			multi colored chert frags as grains
57.5	qtz ss, sh	ltgygn-ltbn	m-cr	p	sa								N			
60.0	qtz ss	gy	vf-f	f	sr								N			
62.5	qtz ss, sh	gybn	vf-f	f	sr								N			
65.0	qtz ss, sh	ltgybn	vf-f	f	sr								N			
67.5	qtz ss	ltgybn	f	w	sr								N			
70.0	qtz ss	gybn	f	w	sr								N			
72.5	qtz ss	gybn	f	w	sr								N			
75.0	qtz ss	gybn	f-c	p	sa								N			some chert fragments as sand grains
77.5	qtz ss, sh	gy	vf-f	p	sr								VW			
30.0	qtz ss	ltgy	f-m	f	sr								VW			
32.5	qtz ss	ltgy	f	f	sr								N			
35.0	qtz ss	ltgytn	m-cr	f	sr								N			
3'	qtz ss	ltgy	m-cr	f	sr								S			
70.0	qtz ss	tnbn	f-m	f	sr		L						S			
12.5	qtz ss	ltgytn	m-cr	f	sr								W			
50	qtz ss	ltgy	m-vcr	p	sr								VW			Some light colored chert frags. as grains
75	qtz ss	ltgy	m-cr	w	r								VW			" " " " " " "
00.0	qtz ss	ltgy	m-cr	w	r								VW			" " " " " " "
2.5	qtz ss	ltorgy	m-cr	f	sa								N			" " " " " " "
5.0	qtz ss	ltgy	m-cr	f	sr								N			" " " " " " "
7.5	qtz ss	lt tn	f	w	sr								N			
2.0	qtz ss	lt tn	f-m	w	sr								N			
2.5	qtz ss	lttn	f-m	w	sr								N			
5.0	qtz ss	ltgytn	m	w	sr								N			
75	qtz ss	ltgytn	m	w	r								N			
26	qtz ss, sh	ltgytn-gn											VW			upper Brushy Basin Ct. @ 118.5 ft.
70.																

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Core Log of Well No. MW-24

Cored Interval 20.0 ft. to 120.0 ft. T.D.

Depth	Description
20.0 - 29.0	Quartz sandstone, very fine - fine grained, non calcareous cement, some chert pebbles from 20.0 - 20.5 ft.. 20.5 - 23.5 quartz sandstone, very fine - fine grained, gray to light tan brown, weathered contact at 23.5 ft. with hematite/limonite. 23.5 - 27.5 siltstone/shale, very light gray, high angle parting with slickensides at 25.5 ft. 27.5 - 29.0 quartz sandstone, very fine grained, light gray tan, some low angle parting with hematite/limonite coatings.
29.0 - 38.0	Quartz sandstone, very fine - fine grained, light gray with disseminated hematite/limonite staining from 29.0 - 29.2 ft. and from 29.0 - 29.2 and 29.3 - 29.4 ft., also some low angle partings with hematite staining. 30.0 - 34.0 quartz sandstone, very fine - fine grained, light gray tan, non calcareous. 34.0 - 34.5 quartz sandstone, fine - medium grain, abundant disseminated limonite. 34.5 - 38.0 quartz sandstone, fine - medium grained, very light gray tan, non calcareous cement, some low angle partings.
38.0 - 48.0	Core recovery 100%, 38.0 - 39.9 ft., quartz sandstone, very fine grained, very light gray, well sorted. Non calcareous cement. 39.9 - 48.0 quartz sandstone, very light gray - white, medium grained, well sorted, some disseminated limonite patches from 47.0 - 47.5 ft., non calcareous cement. No mineralized partings.
48.0 - 58.0	Core recovery 88%, 48.0 - 51.5 ft., quartz sandstone, light gray, fine - coarse grained, non calcareous cement, disseminated limonite at 48.5 and 50.5 - 51.2 ft. 51.5 - 56.0 ft., quartz sandstone / conglomerate, medium - grit sized grains, consists of chert fragments and pebbles, conglomerate zones at 51.5 - 52.0 ft., 53.7 - 54.0 ft., 55.5 - 56.0 ft., non calcareous. 56.0 - 58.0 ft., siltstone / shale, light gray-green.
58.0 - 69.0	Core recovery 93%, 58.0 - 69.0 ft., quartz sandstone / siltstone, very fine grained, light tan, rounded grains, disseminated limonite from 58.9 - 59.5 ft., and 60.5 - 61.0 ft., low angle partings with hematite / limonite coatings at 62.7 ft., and 66.0 ft., grain size increases to fine from 67.0 - 69.0 ft., two small 2 - 4 cm patches of limonite after pyrite with remnant pyrite in center of patchs at 68.5 ft.
69.0 - 80.0	Core recovery 73%, 69.0 - 70.0 ft., quartz sandstone, fine - medium grained, light tan, very clean sandstone, non calcareous cement. 70.0 - 72.0 ft. core not recovered.

Core log of well MW- 24 Cont.

	72.0 - 72.2 ft., green shale. 72.2 - 76.0 ft., quartz sandstone / conglomerate, fine - medium grained, grading downward into conglomerate from 75.0 - 76.0 ft., light gray-tan to tan. 76.0 - 78.0 ft., quartz sandstone, very fine grained, light purple-pink to yellow-tan. 78.0 - 79.5 ft., shale, gray-green, poor recovery. 79.5 - 80.0 ft., quartz sandstone, fine - medium grained, gray, abundant disseminated limonite, some manganese dendrites.
80.0 - 90.0	Core recovery 100%, 80.0 - 80.2 ft., shale, gray-green. 80.2 - 90.0 ft., quartz sandstone, medium - grit size grains, light gray-tan, abundant 2 - 3 cm diameter spherical patches of disseminated black mineral from 80.2 - 83.0 ft., no mineralized partings observed. conlomerate zones at 84.0 - 84.3 ft., 84.5 - 85.0 ft., and 87.7 - 88.2 ft., non calcareous cement.
90.0 - 100.0	Core recovery 90%, 90.0 - 95.0 ft., quartz sandstone, fine - grit sized grains, light gray-tan, conglomerate zones at 90.2 - 91.0 ft., 92.3 - 95.0 ft., non calcareous cement, some disseminated limonite. 95.0 - 97.0 ft., quartz sandstone, fine - medium grained, light gray. 97.0 - 98.0 ft., quartz sandstone, medium - grit sized grains, light yellow-gray, some conglomerate zones. 98.0 - 99.0 ft., core not recovered. 99.0 - 100.0 ft., quartz sandstone, medium grained, light gray-tan, very friable.
100.0 - 110.0	Core recovery 70%, 100.0 - 105.0 ft., quartz sandstone / conglomerate, fine - grit sized grains, light gray to tan, conglomerate zones from 100.0 - 100.2 ft., 102.5 - 103.5 ft., 103.5 - 105.0 ft., quartz sandstone, medium grained, non calcareous cement. 105.0 - 110.0 ft., quartz sandstone, medium grained, some disseminated limonite, very soft and friable.
110.0 - 120.0	Core recovery 100%, 110.0 - 114.5 ft., quartz sandstone, yellow-tan to gray-pink, medium grained, abundant disseminated limonite in this zone. 114.5 - 116.7 ft., quartz sandstone, medium grained, light gray. 116.7 - 117.5 ft., abundant disseminated limonite. 117.5 - 118.5 ft., quartz sandstone, fine - medium grained, gray, calcareous cement. 118.5 - 118.6 ft., conglomerate / shale, green, upper Brushy Basin Mbr. contact at 118.5 ft., contact is high angle. 118.6 - 120.0 ft., shale, green. T.D.

ate 4-9-05 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. MW-25
Property White Mesa Mill Project ______ Unit No. ______ Sec. 33 Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ≈ 5610

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 115.0
FLUID LEVEL ______

DEPTH	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																
2.5	Sndy sltst	rdbn	vf-f	p	sa								M			Surface soil
5.0	Sndy sltst	rdbn	vf-f	p	sa								M			Mancos Shale
7.5	Sndy sltst	rdbn	vf-f	p	sa								N			
10.0	Sndy sltst	rdbn	vf-m	p	sa								M			
12.5	sltst, sh	rdbn-vlttn											VS			
15.0	sltst, sh	rdbn-vlttn											VS			
17.5	sh	ltpktn											VS			
20.0	sh	ltywtn											VS			
22.5	sh	ltywtn											VS			
25.0	sh	ltywtn					L	T					VS			
27.5	sh	ltywgy											S			
30.0	sh	ltywgy											VS			
32.5	sh	ltywgy											M			Sparse selenite (gyp) xls
3...	Sndy sltst	ywgy	vf-f	p	sa		L	T					VW			Sparse selenite (gyp) xls
37.5	Sndy sltst	ywgy	vf-f	p	sa		L	m					N			Sparse selenite (gyp) xls
40.0	Sndy sltst	ywgy	vf-f	p	sa		L	m					N			Sparse selenite (gyp) xls.
42.5	sltst, qtzss	ywgy	f-m	f	sa		L	m					N			Upper Dakota Fm contact @ approx 42.0 ft.
45.0	qtzss, chert	tnbn	f-vcr	p	sa		L	T					N			
47.5	sh, qtzss	gy-tn	m	p	sa								N			Sparse selenite xls.
50.0	slty sh	gy-ortn					L/H	T					N			
52.5	qtzss	tn	f-m	f	sa		L	T					N			
55.0	qtz ss, chert	tn	m-vcr	p	sa								N			
57.5	qtz ss, chert	tnbn	m-vcr	p	sa								N			
60.0	qtz ss	ortn	f-cr	f	sa		L	T					N			
62.5	qtz ss	vlttn	f-m	f	sr								N			
65.0	qtz ss	vlttn	f-m	f	sr								N			
67.5	qtz ss	tn	m-cr	f	sr		L	m					N			
70.0	qtz ss	tn	vf-m	f	sa								N			
72.5	qtz ss	tn	m	w	sr								N			
75.0	qtz ss	tn	m	w	sr								N			
77.5	qtz ss	tn	m	w	sr								N			
80.0	qtz ss	tn	m-cr	f	sr								VW			
82.5	qtz ss, sh	tn-gy	f-m	f	sa								VW			
85.0	qtz ss	tn	f-cr	f	r								VW			
8?	qtz ss	tn-blgy	f-m	f	sr								S			Sparse blgy sh frags.
90.0	qtz ss	vltblgy	vf-f	f	sr								VW			weakly cemented
92.5	qtz ss	vltblgy-wh	vf-f	f	sr								VW			" "
95.0	qtzss, cgl	vltblgy-wh	vf-peb	p	sa								VW			sparse dk gy chert pebbles
97.5	qtz ss	vlttn	vf-f	f	sa								N			
100.0	qtz ss	vlttn-wh	vf-f	f	sa								N			
102.5	qtz ss	wh	f-m	f	sr								N			
105.0	qtzss, cgl	ltgytn	f-peb	p	sr								N			abnt. multi colored chert pebbles & frags.
107.5	qtz ss	vltgy-wh	m	w	r								W			Moisture first noted
110.0	qtz ss	vlttn-wh	vf-m	f	sr								W			
112.5	qtzss, cgl	vlttn-wh	f-m	w	sr								W			Sparse dk chert frag.
115.0	qtz ss, cgl, sh	wh-blgn	f-peb	p	r								N			upper Brushy Basin Ct. @ approx 113.0 ft.
																T.D.

PERCENTAGE COMPOSITION IMAGE

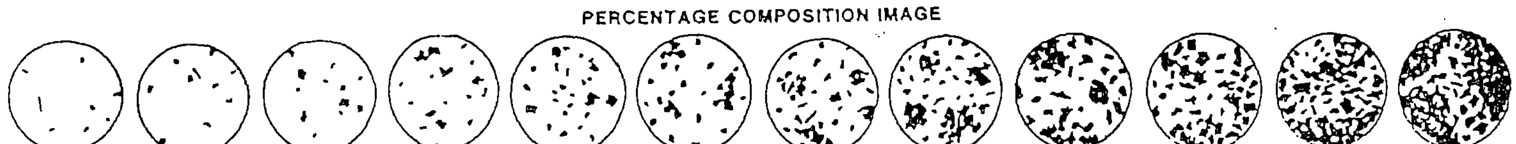
1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 4-5-05 Geologist L. Casebolt Drilling Co. Boyles Exploration Co. Hole No. MW-27
Property White Mesa Mill Project ______ Unit No. ______ Sec. 28 Twp. 37S Rge. ______
County San Juan State Utah Location ______ Elev. ≈5625

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 95.0
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						Sndy Sltst	rdbn	vf cr	p	a								N			Surface soil.
5.0						Sndy Sltst	rdbn	vf cr	p	a								W			
7.5						Sltst	rdbn											W			
10.0						Sltst, ss	ywbn	f m	P	sa								S			
12.5						qtz ss	tn	m	w	sr		LT						VW			
15.0						qtz ss, sh	vltgy-ltpk	vf-m	P	sa		LT						N			
17.5						sltst	vltgy-wh											N			
20.0						sltst	vltgy-wh											N			
22.5						sltst	vltgy-wh											N			
25.0						qtz ss, chert	ltpktn	vf vcr	p	a								N			Upper contact Dakota Fm @ approx. 23.0 ft.
27.5						qtz ss	lttn	f-m	w	sr								N			Moisture First noted 27.0'
30.0						qtz ss	ltpktn	f- m	w	sr		LT						N			
32.5						qtz ss, chert	ltpktn	f-vcr	p	a								N			
3						qtz ss	lttn	f-vcr	p	a		LM						N			
37.5						qtz ss, chert	ltgytn	f-vcr	p	a		LT						N			
40.0						qtz ss, chert	gytn	f-vcr	P	a		LT						N			abnt. multicolored chert frags.
42.5						qtz ss, chert	gytn	f-vcr	p	a								N			" " " " "
45.0						qtz ss	tn	m-cr	f	sa								N			
47.5						qtz ss	tn	m-cr	f	sa								N			
50.0						qtz ss	vlttn-wh	f-cr	P	sa								N			
52.5						qtz ss cgl.	tn-ltgy	m-peb	p	sa								N			abnt multicolored chert frags. & pebbles
55.0						qtz ss	tn	m-cr	w	sr								N			
57.5						qtz ss, cgl.	tn-gy	m-peb	p	a		LT						N			
60.0						qtz ss	lttn	m-cr	w	sr								N			
62.5						qtz ss, sltst	tn-gy	vf-cr	P	sa								N			trace manganese dendrites
65.0						sh	ppgy											N			
67.5						sh, qtz ss	blgy-wh	vf f	w	sa								N			
70.0						qtz ss, sh	wh-vltgy	vf-f	f	sa			T	C				N			
72.5						qtz ss	wh	m	w	sr								N			
75.0						qtz ss	wh	f m	f	sr								N			
77.5						qtz ss	wh	vf f	f	sr								N			
80.0						qtz ss	wh	m cr	f	sr			T	C				N			
82.5						qtz ss, chert	vlttn	m cr	f	sr			T	C				N			sparse dk chert frags & grains
85.0						qtz ss	vlttn-wh	m	w	sr								N			
8'						qtz ss	vltgytn	m cr	f	sr			A	C				N			
90.0						qtz ss, sh	ltgy-blgy	f-vcr	p	sr								M			upper Brushy Basin Ct @ approx. 88.0 ft.
92.5						sh, sltst	gygn											N			
95.0						sh	gygn											N			TD

PERCENTAGE COMPOSITION IMAGE



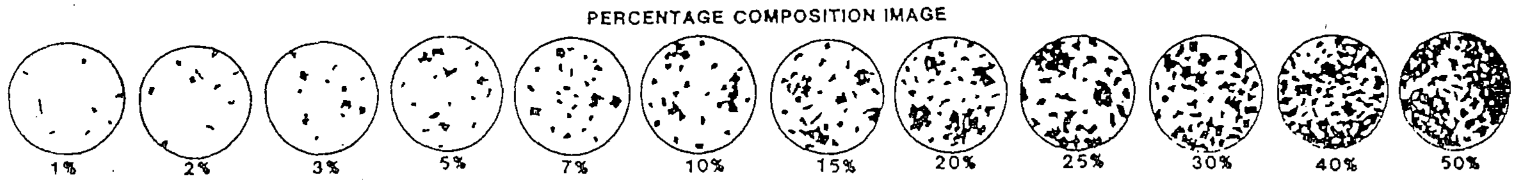
1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

ate 4-5-05 Geologist L. Casebolt Drilling Co. Bayles Exploration Co Hole No. MW-28
Property White Mesa Mill Project ______ Unit No. ______ Sec. 33 Twp. 37S Rge. ______
County San Juan State Utah Location ______ Elev. ≈ 5618

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 110.0
FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																					
2.5						sltst-sh	lt tn-gy											VS			
5.0						sltst-sh	lt rd bn											VS			
7.5						slty sh	lt rd bn											VS			
10.0						slty sh	lt rd bn											VS			
12.5						slty sh	lt rd bn											VS			
15.0						slty sh	lt rd bn											VS			abunt. selenite xls (gypsum)
17.5						slty sh	dk rd br											VS			
20.0						sh	rdbr-lt yw gy											S			Significant Color Change
22.5						sh-qtz ss	vlt gy-wh	vf-f	f	sa								M			Upper Dakota Fm Contact @ approx 22.0 ft.
25.0						qtz ss	vlt tn-wh	f-m	f	sa								N			
27.5						qtz ss	wh-lt tn	vf-f	f	sa		L						N			
30.0						qtz ss sltst	lt gy-lt tn	m-cr	f	sa		L						N			
3						qtz ss	tn	m-cr	w	sr								N			
35.0						qtz ss	yw tn	f-m	f	sa								N			
37.5						qtz ss	lt tn	f-m	f	sr								N			
40.0						qtz ss	lt yw tn	m	w	sr								N			
42.5						qtz ss	yw tn	m-cr	f	sr								N			
45.0						qtz ss	lt gy tn	f-vcr	p	sa								N			
47.5						qtz ss	lt tn	m-cr	f	sr								N			
50.0						qtz ss	lt yw tn	f-m	f	sr								N			Moisture first noticed
52.5						qtz ss	yw tn	f-m	f	sa								VW			
55.0						qtz ss	yw tn	m	w	sr								N			
57.5						qtz ss	yw tn	m	w	sr								N			
60.0						qtz ss	tn	f-m	f	sr								N			
62.5						qtz ss	tn	m-cr	f	sr								N			multi colored chert frags.
65.0						qtz ss-sh	tn-lt bn	m-cr	f	sr								N			
67.5						qtzs-sh	tn-lt bn	f-m	f	sr								N			
70.0						qtz ss-cgl.	tn-gy	m-grit	p	sa								W			abunt multicolored chert frags.
72.5						grit st. cgl	rd gy tn	cr-grit	p	a								N			" " " " "
75.0						grit st, cgl	rd gy tn	m-grit	p	a								N			
77.5						qtz ss, grit	rd gy tn	m-grit	p	a								N			
80.0						qtz ss	tn rd gy	f-vcr	p	sa								N			
82.5						qtz ss	tn	f-cr	p	sa								N			
85'						qtz ss	tn	m	f	sr								N			
87.-						qtz ss	tn	m-cr	f	sr								N			
90.0		X																X			No cuttings
92.5						qtz ss	tn	f-m	f	sr								N			
95.0						qtz ss	tn	m	w	sr								N			
97.5						qtz ss	tn	m-cr	w	r								N			
100.0						qtz ss	tn	m-cr	w	r								N			
102.5						qtz ss cgl	tn-gy	m-grit	p	a								N			
105.0						qtz ss cgl sh	tn-gy	m-grit	p	a								N			upper Bruchy Basin Ct @ approx 104.0 ft.
107.5						qtz ss, sh	tn-gy	m-vcr	p	a								N			(note contact from core)
110.0						qtz ss, sh	tn-gn	m-cr	f	sr								N			T.D.

PERCENTAGE COMPOSITION IMAGE



Core Log of Well No. MW-28

Cored Interval 49.0 ft. to 110.0 ft. T.D.

Depth	Description
49.0 - 60.0	Core recovery 55%, 49.0 - 54.0 ft., no core recovered. 54.0 - 54.3 ft., conglomerate, non calcareous. 54.3 - 60.0 ft., quartz sandstone, fine - medium grained, yellow-orange to tan, no mineralized or weathered surfaces, disseminated limonite zones from 55.0 - 56.0 ft., and 57.8 - 59.8 ft..
60.0 - 70.0	No core recovered from this interval.
70.0 - 80.0	Core recovery 22%, 70.0 - 77.8 ft., no core recovered, 77.8 - 80.0 ft., quartz sandstone, fine - medium grained, yellow-tan, cross-bedded with some grit sized grains occuring along bedding planes, very friable, non calcareous.
80.0 - 90.0	Core recovery 63%, 80.0 - 83.8 ft., no core recovered. 83.8 - 86.3 ft., quartz sandstone, medium - grit sized grains, yellow-tan, sharp contact with underlying shale. 86.3 - 86.5 ft., shale, yellow-gray. 86.5 - 90.0 ft., quartz sandstone, medium grained, yellow-tan to gray, non calcareous, very friable.
90.0 - 100.0	Core recovery 82%, 90.0 - 91.7 ft., no core recovered. 91.7 - 93.5 ft., quartz sandstone, fine - medium grained, gray-tan to light tan, several nonmineralized mechanical partings, non calcareous. 93.5 - 100.0 ft., quartz sandstone / gritstone, yellow-gray, grit zone from 95.5 - 97.5 ft., conglomerate zone from 99.9 - 100.0 ft., non calcareous, core becomes almost unconsolidated from 91.7 - 100.0 ft..
100.0 - 110.0	Core recovery 67%, 100.0 - 103.3 ft., no core recovered. 103.3 - 103.5 ft., conglomerate with chert pebbles up to 1 1/2 inch diameter. 103.5 - 104.0 ft., quartz sandstone, fine - medium grained, yellow-gray, some limonite on contact at 104.0 ft., upper Brushy Basin Mbr. contact. 104.0 - 110.0 ft., shale, green to purple-brown, some carbonaceous patches at 105.0 - 105.4 ft., purple -brown mottling from 106.5 - 108.5 ft. End of core at 110.0 ft., T.D.

Date 4-4-05 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. MW-29

Property White Mesa Mill Project ______ Unit No. ______ Sec. 32 Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ≈ 5612

PAGE 1 OF 2
T.D. PROBE ______
T.D. DRILL 130.0
FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																					
2.5						sndy sh	ltywbn	vf													Dike fill material
5.0						sndy sh	lt tn	vf													Dike fill material
7.5						sndy sh	lt pktn	vf													Dike fill material
10.0						sndy sh	lt tn	vf													Dike fill material
12.5						sndy sh	lt tn	vf													Possible in place material
15.0						Sndy sh	lt bn	vf f													
17.5						Sndy sh	lt tn	vf f													
20.0						Sndy sh, ss	lt tn	vf f													Upper Dakota Fm Ct @ approx 19.5 ft.
22.5						qtz ss, sh	tnbn	m-cr	p	sa											
25.0						qtz ss	tn	m-vcr	p	sa		La									
27.5						qtz ss	ywtn	m-cr	p	sa		La									
30.0						qtz ss, cgl	gytn	m-peb	p	sa											Some dk gy-blk chert frag.
32.5						qtz ss, cgl.	ywtn	f-peb	p	sa											" " " " "
0						qtz ss	tn	f-m	f	sa											
37.5						qtz ss, cgl	gytn	f-vcr	p	sa											
40.0						qtz ss, cgl	ltgytn	f-vcr	p	sa											
42.5						qtz ss	lttn-wh	vf-cr	p	sa											
45.0						qtz ss	lttn-wh	vf-m	p	sa											
47.5						qtz ss	vlttn	f-m	f	sr											
50.0						qtz ss	vlttn-wh	vf-m	f	sr											
52.5						qtz ss	wh	m	w	r								N			sparse frag. blgn sh.
55.0						qtz ss	vltgy	m-cr	f	sr								N			Some multicolored chert frag.
57.5						qtz ss	vltgy	m	w	sr								N			
60.0						qtz ss	vltgy-wh	m	f	sr								N			
62.5						qtz ss	gy-pk	m-cr	f	sa								N			30% chert frags & grains
65.0						qtz ss	ltgytn	f cr	p	sa		LT						N			
67.5						qtz ss	ltywgy	f-peb	p	sa								N			some dk gy chert frags.
70.0						qtz ss	ltgy	f-m	f	sa								N			
72.5						qtz ss	ltgy	f-m	w	sr								N			
75.0						qtz ss	ltgy	m	w	sr								N			
77.5						qtz ss	gy	m	f	sa								N			
80.0						qtz ss, cgl.	gy	m-peb	p	sa								N			cgl. zone, dk chert frags.
82.5						qtz ss	ltywgy	m-cr	f	sr								N			
85.0						qtz ss	ltgy	vf-m	f	sr		LT						N			
87						qtz ss	ltgy	m-cr	f	sr								N			some chert frags.
90.0						qtz ss, cgl.	ltgytn	m-peb	p	sa								N			cgl. zone, chert frag.
92.5						qtz ss	ltgytn	f-cr	p	sa								N			abnt chert grains
95.0						qtz ss	vltgy	m	w	sr								N			
97.5						qtz ss	vltgy-wh	m	w	sr								N			
00.0						qtz ss	ltgytn	f-m	f	sr		LT						N			
02.5						qtz ss	vltgytn	m-vcr	p	sa								N			Some multicolored chert frags.
05.0						qtz ss	vltgy	m-vcr	p	sa								N			some multicolored chert frags
07.5						qtz ss	wh	f-cr	f	sr								N			
10.0						qtz ss	wh	m	w	r								N			
12.5						qtz ss	wh	f-m	w	r								N			
15.0						qtz ss	wh-vltgy	f-m	w	sr								N			
17.5						qtz ss	wh	f-m	w	r								N			
20.0						qtz ss	wh	f-m	w	r								N			
22.5						qtz ss	wh	f-m	w	r								N			
25.0						Sh, qtz ss	dkgybl-pp	m	p	sr			T	C				N			Upper Brushy Basin Mbr. Ct @ approx 123.0 tr. pyrite

PERCENTAGE COMPOSITION IMAGE

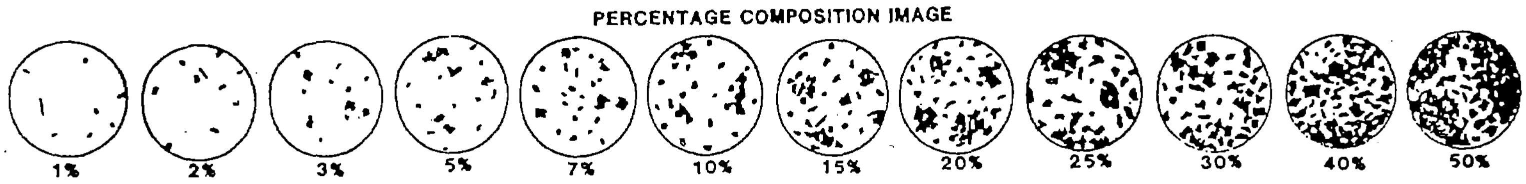
1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 4-12-05 Geologist L. Casebolt Drilling Co. Boyles Exploration Co. Hole No. MW-29
Property White Mesa mill Project ______ Unit No. ______ Sec. 32 Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ≈5612

PAGE 2 OF 2
T.D. PROBE ______
T.D. DRILL 130
FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
125.0																					
127.5						Sh	ltpp-ltgybn											N			
130.0						Sh	ltpp-ltrdbn											N			T.D.

PERCENTAGE COMPOSITION IMAGE



Date 4-6-05 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. MW-30
Property White Mesa Mill Project ______ Unit No. ______ Sec. 33 Twp. 37S Rge. ______
County San Juan State Utah Location ______ Elev. ≈5612

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 110.0
FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Iron Oxide	Amount	React.-10% HCl	Remarks
2.5	sndy sh	ltywbn						VS	Surface soil/fill, frags. of flyash from mill
5.0	Sndy sh	lt bn						VS	Possible fill material
7.5	Sndy sh	ltywbn						VS	Possible fill material
10.0	Sh	lt yw						VS	possible bedrock contact, abnt. gyp. (selenite) frags.
12.5	Slty sh	lt bn						VS	trace selenite
15.0	Sh	ltgnyw						VS	trace selenite
17.5	Sh	ltyw-gy						VS	
20.0	Sh	ltywgy						S	Trace selenite
22.5	Sh, qtz ss	ltppbn-	vf-m	p	sa			S	upper Dakota Fm. ct. @ approx 22.0 ft.
25.0	qtz ss	ltywtn	f-m	f	sa			S	
27.5	qtz ss, cgl	wh-lttn bn	f-vcr	p	sa			S	dk chert fragments.
30.0	qtz ss, cgl	lttn-dkgy	m-vcr	f	sr			S	note: some contamination with flyash
-	qtz ss, cgl	ltgy-lttn	f-vcr	f	sr			S	
35.0	qtz ss	ltgytn.	m-vcr	w	sr			S	
37.5	sltst, sh.	lttn-ltgy	vf					N	
40.0	sltst, sh	ltgy-vlttn	vf					W	
42.5	sltst, qtz ss	wh-vltgy	vf-f					m	
45.0	qtz ss	vltgy-wh	f					m	
47.5	sltst-qtz ss	ltgy	vf-f					M	
50.0	qtz ss	vlt bn	vf					m	
52.5	Sndy sltst	ltppbn	vf-f	p	sa			VS	
55.0	sltst, qtz ss	rdbn-ltgy	vf-m	p	sa			S	
57.5	sltst, qtz ss	rdbn-gy	vf-m	p	sa			S	
60.0	qtz ss, cgl	tn-gy	f-peb	p	sa			W	abnt. multicolored chert frags. & pebbles
62.5	qtz ss, cgl.	gytn	m-peb	p	sa			VW	" " " " "
65.0	qtz ss	ortn	m-vcr	p	sa	L	T	N	" " " " "
67.5	sltst, sh, ss	ywtn-gy	vf-f	f	sa	L	T	N	
70.0	sltst, sh, ss	gybn	vf-f	f	sa	L	T	N	
72.5	qtz ss-sltst	vltgy	vf-f	f	sa			N	
75.0	qtz ss-	wh	vf-f	f	sa			N	
77.5	qtz ss	wh-vltgy	vf-f	f	sa			N	frags. very soft & friable
80.0	qtz ss	lt tn	f-m	f	sa			N	
82.5	qtz ss, sh	ltgygn-rd	f-m	p	sa			N	frags soft & friable
[illegible]	qtz ss, sh	ltgygn-wh	f-m	p	sa			N	
[illegible]	qtz ss	vlttn-wh	f-m	f	sr			N	
90.0	qtz ss	vlttn-wh	f-m	w	sr			N	some dk chert grains
92.5	qtz ss	wh	f-m	w	sr			N	
95.0	qtz ss	wh	f-m	w	sr			N	
97.5	qtz ss	wh	f-m	w	sr			N	
100.0	qtz ss	wh	f-m	w	sr			N	
102.5	qtz ss	wh	f-m	w	sr			N	
105.0	qtz ss cgl	vltgywh	m-peb	p	sa			N	abnt dk chert frags.
107.5	sh	blgn						N	Upper Brushy Basin Mbr @ approx 105.0 ft.
110.0	sh	blgn						N	T.D.

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Core Log of Well No. MW-30

Cored Interval 20.0 ft. to 60.0 ft.

Depth	Description
20.0 - 30.0	Core recovery 36%, 20.0 - 20.3 ft., quartz sandstone / siltstone, very fine grained, yellow-pink- tan, calcareous cement. 20.3 - 27.0 ft., no core recovered. 27.0 - 30.0 ft., quartz sandstone, medium grained, pink-tan to tan-brown, disseminated limonite from 27.0 - 28.0 ft..
30.0 - 40.0	Core recovery 100%, 30.0 - 40.0 ft., quartz sandstone, cross-bedded, medium - grit sized grains, tan, non calcareous, grit zone from 31.3 - 31.7, dark gray clay galls from 32.1 - 33.0 ft., no mineralized partings.
40.0 - 50.0	Core recovery 67%, 40.0 - 40.7 ft., quartz sandstone, tan, medium - grit sized grains, grit zone from 40.7 - 41.0 ft., contact with weathered surface at 41.0 ft., manganese dendrites. 41.0 - 45.2 ft., quartz sandstone, light gray, fine - medium grained. 45.2 - 46.6 ft., quartz sandstone, yellow-gray to yellow-tan, low angle limonite mineralized parting at 46.3 ft. 46.6 - 50.0 ft., no core recovered.
50.0 - 60.0	Core recovery 95%, 50.0 - 51.0 ft., siltstone, yellow-gray-tan. 51.0 - 52.5 ft., quartz sandstone / siltstone, dark gray-brown. 52.5 - 55.5 ft., shale, purple-red. 55.5 - 60.0 ft., siltstone, yellow-brown, very soft, lower contact is low angle parting, grades into quartz sandstone to 60.0 ft., tan to yellow-orange conglomerate zones at 57.0 - 57.3 ft., 58.0 - 58.7 ft., and 59.8 - 60.0 ft., end of core.

Date 4-5-05 Geologist L. Casebolt Drilling Co. Boyles Exploration Co. Hole No. MW-31
Property White Mesa Mill Project ______ Unit No. ______ Sec. 33 Twp. 37S Rge. ______
County San Juan State Utah Location ______ Elev. ≈ 5614

PAGE 1 OF 2
T.D. PROBE ______
T.D. DRILL 130
FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5	sndy sltst	lt rd bn	vf-m	p	sa								S			possible fill material from dike
5.0	sndy sltst	lt pk tn	vf-m	p	sa								S			possible fill material from dike
7.5	sndy sh, ss	lt pk tn	vf-m	p	sa								S			possible fill material from dike
10.0	sndy sh,	lt pk-vlt tn	vf m	p	sa								S			possible fill material from dike
12.5	sndy sh,	lt pk tn	vf m	f	sa								VS			Mancos Shale Fm.
15.0	sndy sh	rd bn-yw tn	f-m	f	sa								VS			
17.5	slty sh	rd bn-yw tn	vf f	p	sa								S			
20.0	Sh	ywgy-lt pk											S			
22.5	Sh	ywgy-lt pk											m			
25.0	Sh	ywgy											S			
-	Sh	ywgy											m			
30.0	qtz ss, sh	ywgy	vf-f	p	sa		LM						VW			
32.5	sndy sltst	gy bn	vf f	p	sa								W			
35.0	sndy sltst	gy bn	vf f	p	sa								W			
37.5	qtz ss, sh	gy-tn	vf-m	f	sa								VW			Upper contact Dakota Fm. @ approx 36.0
40.0	qtz ss	tn	m	f	sa		LM						N			
42.5	qtz ss	tn	m-cr	f	sa		LT						N			
45.0	qtz ss	gy tn	m-vcr	p	a								N			
47.5	qtz ss	lt bn	m-vcr	p	a								N			sparse chert frags.
50.0	qtz ss	lt bn	m-vcr	p	a								N			sparse chert frags.
52.5	qtz ss	lt yw bn	m-peb	p	a								N			abnt. chert frags.
55.0	qtz ss	lt tn	m	w	sr								N			
57.5	qtz ss	lt tn	m	w	sa								N			
60.0	qtz ss	lt tn	m	w	sr								N			
62.5	qtz ss	lt tn	m-cr	f	sa								N			
65.0	qtz ss	lt tn	m	f	sa								N			sparse wh chert grains
67.5	qtz ss	lt tn	m	f	sr								N			
70.0	qtz ss	lt tn	m-cr	f	sa								N			some dk gy chert grains
72.5	qtz ss	lt tn	m-cr	f	sa								N			" " " " "
75.0	qtz ss, cgl.	lt tn	m-peb	p	sa								W			" " " " pebbles
77.5	qtz ss, cgl	yw gy	m-peb	p	a								W			" " " " "
ε	qtz ss, cgl	lt tn	m-vcr	p	sr								N			abnt. multicolored chert frags & pebbles
82.5	qtz ss cgl	gy tn	m-peb	p	a								W			" " " " " "
85.0	qtz ss, cgl	gy tn	m-peb	p	a								W			" " " " " "
87.5	qtz ss, cgl	gy tn	cr-peb	p	a								W			" " " " " "
90.0	qtz ss	tn	m	w	sr								N			
92.5	qtz ss, sltst	lt gy-lt bl gy	f-m	f	sr								N			
95.0	qtz ss, sltst	lt tn-lt bl gy	vf m	f	sr								N			
97.5	qtz ss	vlt tn-wh	f-m	f	sr		LT	T	C				N			
100.0	qtz ss	vlt tn-wh	m	w	sr								N			
102.5	qtz ss	vlt tn	m-cr	f	sr								N			dk gr chert frags.
105.0	qtz ss	vlt tn	m-cr	f	r								N			" " " "
107.5	qtz ss	vlt tn-wh	m	w	r								N			
1'	qtz ss	vlt tn-wh	m	w	r								N			
11_	qtz ss	vlt tn-wh –	m	w	r								N			
15.0	qtz ss	vlt tn-wh	m	w	r								N			
'17.5	qtz ss	vlt tn-wh	m	w	r								N			
'20.0	qtz ss, chert	lt tn-dk gy	cr-peb	p	a								N			cgl. zone multicolored chert frags & pebbles
'22.5	qtz ss, chert	lt tn-tn	m-peb	p	a								N			" " " " " " "
25.0	qtz ss, chert	lt tn-tn	vcr	p	sr			T	C				N			" " " " " " "

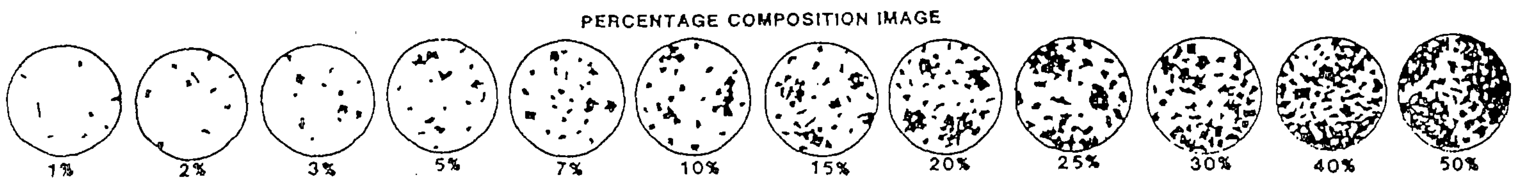
PERCENTAGE COMPOSITION IMAGE

ate 4-1-05 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. MW-31
Property White Mesa Mill Project ______ Unit No. ______ Sec. 33 Twp. 37S Rge. ______
County San Juan State Utah Location ______ Elev. ≈ 5614

PAGE 2 OF 2
T.D. PROBE ______
T.D. DRILL 130
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite: Amount	Pyrite: Habit	Pyrite: Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon: Amount	Carbon: Type	Remarks
125.0																					
127.5						qtz ss, cgl, sh	wh-gygn	m-peb	p	a							m				Upper Brushy Basin Mbr Ct @ approx 126.0 ft.
130.0						sh	gygn-ppbn										W				

PERCENTAGE COMPOSITION IMAGE



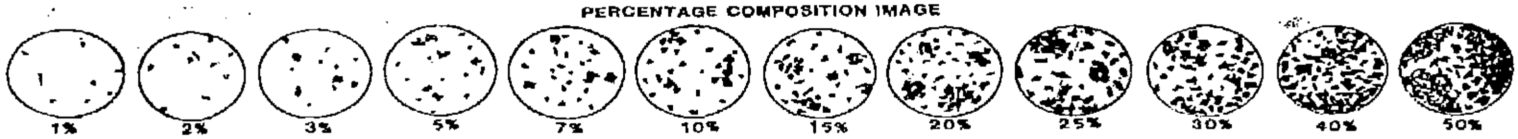
1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 8-31-16 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. MW-33
Property White Mesa Mill ~~[illegible]~~ Tailings Cell Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 110.0
FLUID LEVEL Dry Hole

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						mdst	rd bn											S			Surface soil
5.0						mdst	rd bn - lt pk											VS			mancos shale fm.
7.5						sndy mdst	rd bn - lt pk	m-cr	m	a								VS			
10.0						sndy mdst	rd bn	m	m	a								VS			
12.5						mdst	rd bn											S			
15.0						sh	vlt pk											VS			
17.5						sh, qtz ss	lt pk	m-cr	m	a								VS			Dakota fm. contact @ 16.0 ft.
20.0						qtz ss	tn	m cr	m	a								S			
22.5						qtz ss	rd bn - tn	m-cr	m	r								M			
25.0						qtz ss	lt gy bn	m	w	r								m			
27.5						qtz ss	lt gy bn	m-cr	m	a		L						N.			
30.0						qtz ss	gy bn	m-cr	p	a		L						VW			
32.5						qtz ss	gy bn	f-vcr	p	a								VW			
35.0						qtz ss	gy bn	m-vcr	p	a								N			
37.5						qtz ss	gy bn	m-cr	p	a								N			
40.0						qtz ss	gy bn	m-gr	p	a								N			
42.5						mdy qtz ss	lt rd bn	f-cr	p	a								S			mdst is believed to be material from 12.5' above
45.0						qtz ss	tn	f-gr	p	a								S			multi colored chert grains and frag.
47.5						qtz ss, sh	tn	f-gr	p	a								m			some chert grains and fragments
50.0						qtz ss, sh	tn - lt gy	f-gr	p	a								VW			some chert grains and fragments.
52.5						qtz ss, sh	tn - lt gy	f-gr	p	a								W			abunt chert grains
55.0						qtz ss, sh	tn - lt gy	f-gr	p	a								W			" " "
57.5						sh												W			
60.0						sltst.												W			
62.5						sndy sh	lt gy tn	f-m	m	a								N			
65.0						sndy sh	lt gy tn	f-m	m	a								N			
67.5						sltst	lt tn											N			
70.0						qtz ss, sh	lt tn - lt gy	f-m	m	a								S			
72.5						sh	lt gy											W			
75.0						sh	bl gy - yw or					L						VW			
77.5						sh	bl gy											N			
80.0						sltst-ss	tn	vf-f	m	r								N			
82.5						qtz ss, sh	gy tn - yw or	m	w	r		L						N			
85.0						qtz ss	vlt gy tn	m-cr	m	a								W			qtz ss
87.5						qtz ss, sh	vlt tn - lt gn	m-cr	m	a								N			
90.0						qtz ss	lt tn	m-cr	m	a								W			
92.5						qtz ss	lt tn	cr-vcr	m	a								M			
95.0						qtz ss, sh	lt tn - lt gn	m-cr	p	a								N			
97.5						qtz ss	lt tn	m-vcr	p	a								N.			sparse chert grains
100.0						qtz ss	tn	m-gr	p	a								VW			" " " some contamination from up hole cuttings
102.5						qtz ss	tn bn	m-cr	m	a		L						m			
105.0						sh	gy gn - pp bn											N			Brushy Basin Ct @ 102.5
107.5						sh	gy gn - pp bn											VW			
110.0						sh	gy gn - pp bn											N.			T.D. Well bore was dry to T.D.

PERCENTAGE COMPOSITION IMAGE

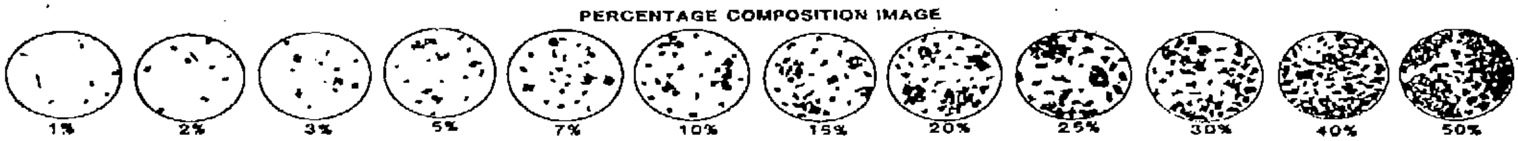


Date 8-31-10 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. MW-34
Property White Mesa Project Tailings Cell Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location Tailings cell DIKE Elev. ______

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 115.0
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						mdst	rd bn											VS			Compacted fill material for cell dike
5.0						mdst	rd bn-yw bn											VS			" " " " " "
7.5						mdst	rd bn											VS			" " " " " "
10.0						mdst	rd bn											VS			" " " " " "
12.5						mdst	rd bn											VS			" " " " " "
15.0						mdst	rd bn											VS			" " " " " "
17.5						mdst	pk bn											VS			" " " " " "
20.0						sndy mdst	yw gy bn	f-m	P	a								VS			" " " " " "
22.5						sndy mdst	rd bn	f-m	P	a								VS			" " " " " "
25.0						sndy mdst	lt rd bn	f-m	m	a								VS			" " " " " "
27.5						sndy mdst	lt rd bn	f-m	m	a								VS			" " " " " "
30.0						sndy sh	lt pk tn	f-m	P	a								VW			" " " " " "
32.5						qtz ss	tn-	m	m	a		L						VW			Mancos Shale fm.
35.0						sndy sh	yw gy bn	m-cr	m	a								N			" " "
37.5						qtz ss	lt bn	m-cr	m	a		L						N			Dakota fm contact @ 35.0 ft.
40.0						qtz ss	lt gy bn	f-cr	P	a								m	tr	HY	poss. tr of hydrocarbon
42.5						qtz ss	v lt tn-wh	f-vcr	P	A								VW			Very hard drilling
45.0						qtz ss	v lt tn	f-m	m	a								N			" " "
47.5						qtz ss	wh	m-vcr	P	A								N			" " " sparse chert grains
50.0						qtz ss	wh	m-gr	P	A								VW			" " " chert grains
52.5						qtz ss	v lt tn	f-vcr	P	A								VW			
55.0						qtz ss	tn	m	w	R								N			
57.5						qtz ss	tn	f-m	m	a								N			
60.0						qtz ss, sh	lt tn-v lt gn	m-vcr	P	a								N			
62.5						qtz ss, sh	lt tn-lt gn	cr-gr	P	a								N			abund multi colored chert grains & frags.
65.0						qtz ss, sh	lt tn-lt gn	m-gr	P	a								N			" " " " " "
67.5						sh, cgl	dk gy-lt gy gn	gr	P	a								N			" " " " " "
70.0						qtz ss, sh	yw tn-gy gn	f-cr	P	a			tr					N			dissem. pyrite
72.5						qtz ss	dk tn	f-cr	P	a		L						N			sparse chert grains
75.0						qtz ss	tn	f-cr	P	a								S			sparse chert grains
77.5						qtz ss, sh	tn-lt gy	f-cr	P	a		L						S			
80.0						qtz ss	tn	m-cr	P	a								S			
82.5						qtz ss	tn	f-m	m	r								N			
85.0						qtz ss	tn	f	w	r								S			sparse chert grains
87.5						qtz ss	tn	f	w	r								N			
90.0						qtz ss, sh	v lt gy tn	f	w	r								VW			
92.5						qtz ss	v lt tn	f-m	m	r								N			
95.0						qtz ss	v lt tn	m	m	r								N			
97.5						qtz ss	v lt tn	m	w	r								N			
100.0						qtz ss	v lt tn	m	w	a								N			
102.5						qtz ss, sh	v lt tn-wh	f-m	m	r								S			
105.0						qtz ss	gy bn	m-vcr	P	a								S	tr	hy	
107.5						qtz ss	gy bn	m-vcr										M			Moisture first noted @ 107.5
110.0						sh, qtz ss	gy bn	v-vcr										M			Brushy Basin fm contact @ 107.5
112.5						sh	lt gy gn -											N			
115.0						sh	gy gn-pp bn											N			mottled frags.

PERCENTAGE COMPOSITION IMAGE



Date 9-1-10 Geologist L. Casebolt Drilling Co. Boyles Exploration Co. Hole No. MW-35

Property White Mesa Project Tailings cell Unit No. Sec. Twp. Rge.

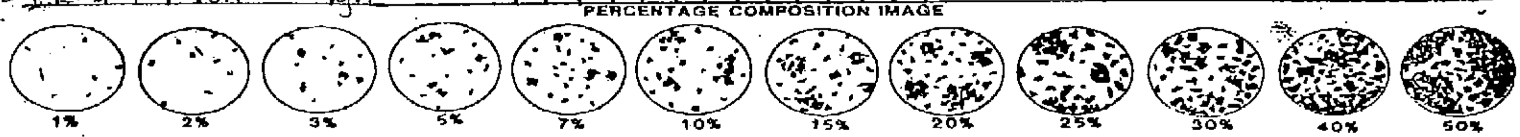
County San Juan State Utah Location Elev.

PAGE 1 OF 1
T.D. PROBE 127.0
T.D. DRILL 127.5
FLUID LEVEL 112.6 (9-2-10)

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5	mdst	rdbn											w			surface soil
5.0	sndy mdst	rdbn	f	P	a								S			Mancos Shale fm.
7.5	sndy mdst	lt rdbn	f-m	P	a								VS			
10.0	qtz ss	lt rdbn	vf-m	P	a								VS			
12.5	mdst	rdbn											VS			
15.0	mdst-sh	rdbn-ltpktn											VS			
17.5	shale	wh											VS	tr	HV	
20.0	sndy sh.	lt pktn	f-m	P	a								VS			
22.5	sndy sh	lt pktn	f-m	P	a								VS			
25.0	sndy sh	ywgybn	f m	P	a		L						S			
27.5	sndy sh	ywgybn	f-m	P	a		L						W			
30.0	qtz ss	tn	m	M	a		L						N			Dakota Ct. @ 27.5
32.5	qtz ss	lt tn	m	M	a								N			
35.0	qtz ss	lt tn	m	M	a								N			
37.5	qtz ss	v.lt bn	m-cr	P	a								N			
40.0	qtz ss	vlt bn	m-cr	P	A								N			
42.5	qtz ss	bn	f-m	M	a								N			
45.0	qtz ss	tn	f	W	r								N			
47.5	qtz ss	gybn	f-m	W	r								N			
50.0	qtz ss	vlt tn	f	W	r								N			
52.5	qtz ss	vlt tn	f	W	r								N			
55.0	qtz ss	tn	f-m	M	a								N			
57.5	qtz ss	tn	m-cr	P	a								N			abund wh-pk chert grains
60.0	qtz ss	tn	f-m	M	r								N			some wh chert grains
62.5	qtz ss	tn	f-m	M	r								N			
65.0	qtz ss	gytn	m	W	r								N			some wh-dkgy chert frags.
67.5	qtz ss	gytn	m-vcr	P	a								N			abund wh-dkgy chert frags.
70.0	sndy sh	ltywgy	vf f	P	a		L						N			thin shale lens
72.5	qtz ss	tn	f-m	M	a								N			
75.0	qtz ss	tn	m	W	r								N			
77.5	qtz ss	tn	f-m	M	r								N			
80.0	qtz ss	tn	m	M	r								N			
82.5	qtz ss	tn	m	W	r								N			
85.0	qtz ss	tn	m	W	r								N			
87.5	qtz ss, sh	ltgygn	m	M	r								N			
90.0	sndy sh	ltgygn	f	M	r								N			
92.5	sh	ltgn											N			
95.0	sh	ltgn						tr	c				N			py
97.5	sh	ltgygn						tr	c				N			py
100.0	qtz ss	ltpktn	f-m	M	a			tr	c				N			py
102.5	qtz ss	ltgy	m	W	r								N			
105.0	qtz ss	ltgy	m	W	r								W			
107.5	qtz ss	ltgy	m-cr	M	r								W			
110.0	qtz ss	ltgy	m-cr	M	r								W			
112.5	qtz ss	ltgy	f-m	M	r								VS			Moisture first noted 112.5
115.0	qtz ss	ltgybn	m-cr	M	r								N			tr hydrocarbon
117.5	qtz ss, cgl	dk ywgy	m-cr	P	r								N			abund dk chert frags & grains
120.0	qtz ss, cgl	wh-dkgy	vcr	P	r			tr	c				N			" " " " "
122.5	qtz ss cgl	wh-dkgy	vcr	P	a								N			" " " " "
125.0	cgl-sh	gy-gn	vcr	P	a			tr	c				N			Brushy Basin Contact @ 123.6'
127.5	sh	gn											N			

TD.

PERCENTAGE COMPOSITION IMAGE

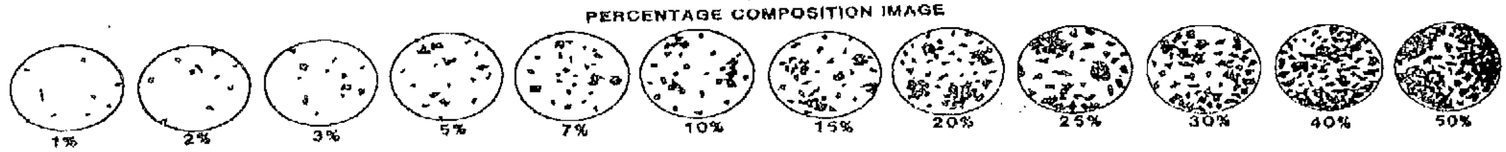


Date 26 APR 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. MW 36
Property White Mesa Mill Project Cell 4B Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ≈5615

PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 120.0
FLUID LEVEL ____

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0						mdst	rdbn											S			Surface Soil-unconsolidated CL
2.5						mdst, sh	rdbn-ltpk											VS			Mancos Sh CL
5.0							rdbn											VS			CL
7.5							rdbn											S			
10.0							rdbn											S			
12.5							rdbn-ltpk											VS			
15.0							ltpk											VS			
17.5							ltywtn											VS			
20.0						sltst	ltpktn											S			
22.5						qtz ss	ywtn	m	w	r								N			Upper Dakota Ct @ 22.5 ft.
25.0						qtz ss	tn	m	w	r								N			
27.5						qtz ss	tn	m	w	r		L						N			
30.0						qtz ss	tn	m	w	a		L						N			
32.5						qtz ss	tn	m	w	a								N			
35.0						qtz ss	tn	m	w	a								N			
37.5						qtz ss	tn	m-c	m	a								N			
40.0						qtz ss, sh	tn-gy	m-c	m	a								N			
42.5						qtz ss	tn	m	w	r								N			
45.0						qtz ss	tn	f-m	m	r								N			
47.5						qtz ss	tn	m	w	R								N			
50.0						qtz ss	tn	m-c	m	r								N			
52.5						qtz ss	tn	m	w	r								N			
55.0						qtz ss	tn	m	w	R								N			
57.5						qtz ss	ltbn	m-c	m	r								N			some wh-gy chert grains and frags.
60.0						qtz ss	tn	m-vc	f	r								N			"
62.5						sh, sltst	gy-lttn											N			CL
65.0						sh	ltgytn											N			CH
67.5						qtz ss	vltgy	vf-f	m	r								N			
70.0						qtz ss	ltywbn	m	w	r		L						N			
72.5						qtz ss	lttn-ltywbn	m	w	r		L						S			
75.0						qtz ss	wh-lttn	m	w	r		L						W			CH
77.5						sh	ltblgy											N			
80.0						sh	pprdbn											N			
82.5						sh	pprdbn											N			mottled cuttings
85.0						sh	ltblgy, pprdbn											N			
87.5						sh	ltblgy						1%	A				VW			
90.0						qtz ss	vlttn	vf	w	r								N			
92.5						qtz ss	vltn	vf	w	r								N			
95.0						qtz ss	vltn	f-m	m	r		L						VW			
97.5						qtz ss	vlttn	f-m	m	r								N			
100.0						qtz ss	wh	m	w	r								N			
102.5						qtz ss	vlttn	m	w	R		L						N			
105.0						qtz ss	vlttn	m	w	r								N			
107.5						qtz ss	vlttn	m	w	r								N			
110.0						qtz ss	vlttn	f-m	m	a								W			moisture first noted
112.5						qtz ss	vlttn	f-m	m	r			tr	C				S			Brushy Basin Ct. @ 115.0
115.0						sh	blgn											N			
117.5						sh	blgn											N			T.D.
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE

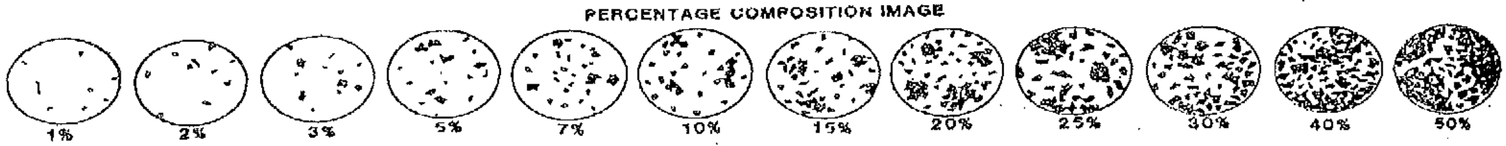


Date 25 APR 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. MW-37
Property White Mesa Mill Project Cell 4B Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location CELL 4B DIKE Elev. 5618 ≈

PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 120.0
FLUID LEVEL ____

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0–2.5						mdst	rdbn											VS			Compacted Tailings Cell Dike Material
2.5–5.0						mdst	rdbn											VS			"
5.0–7.5						mdst	rdbn											VS			"
7.5–10.0						mdst	rdbn											VS			"
10.0–12.5						mdst	rdbn											VS			"
12.5–15.0						mdst	rdbn											VS			"
15.0–17.5						mdst	rdbn											VS			"
17.5–20.0						mdst	rdbn											VS			"
20.0–22.5						mdst	rdbn											VS			"
22.5–25.0						mdst	rdbn											VS			"
25.0–27.5						sh	ywbn											VS			Mancos Sh
27.5–30.0						sh-mdst	rdbn-ltpk											VS			Mancos Sh.
30.0–32.5						qtzss, sh	tn	f-m	m	r								VS			upper Dakota Ct @ 30.0'
32.5–35.0						qtzss	tn	f-m	m	r								VW			
35.0–37.5						qtz ss sh	tn	f-m	m	r								N			
37.5–40.0						qtzss sh	gybn	m	m	r								N			
40.0–42.5						qtzss, sh	wh-ltorbo-dkgy	m	m	r								N			
42.5–45.0						qtzss	wh-ltorbn	f-m	m	r		L						N			
45.0–47.5						qtz ss	vlttn	m	w	R		L						VW			
47.5–50.0						qtzss, qtzite	wh	m	w	R								N			very hard drilling
50.0–52.5						qtzss-qtzite	wh	f-m	w	r								N			extremely hard drilling
52.5–55.0						qtz ss-qtzite	wh-lttn	f-m	w	r								N			moisture first noted @ 54'
55.0–57.5						qtzss	tn	f-m	w	r								N			abund. chert grains
57.5–60.0						qtzss, cgl	lttn	m-peb	p	a								N			very abund chert grains and pebbles.
60.0–62.5						cgl-sh	ltywgygn	peb	p	a								N			Some chert pebble frags.
62.5–65.0						sh-cgl	ltgn-tn	peb	p	a								N			" " "
65.0–67.5						sltst, qtzss	lttn	vf-peb	p	a								N			
67.5–70.0						qtzss	lttn	vf-peb	p	r								N			
70.0–72.5						qtz ss	lttn	f-peb	p	r								VW			
72.5–75.0						qtz ss	lttn	m-peb	p	r								S			
75.0–77.5						qtz ss	vlttn	m-peb	p	r		L						VW			abund chert frags.
77.5–80.0						qtz ss	vltbn	m	w	r		L						N			
80.0–82.5						qtzss, cgl	wh-vdkgy	m peb	p	r		L						N			Abund. water @ 80.0' abund chert frags + pebbles.
82.5–85.0						sh, qtzss, cg	lttn-gn	f-peb	p	r		L						N			abund chert frags and pebble.
85.0–87.5						sh, qtzss	gn-wh	f-peb	p	r								N			
87.5–90.0						qtz ss	wh	m-peb	m	r								N			
90.0–92.5						qtz ss	ltgy bn	m-peb	m	r		L						N			
92.5–95.0						qtz ss	vlttn	m	w	R		L						N			
95.0–97.5						qtz ss	vlttn	m-peb	p	r								N			
97.5–100.0						qtz ss	lttn	m-c	p	r								N			
100.0–102.5						qtz ss	lttn	f-m	m	r								W			
102.5–105.0						qtz ss	lttn	f-m	m	r								N			
105.0–107.5						qtzss, sh	lttn-gn	f-peb	p	r								N			
107.5–110.0						qtz ss	wh-tn	m	w	R			tr	C				N			
110.0–112.5						qtz ss	vlttn	m	w	R			3%	C				W			
112.5–115.0						qtz ss	wh-blgn	f-m	m	r			1%	C				W			
115.0–117.5						qtzss, sh	wh-blgn											N			Brushy Basin Ct @ 117.0' (good contact)
117.5–120.0						sh	blgn-gybn											N			120.0 T.D.
120.0–122.5																					
122.5–125.0																					

PERCENTAGE COMPOSITION IMAGE



APPENDIX A.3

PIEZ - SERIES

Date 12-18-2001 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. PIEZOMETER WELL #1

Property White Mesa Mill Project ____ Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 1

T.D. PROBE ____

T.D. DRILL 107.5 T.D.

FLUID LEVEL ____

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	React.-10% HCL	Remarks
0							
2.5	Sltst, sh	rdbn				VW	Soil
5.0	sltst, sh	rd bn				S	Soil
7.5	sltst, sh	rdbn-lttn				VS	
10.0	sltst, sh	ltpktn				VS	
12.5	sltst, sh	ltpk-ltgy				VS	
15.0	sltst, qtz ss	lttn	f-m	f	sr	N	Upper Burro Cyn Fm. Contact @ 14.5 ft.
17.5	qtz ss	lt tn	vf-f	m	sr	N	
20.0	qtz ss	lttn	vf-f	m	sr	VW	
22.5	qtz ss	tn	f-m	f	sr	N	
25.0	qtz ss	tn	f-m	f	r	N	
27.5	qtz ss	tn	f-m	m	r	N	
30.0	qtz ss	tn	f-m	p	sa	W	
32.5	qtz ss	tn	f-m	p	sa	VW	
35.0	qtz ss	lt tn	vf-f	f	sr	N	
37.5	qtz ss	lttn	f-m	f	sr	VW	
40.0	qtz ss	lttn	f-m	f	sr	N	
42.5	qtz ss	tn	f-m	f	sr	N	
45.0	qtz ss	gy	f-m	p	sr	N	
47.5	qtz ss	ltgytn	f-m	m	r	N	
50.0	qtz ss	ltbn	f-m	m	r	N	
52.5	qtz ss	lttn	m	w	r	N	
55.0	qtz ss	ltgytn	m-c	m	r	N	
57.5	qtz ss	ltgytn	f-vc	p	sr	N	
60.0	qtz ss	ltgy	vf-f	f	sr	N	
62.5	qtz ss	vltgy	f-c	f	sr	N	
65.0	qtz ss	vltgy	vf	w	sr	N	
67.5	qtz ss	vltgy	vf-m	f	sr	N	
70.0	qtz ss	vlttn	vf-m	f	sr	N	
72.5	qtz ss	vlttn	f-m	w	sr	N	
75.0	qtz ss	vlttn	f	m	sr	N	
77.5	qtz ss	vlttn	f	m	sr	N	
80.0	qtz ss	vlttn	f-m	m	r	N	
82.5	qtz ss	ltgy-multicolor	f-vc	p	r	N	abnt. chert frags.
85.0	qtz ss	ltgy-multicolor	m-vc	f	r	N	" " "
87.5	qtz ss	ltgy-multi-color	m-vc	f	r	N	" " "
90.0	qtz ss, cgl	multi-color	m-vc	f	r	N	" " " (high perm zone)
92.5	qtz ss, cgl	wh-multicolor	m-vc	f	r	N	" " " (high perm zone)
95.0	qtz ss	wh	m-vc	f	r	N	abnt chert frags (high perm zone)
97.5	qtz ss, cgl	multicolor	m-vc	p	r	N	" " " (high perm zone)
100.0	qtz ss, cgl	multicolor	m-vc	p	r	VW	" " " (high perm zone)
102.5	qtz ss	wh-vltgn	m-vc	p	sr	N	Burro Cyn / Brushy Basin Fm Ct @ 102.5
105.0	sh, sltst	gn				N	
107.5	sh	gn-pp				N	T.D.
110.0							
112.5							
115.0							
117.5							
120.0							
122.5							
125.0							

PERCENTAGE COMPOSITION IMAGE

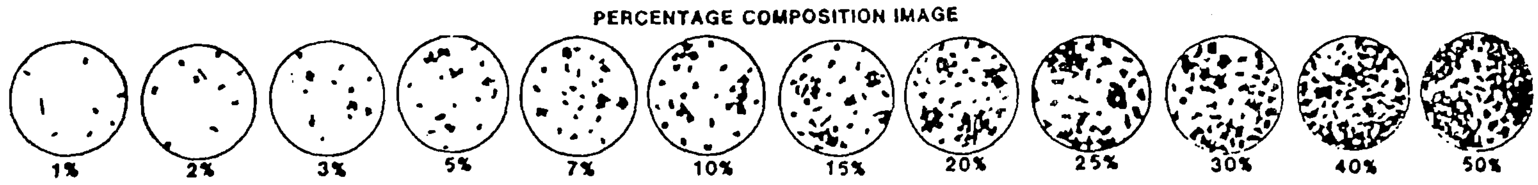
1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 12-17-2001 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. piezometer well #2
Property White Mesa Mill Project ____ Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 100.0
FLUID LEVEL ____

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite: Amount	Pyrite: Habit	Pyrite: Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon: Amount	Carbon: Type	Remarks Bit Dia. 4.75"
0																					
2.5						sltst, sh	rd bn											S			
5.0						sltst.	rd bn											S			
7.5						sltst, ss	yw bn-rd bn	f-m	f	sr								W			Upper Burro Cyn Contact @ 6.0 feet
10.0						sltst, ss	yw bn-rd bn	f-m	p	sr								VW			
12.5						qtz ss	tn	vf-f	f	sr								N			
15.0						qtz ss	tn	f	w	sr								N			
17.5						qtz ss	vlt gy	f	w	sr								N			
20.0						qtz ss	lt gy	f-m	m	sr								N			
22.5						qtz ss	wh-lt gy	f-m	m	sr		Hem						N			Encounter water @ 21 feet, begin injection
25.0																					No sample
27.5						qtz ss	dk gy	vf-f	f	sr								N			
30.0						qtz ss	dk gy	vf-f	f	sr								N			
32.5						qtz ss, cgl	wh-multicolor	m-vc	p	sr								N			abnt. chert frag.
35.0						qtz ss, cgl	multi-color	f-vc	p	sr								N			" " "
37.5						qtz ss, cgl	multi-color	m-vc	p	sr								N			" " "
40.0						qtz ss, cgl	multi-color	m-vc	p	sr								N			" " "
42.5						qtz ss, cgl	multi-color	m-vc	p	sr								N			" " "
45.0						qtz ss, cgl	multi-color	m-vc	p	sr								N			" " " tr. hem after pyrite
47.5						qtz ss, cgl	multi-color	m-vc	p	sr								N			" " "
50.0						qtz ss, cgl	multi-color	m-vc	p	sr								N			" " "
52.5						qtz ss, cgl	multi-color	m-vc	p	sr								N			" " " high perm zone
55.0						qtz ss, cgl	multi-color	m-vc	p	sr								N			" " "
57.5						qtz ss, cgl	multi-color	m-vc	p	sr								N			" " "
60.0						qtz ss, cgl	wh-multicolor	m-vc	p	sr								N			
62.5						qtz ss	yw	f-m	f	sr								N			
65.0						qtz ss	wh	f-m	f	sr								N			
67.5						qtz ss	wh-lt bn	f-m	f	sr								N			
70.0						qtz ss	bn	vf-c	p	sr								N			
72.5						qtz ss	wh-bn	f-m	p	sr								N			
75.0						qtz ss	wh-bn	f-m	p	sr								N			
77.5						qtz ss	bn-multicolor	m-vc	p	sr								N			abnt chert frags.
80.0						qtz ss	bn	f-m	f	sr								N			
82.5						qtz ss	bn	f-m	f	sr								N			
85.0						qtz ss	wh-lt tn	f-m	f	sr								N			
87.5						qtz ss	wh	m-cr	p	sr								N			
90.0						qtz ss	wh	m-cr	p	sr								N			some chert frag.
92.5						qtz ss, sh	lt bn-gy gn	vf-m	p	sr								N			Burro Cyn/Brushy Basin Fm ct @ 92.0 feet
95.0						sltst, sh	gy														
97.5						sltst, sh	gy														
100.0						sltst, sh	gy														T.D
102.5																					
105.0																					
107.5																					
110.0																					Note: this well was initially drill without
112.5																					surface casing to a depth of 80.0 feet.
115.0																					The top 6 feet of the well sloughed excessively
117.5																					distributing this material throughout the resulting
120.0																					cuttings. Surface casing was installed resulting
122.5																					in improved cutting recovery and quality.
125.0																					

PERCENTAGE COMPOSITION IMAGE



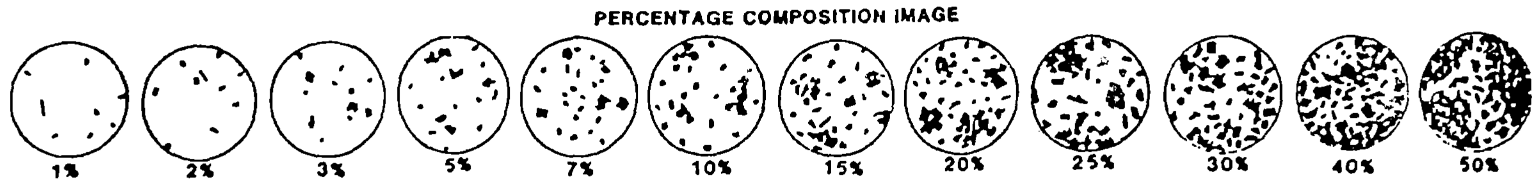
Date 12-17-2001 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. piezometer well #3
Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF ______
T.D. PROBE ______
T.D. DRILL 100.00
FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	React.-10% HCL	Remarks Bit dia. 4.75"
0							
2.5	Sltst, sh	rd bn				S	Soil
5.0	sltst, sh	rd bn				S	Soil
7.5	sltsh, sh	lt pk bn				VS	
10.0	sltst, sh	lt pk bn				VS	
12.5	sltsh, sh	lt pk bn				VS	
15.0	sltst, sh	lt pk bn				VS	
17.5	sltst, sh	lt tn				VS	
20.0	sltst, sh	lt ywgy				S	
22.5	qtz ss	lt tn	f-c	f	r	M	Upper Burro Cyn Fm. Ct. @ 20.0 feet
25.0	qtz ss	lt tn	m-c	m	sr	VW	
27.5	qtz ss	tn	m	w	r	VW	
30.0	qtz ss	tn	f-m	f	sr	N	
32.5	qtz ss	tn	f-m	f	sr	N	
35.0	qtz ss	tn	f	m	sr	N	
37.5	qtz ss	tn	f	m	sr	N	
40.0	qtz ss	lt tn	f	m	sr	N	
42.5	qtz ss	lt gy	f-m	f	sr	N	
45.0	qtz ss	lt tn	f-c	f	sr	N	
47.5							No sample
50.0							No Sample
52.5							No Sample
55.0							No Sample
57.5							No Sample
60.0	qtz ss, cgl	wh-multicolor	f-m	f	r	N	abnt. chert frag.
62.5	qtz ss, cgl	multicolor	f-m	f	r	N	" " "
65.0	qtz ss, cgl	multicolor	f-vc	p	a-r	N	" " "
67.5	qtz ss, cgl	multicolor	f-vc	p	a-r	N	" " "
70.0	qtz ss, cgl	multicolor	vc	p	a	N	" " "
72.5	qtz ss, cgl	multicolor	vc	p	a	N	" " "
75.0	qtz ss, cgl	multicolor	f-vc	p	a-r	N	" " "
77.5	qtz ss.	tn-multicolor	f-vc	p	r	N	" " "
80.0	sltst, cgl	gn-multicolor				N	Burro Cyn/Brushy Basin Ct. @ 79 feet
82.5	sltst, cgl	gn				N	
85.0	sltst	gn				N	
87.5	sltst, cgl	gn-gytn				N	
90.0	sltst, sh	gn				N	
92.5	sltst, ss	gn-tn				N	
95.0	sltst, cgl	gn-wh				N	
97.5	sltst, sh	gn-wh				N	
100.0	sltst, cgl	gn-multicolor				N	T.D.
102.5							
105.0							
107.5							
110.0							
112.5							
115.0							
117.5							
120.0							
122.5							
125.0							

Other column headings on form (no entries): Sample Taken, Graphic Log, Alteration, Gamma Anomaly, Breccia Pipe, Cement Matrix, Iron Oxide, Pyrite (Amount, Habit, Alter.), Metallic, Non-Metallic, Carbon (Amount, Type).

PERCENTAGE COMPOSITION IMAGE



Date 12-18-2001 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. Piezometer well #4
Property White Mesa Mill Project ____ Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

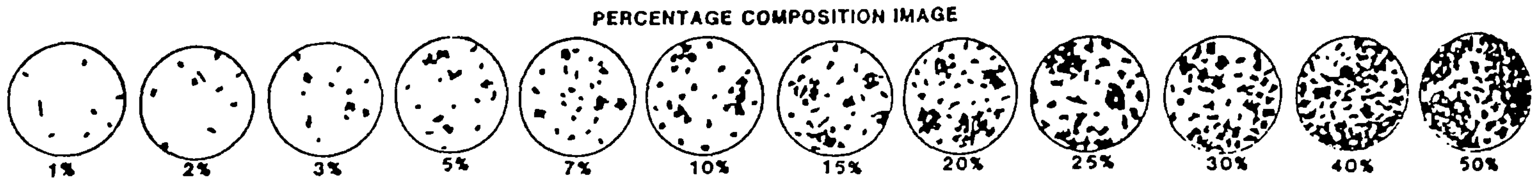
PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 90.0
FLUID LEVEL ____

REMARKS Bit dia. 4 3/4"

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						sltst,sh	lt rd or											S			soil
5.0						sh	lt pk tn											VS			
7.5						sh	lt pk tn											VS			
10.0						sh	lt yw tn											VS			
12.5						qtz ss, sh	lt yw tn	vf-f	f	sr								VS			
15.0						qtz ss, sh	lt yw gy	vf-f	f	sr								m			Upper Burro Cyn Fm ct @ 14 feet
17.5						qtz ss	tn	f	m	sr								N			
20.0						qtz ss	lt gy tn	f	m	sr								N			
22.5						qtz ss	tn	f-m	f	sr								N			
25.0						qtz ss	tn	f	M	r								N			
27.5						qtz ss	tn	f-m	c	r								N			
30.0						qtz ss	lt tn	f-m	f	r								N			
32.5						qtz ss	lt tn	f-M	f	sr								N			
35.0						qtz ss	lt gy	f-cr	p	sr								N			
37.5						qtz ss	vlt gy tn	vf-f	m	sr								N			
40.0						qtz ss	lt tn	vf-m	f	sr								N			
42.5						qtz ss	lt tn	vf-m	f	sr								N			
45.0						qtz ss	tn	f-m	f	sr								N			
47.5						qtz ss cgl	multicolor	f-vc	p	sr								N			abnt chert frag.
50.0						qtz ss cgl	multicolor	f-vc	p	sr								N			" " "
52.5						qtz ss cgl	multicolor	f-m	f	sr								N			" " "
55.0																					No Sample
57.5						qtz ss, cgl	wh-multicolor	f-cr	p	r								N			abnt. chert frag.
60.0						qtz ss, cgl	multicolor	f-vc	p	r								N			" " "
62.5						qtz ss, cgl	multicolor	vc	p	r								N			" " "
65.0						qtz ss, cgl	multicolor	f-vc	p	r								N			" " "
67.5						qtz ss, cgl	multicolor	vc	p	r								N			" " "
70.0						qtz ss, cgl	multicolor	m-vc	p	r								N			" " "
72.5						qtz ss, cgl	wh-multicolor	m-c	m	r								N			chert frag.
75.0						qtz ss, cgl	multicolor	m-c	m	r			tr					N			trace pyrite chert frag
77.5						qtz ss, cgl	multicolor	f-vc	p	r								N			chert frag.
80.0						qtz ss, cgl	multicolor	f-vc	p	r								N			" "
82.5						qtz ss, cgl	multicolor	f-vc	p	r		Hem	tr					N			trace pyrite / hem. after pyrite chert
85.0						qtz ss, cgl	multicolor	f-vc	p	r								N			chert
87.5						qtz ss cgl	wh-multicolor	f-vc	p	r								N			chert
90.0						qtz ss, cgl, sh	multicolor-gn	f-vc	p	r								N			Burro Cyn/Brushy Basin Ct @ 89 feet. T.D.
92.5																					
95.0																					
97.5																					
100.0																					
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

(Bracket in remarks margin, 47.5–87.5: high perm. zone)

PERCENTAGE COMPOSITION IMAGE



Date 12-18-2001 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. Piezometer well #5

Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______

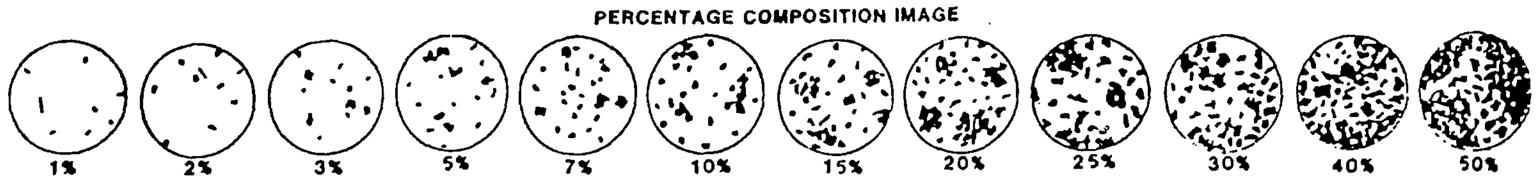
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 107.5
FLUID LEVEL ______

REMARKS Bit dia. 4 3/4"

Depth	Sample taken	Graphic log	Alteration	Gamma anomaly	Breccia pipe	Lithology	Color of wet sample	Grain size	Sorting	Angularity	Cement matrix	Iron oxide	Pyrite: Amount	Pyrite: Habit	Pyrite: Alter.	Metallic	Non-metallic	React.-10% HCL	Carbon: Amount	Carbon: Type	Remarks
2.5						sHst, sh	rdbn											m			Soil
5.0						sHst, sh	ltpktn											VS			
7.5						sHst, sh	ltpktn											VS			
10.0						qtzss sHst	ltpktn	f-m	p	sa								S			
12.5						qtzss, sHst	ltywgy	vf-f	p	sa								VS			
15.0						qtzss, sHst	ltywgy	vf-f	p	sa								m			
17.5						qtzss, sHst	lt ywgy	vf-f	f	sa								VW			
20.0						qtzss, sHst	lt ywgy	vf-f	f	sa								VW			
22.5						qtzss	ltgytn	f	w	sr								N			Upper Burro Cyn Fm. Ct. @ 20 feet
25.0						qtzss	ltgytn	vf-f	m	sr								N			
27.5						qtzss	ltgytn	f-m	m	sr								N			
30.0						qtzss	ltgytn	f-m	m	sr								N			
32.5						qtzss	ltgytn	f-m	f	sr								N			
35.0						qtzss	lttn	f-m	m	sr								N			
37.5						qtzss	ltgytn	vf-f	m	sa								N			
40.0						qtzss, cgl	gy-ltorbn	f-cr	f	sr	lim							N			chert frag.
42.5						qtzss, cgl.	ltpkgy	f-vc	p	sr	lim							N			" "
45.0						qtzss	ltpkgy	f-c	f	sr								N			
47.5						qtzss	ltpkgy	f-c	f	sr								N			
50.0						qtzss	ltpkgy	f-m	m	sr	lim							N			
52.5						qtzss, cgl	lt pkgy	f-m	f	sr								N			Mult. colored chert frag.
55.0						qtzss, cgl	"	m-vc	f	sr								N			" " " "
57.5						qtzss, cgl		m-vc	p	sr		1%						N			notable pyrite, chert frag.
60.0						qtzss, cgl	multicolor	m-vc	p	sr	lim	tr						N			trace pyrite " "
62.5						qtzss, cgl	multicolor	m-c	f	sr								N			" "
65.0						qtzss, cgl	multicolor	m-vc	f	r								N			" "
67.5						qtzss, cgl	wh-multicolor	m-c	f	r								N			" "
70.0						sltsh, sh	v ltgy											N			" "
72.5						qtzss	ltgytn	m-c	m	r								N			" "
75.0						qtzss cgl.	multicolor	m-c	m	r								N			" "
77.5						qtzss, cgl	multicolor	c	m	r								N			" "
80.0						qtzss, cgl	multicolor	c	m	r								N			" "
82.5						qtzss, cgl	multicolor	c	m	r								N			" "
85.0						qtzss	wh-lttn	m-vc	f	r								N			" "
87.5						qtzss	wh-lttn	m-vc	f	r								N			" "
90.0						qtzss	wh-lttn	m-c	f	r								N			" "
92.5						qtzss	wh-lttn	m-c	f	r								N			" "
95.0						qtzss	wh-lttn	m-vc	f	r								N			" "
97.5						qtzss, cgl	multicolor	m-c	p	sr								N			abnt. chert frag.
100.0						qtzss, cgl	multicolor	m-vc	p	r								N			" " "
102.5						qtzss	wh	f-m	f	r								N			" "
105.0						qtzss	wh-multicolor	f-c	f	r								N			abnt. chert frag.
107.5						qtzss, sh	wh-gn	f-m	f	r								N			Burro Cyn/Brushy Basin Ct@ 106 feet, T.D 107.5'
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



APPENDIX A.4

TW4 - SERIES

DEC 13 '99

DEC 13 1999

Date 11-5-99 Geologist L. CASEBOLT Drilling Co. BAYLES EXPLORATION, INC Hole No. #1

Property WHITE MESA MILL Project MW-4 PHASE 2 Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County SAN JUAN State UTAH Location ____ Elev. ____

PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 110.0
FLUID LEVEL ____

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite: Amount	Pyrite: Habit	Pyrite: Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon: Amount	Carbon: Type	Remarks
0																					
2.5						Sh, Sltst	dkrdbn 10 R 3/4											W			
5.0						Sh Sltst	rdbn-prdbn											VS			
7.5						Sh, Sltst	rdbn-prdbn											VS			
10.0						Sh, Sltst.	lt ywgy											VS			Noteable color change
12.5						Sh	ywgy											VS			
15.0						Sh,	dkywbn 10YR 4/2											S			
17.5						Sh, Sltst	dkywbn 10YR4/2					HL						N			
20.0						Sh, Sltst	ywgybn					H						N			Noteable selenite (gypsum) crystals
22.5						Sh	dkywgy											N			Noteable selenite (gypsum) crystals
25.0						Sh	dkywgy											N			
27.5						qtz Ss	ywbn	m-F	F	SR		H						N			
30.0						qtz Ss	tn	m-F	F	SR		H						N			TOP of Burro Cyn Fm.
32.5						qtz Ss	tn	m-F	F	SR		H						N			sparse dark rock fragments
35.0						qtz Ss	lt tn	m	G	R		H						N			
37.5						qtz Ss	lt tn	m-F	F	SR								N			
40.0						qtz Ss	lt tn	C-F	P	SR								N			
42.5						qtz Ss	lt tn	M-F	F	SR		H						N			sparse hem[illegible]
45.0						qtz Ss	lt tn	M-F	G	R								N			
47.5						qtz Ss	lt tn	M	G	R								N			
50.0						qtz Ss	lt tn	M	G	R								N			
52.5						qtz Ss	lt tn	M	G	R								N			
55.0						qtz Ss	lt ywtn	C-M	G	WR								N			Begin Coring @ 55.0'
60.0						qtz Ss, sh	lt tn - lt gy	C-M	G	WR								N			
65.0						qtz Ss	lt gy tn	C-M	G	WR								N			
70.0						qtz Ss, Congl.	lt gytn	M-F	F	SR								N			1% Dark brown-tn chert & rock fragments
75.0						qtz Ss, Congl	tn - lt bn	C-M	P	SR								N			3% Dark brown-tn chert & rock fragments
80.0						Congl	tn, dkgy - blk	V-C	P	SR								N			large (≥1/4") chert rock fragments & pebbles
85.0						Congl, qtz Ss	dkrdbn - lt tn	C	P	SR								N			Congl. 60% SS 40%
90.0						qtz Ss, Congl	lt tn - lt pk	C	P	SR								N			Ss 60% Congl. 40%
95.0						qtz Ss, Congl	lt tn - lt pk	C	F	SR								N			SS 75% Congl. 25%
100.0						qtz Ss	lt ywbn	m-F	F	R								W			
105.0						qtz SS, sh.	lt gytn - lt gybl	M	F	R								N			5% gray blue shale fragments, Base Burro Cyn
110.0						qtz Ss, sh	tn - lt gy bl	m-F	P	SR								N			10% gray blue shale fragments
T.D.																					

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 11-02-99 Geologist L. CASEBOLT Drilling Co. BAYLES EXPLORATION, INC. Hole No. #2

Property WHITE MESA MILL Project MW-4 PHASE 2 Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County SAN JUAN State UTAH Location ______ Elev. ______

PAGE ____ OF ____

T.D. PROBE ______

T.D. DRILL 120.5

FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																					
2.5						Sh	rd bn-bn											N			Soil
5.0						Sh	rd bn-											S			Soil
7.5						Sh	rd bn-lt rd br											VS			
10.0						Slty sh	rd bn-yw tn											VS			Noteable color change silty shale
12.5						Sh	yw gy											VS			Clean shale
15.0						Sh	yw gy											VS			
17.5						Sh, sltst	ywgy					H						S			sparse hemalite, sparse clear-white qtz grains
20.0						Sh	ywgy					H						S			Clean shale
22.5						Sh, sltst	ywgy											S			Silty
25.0						Sh, sltst	ywgy											VS			Silty, noteable selenite crystals
27.5						Sh, sltst	yw gy					H						m			Shale, siltstone w/ coarse selenite crystals
30.0						Sh, sltst	ywgy											VS			Silty.
32.5						Sh	yw											S			
35.0						Sh	yw gy											S			
37.5						qtz ss, sltst	yw bn	C	P	R		H						S			Top of Dakota/Burro Cyn Fm.
40.0						qtz ss, sltst	lt tn	C-M	P	R		H						W			
42.5						Sh-qtz ss	gy-yw bn	C	W	R		H	SP					VW			Sandstone-shale w/ vsparse pyrite
45.0						qtz ss	v lt tn	M	W	R								N			
47.5						qtz ss	lt ywtn											N			Sparse Hematite F-VF
50.0						qtz ss	lt ywtn	F-VF		SR		H						N			Sparse Hematite F-VF
52.5						qtz ss	lt tn	M-F										N			
57.5						qtz ss	lt tn	M-F										N			Begin core at 52.5'
62.5						qtz ss	lt tn, gy	M-F										N			Color change to gray @
67.5						qtz ss	lt gy tn	C-F										W			
72.5						qtz ss	lt tn	M-F	G	R								N			
77.5						qtz ss	tn	m	VG	WR								N			1% Dark brown-tan chert fragments possible conglom
82.5						congl, ss	tn	VC-M	P	WR								N			5% Dark brown-tan chert fragments first water show
87.5						Congl, ss	tn	VC-m	P	WR								N			3% Dark brown-tan chert fragments - first wet sump
92.5						Congl, Ss	tn	VC-m	P	R			SP					N			15% Multicolored chert & rock fragments
97.5						Congl, Ss, Sh	rd bn-gygn-tn	C-m	P	R								N			
102.5						Ss, Sh	lt tn-gygn	C-M	P	R								N			3% Broken Rock Fragments
107.5						Ss, Sh	lt tn-gygn	C-M	P	R								N			Brushy Basin Ct. @ 105'
112.5						Ss, sltst.	lt tn-gygn	F-VF	P	SR								N			
117.5						Sltst, sh	lt gygn											N			
120.5						Sltst, sh	lt gygn											N			
T.D.																					

PERCENTAGE CO[illegible]ON IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% [illegible] [illegible] [illegible]

Date 11-16-99 Geologist L. CASEBOLT Drilling Co. BAYLES EXPLORATION, INC. Hole No. #3

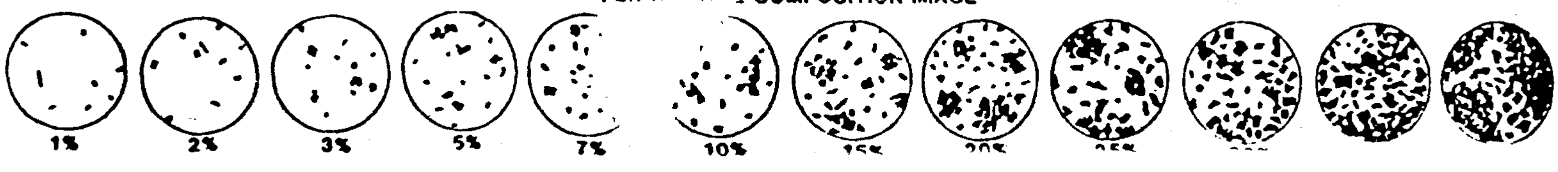
Property WHITE MESA MILL Project MW-4 PHASE 2 Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County SAN JUAN State UTAH Location ______ Elev. ______

PAGE 1 OF ______
T.D. PROBE ______
T.D. DRILL ______
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						Sh, qtz Ss	ltrdbn											S			Soil, frosted qtz grains, vegetation
5.0						Sltst, sh	ltrdbn-ppk											S			
7.5						sh	lttn-rdbn											VS			noteable color change
10.0						sh	lttn											VS			
12.5						sh	ltywbn											VS			
15.0						Sh	ywbn											VS			
17.5						Sh	dkgybn											VS			silty, sparse manganese dendrites on surfaces
20.0						sh	dkgybn											VS			
22.5						Sh	dkgybn											VS			
25.0						Sh	dkgybn											VS			1% gypsum (selenite) crystals
27.5						Sh	dkgybn											VS			2% " " "
30.0						sh sltst	dkgybn											VS			1% " " "
32.5						Sh, sltst, Ss	dkgy-dkrdbn	VF	P	SA								VS			
35.0						Sltst	dkgybn											W			
37.5						Sltst	dkgybn					H						N			
40.0						qtz Ss	ltgytn	m	F	SR		H						N			Top of Burro Cyn Fm.
42.5						qtz Ss	lt tn	m	G	SR		L						N			
45.0						qtz Ss.	lttn	M	G	SR								N			
47.5						qtz SS.	lt tn	m	G	SA		H						N			
50.0						qtz Ss	bn	m-cR	F	SA		H						W			Abundant hematite
52.5						qtz Ss	tnbn	m-cR	P	SA		H						N			" "
55.0						qtz SS	tn	m-cR	P	SA		H						N			" "
57.5						qtz Ss	tn	F-m	F	SA								N			
60.0						qtz ss.	ltbngy	m	G	SR								N			Dark gray rock fragments 2%
62.5						qtz Ss.	lttn	F-m	F	SR								N			
65.0						qtz Ss	lttn	m	G	SR								N			
67.5						qtz Ss	lttn	F-m	G	SR								N			
70.0						qtz Ss	lttn	F-m	F	SA								N			
72.5						qtz Ss.	lt bn	F-m	F	SR								N	SP	P	Sparse carbon from plant fragments
75.0						qtz Ss.	lt bn	F-m	P	SA								N			
77.5						qtz Ss Cgl	lt bn	F-cR	P	A								W			Broken rock fragment
80.0						qtz Ss, Cgl	lt blgy	F-cR	P	A								VS			
82.5						Sh,	lt blgy	-										S			contains qtz grains & rock frag. from 77.5 feet.
85.0						qtz Ss.	lttn	M	G	R								N			
87.5						qtz Ss	lttn	m	G	R								N			
90.0						qtz Ss	lttn	F-m	F	SR								N			
92.5						qtz Ss.	lt tn	m	G	R								N			
95.0						qtz Ss	lt tn	m-cR	F	SR								N			
97.5						qtz Ss, Sh	lttn-ltblgy	F	F	SA								W			Lower contact Burro Cyn Fm.
100.0						Sh, qtz Ss	ltblgy	F-cR	P	SA								W			Brushy Basin Mbr. Morrison Fm.
102.5						Sltst, Sh	ltblgy											m			
105.0						Sltst, Sh	lt blgy-wh											N			
107.5						Sh.	lt blgy-wh											N			
110.0						Sh, qtz Ss	ltblgy-wh	F-m	P	SA			SP					N			Noteable pyrite (<1%)
112.0						Sltst, qtz Ss	ltblgy-wh	F-m	P	SA			SP					N			Sparse pyrite
115.0						Sltst, qtz Ss	blgy	F	P	SA			SP					N			sparse pyrite
117.5						Sh, Sltst	blgy											N			
120.0						Sltst	blgy						SP					N			Sparse pyrite
122.5						Sltst, qtz Ss	blgy	F-m	P	SR			SP					N			Sparse pyrite, chert fragment
125						Sltst, qtz Ss	blgy-gy	VF-m	P	SR								N			Some chert fragment

PERCENTAGE COMPOSITION IMAGE



Date 11-17-99 Geologist L. CASEBOLT Drilling Co. BAYLES EXPLORATION, INC. Hole No. #3

Property WHITE MESA MILL Project MW-4 PHASE 2 Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County SAN JUAN State UTAH Location ______ Elev. ______

PAGE ____ OF ____

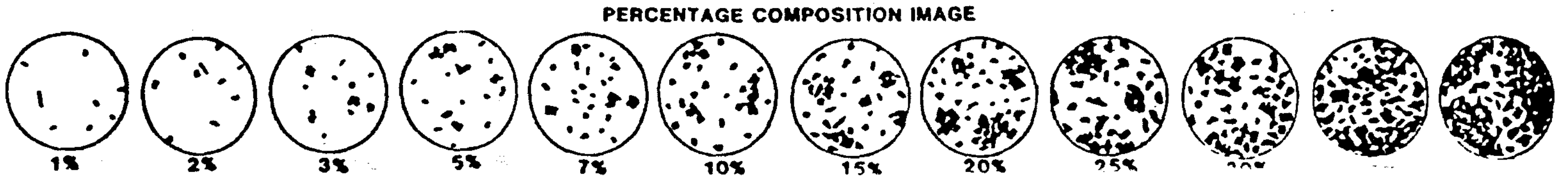
T.D. PROBE ______

T.D. DRILL ______

FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
125.0						qtz Ss, Cgl.	Wh - lt blgy	m-CR	P	SA			SP					VW			Sparse pyrite, Some blgy sltst. Multi colored chert
127.5						qtz Ss, Cgl	Wh	m-CR	P	SA								M			Multi colored chert & qtzite fragments
130.0						qtz Ss, Cgl	Wh	m-CR	P	SA								VW			" " " " "
132.5						qtz Ss, Sh	Wh-dk pp bn-blgn	m-CR	P	SR								N			Ss 50%, Sh 50%
135.0						Sh	dk pp bn											N			
137.5						Sh	dk pp bn											N			
140.0																					
T.D.																					

PERCENTAGE COMPOSITION IMAGE



1% 2% 3% 5% 7% 10% 15% 20% 25%

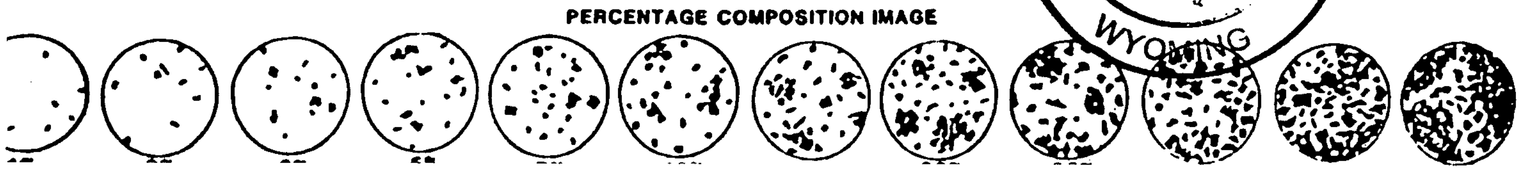
Date 5-11-2000 Geologist L. CASEBOLT Drilling Co. BAYLES EXPLORATION, INC Hole No. TW4-4
Property WHITE MESA MILL Project MW-4 PHASE 2 Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County SAN JUAN State UTAH Location ______ Elev. ______

T.D. PROBE ______
T.D. DRILL 112.0
FLUID LEVEL DRY WELL

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
						Sltst, Caliche	dk rd bn-wh											VS			Soil/caliche w/ wood & plant frag.
						Sltst, Qtz Ss	rd bn	F	F	SA								VS			
						Qtz Ss	lt bn	F	F	SA								VS			
						Qtz Ss	lt bn	F	F	SA								S			
						Sh,	lt yw bn	m-F	P	SA								S			
						Sh,	lt yw bn	m-F	P	SA								S			
						Sh,	lt yw bn	M-F	P	SA								S			
						Qtz Ss,	lt tn	M-F	P	SA								N			Upper Burro Cyn Contact @ 17.5' noteable color change
						Qtz Ss	v lt tn	M-F	F	SA								N			
						Qtz Ss	lt tn	F	F	SA								N			
						Qtz Ss,	lt tn	m-F	P	SA								VW			
						Qtz Ss	lt tn	m-F	P	SA								S			
						Qtz Ss	lt tn	m	F	SA								S			
						Qtz Ss	v lt tn	m	G	SR								N			
						Qtz Ss	v lt tn	m	G	SR								N			noteable absence of hematite in this
						QtzSs	v lt tn	m	G	SR								N			zone.
						Qtz Ss	lt tn	m	G	SR								N			
						Qtz Ss	lt tn	m	G	SR								N			
						Qtz Ss	lt tn	F	G	SR								N			
						Qtz Ss	lt tn	F	G	SR								N			
						Qtz Ss	lt or tn	m-F	G	SR								N			
						Qtz Ss	lt gy tn	m	G	R								N			Multicolored chert & rock frag.
						Qtz Ss	lt gy tn	m	G	SR								N			
						Qtz Ss	lt gy tn	m	G	SR								N			
						Qtz Ss	lt gy tn	m	F	SR								N	SP	P	Sparse carbon frag.
						Qtz Ss	lt gy tn	m	F	SA								N	SP	P	Sparse carbon and wh chert fragments
						Qtz Ss	lt tn	m	F	SA								N			wh-bk chert fragments
						Qtz Ss	lt tn	m	F	SA								N			
						Qtz SS	tn	m	F	SA								N			
						Qtz SS	tn	m	F	SA								N			dkgy-bk chert frag.
						Qtz SS, Cgl	lt or tn	m	F	A		SP						S			Abund. dkgy-wh chert frag. poss congl. sp hematite
						Sh	lt bl gy											N			
						Qtz SS	v lt tn	F	G	SR								S			
						Qtz Ss	v lt tn	F	G	SR								N			
						Qtz Ss	v lt tn	F	G	SR								W			
						Qtz Ss	v lt tn.	F	G	SR								W			Basal Burro Cyn Fm. contact at 90.0 feet.
						Sh, Qtz Ss	bl gy	m-F	P	SA								N			dk rd bn qtzite rock fragments/poss cgl.
						Sh,	bl gy											N			sp dk rd bn qtzite rock fragments.
						QtzSs, Sh	v lt bl gy	m-F	P	SA								N			
						Sh,	bl gy											N			very sparse chert fragments
						Sh	bl gy											VW			
						Sh	bl gy											VW			
						Sh, Qtz SS.	lt gy	F	F	SA								N			
						Sh, Qtz SS	lt gy	F	F	SA								N			
						Sh	lt gy-dk pp bn	-										N			
T.D.																					

PROFESSIONAL GEOLOGIST
LAWRENCE CASEBOLT
PG-3218
WYOMING

PERCENTAGE COMPOSITION IMAGE

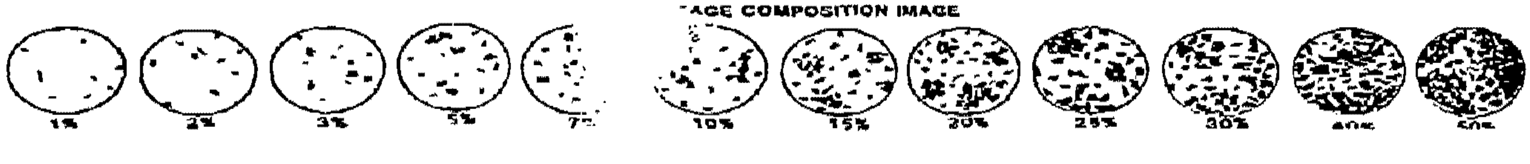


Date 12-15-99 Geologist L. CASEBOLT Drilling Co. BOYLES EXPLORATION, INC. Hole No. 99-09-002-M-05
Property WHITE MESA MILL Project MW-4 PHASE 2 Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County SAN JUAN State UTAH Location ______ Elev. ______

PAGE ____ OF ____
T.D. PROBE ______
T.D. DRILL ______
FLUID LEVEL ______

DEPTH	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
2.5	Sltst	dkrdbn											VS			soil (plant fragments)
5.0	Sltst	rdbn-ltpk											VS			ltpk fragments caliche
7.5	Sltst	ltpk bn											VS			
10.0	Sltst	lt rd bn											VS			
12.5	Sh	wh-vltpk											VS			
15.0	Sh, sltst	wh-vltpk											VS			
17.5	Sh, sltst	wh-lttn											VS			
20.0	Sh	ltywbn											VS			selenite crystals, manganese dendrites
22.5	Sh	ywbn											VS			
25.0	Sh	ywgybn											VS			selenite crystals
27.5	Sh	yw bn											VS			abundant selenite crystals, manganese dendrites
30.0	Sh	ywbn											S			" " " " "
32.5	Sh	ywgybn					H						S			" " "
35.0	Sh Sltst	ywgybn											m			
37.5																Helper missed this sample - No data
40.0	qtz Ss	ltywbn	F-m	G	SR								VM			First show of Burro Cyn. Fm. Sandstone @ 38.0 feet
42.5	qtz Ss	lttn	F-m	F	SR								N			
45.0	qtz Ss	lttn	m	G	SR								N			
47.5	qtz Ss	lttn	m	G	SR								N			
50.0	qtz Ss	tn	F-m	F	SA								N			
52.5	qtz Ss	tn	F-m	F	SR								N			
55.0	qtz Ss	tn	F-m	F	SR								N			
57.5	qtz Ss	ltgytn	F	F	SA								N			
60.0	qtz Ss	ltgytn	VF-F	F	SA								N			
62.5	qtz Ss	vlttn	VF	G	SR								N			
65.0	qtz Ss, Sltst	vlttn	VF	G	SA								N	T	P	
67.5	qtz Ss, Sltst	vlttn	VF	G	SA								N	T	P	trace carbon plant fragments
70.0	qtz ss, sltst	vltgytn	VF	G	SA								N	A	P	abundant " " "
72.5	qtz Ss	gytn	VF-F	G	SA								N	A	P	" " " "
75.0	qtz Ss	gytn	F	G	SA								N	A	P	" " " "
77.5	qtz Ss	tn	m-cr	F	SR								N			trace carbon plant fragments, chert frag.
80.0	qtz Ss	lttn	F-m	F	SR								N			
82.5	qtz Ss	lttn	F-m	F	SR								N			
85.0	qtz Ss, Sh	wh-vltblgy	VF-F	F	SR								N			
87.5	Sh	ltblgy					T						N			
90.0	Sh	ltblgy-rdbn					T						N			
92.5	qtz Ss	lttn	F	F	SR								N			
95.0	qtz Ss	lttn	F-M	G	SR								N			
97.5	qtz Ss	tn	M	G	R								N			
100.0	qtz Ss Cgl	tn	CR	G	R								N			abundant dkgy chert fragments and pebbles
102.5	qtz Ss Cgl	tn-gy	CR	G	R								N			" " " " " "
105.0	Sh	blgy-rdbn											N			Upper Ct. Brushy Basin Fm. @ 102.5 feet
107.5	qtz Ss	lttn	VF-F	P	SR								N			
110.0	qtz Ss	lttn	m	F	SR		T						N			
112.5																cuttings washed away - no sample
115.0	qtz Ss, Cgl	tngy	F-M	P	SR								N			dkgybn chert fragments and pebbles
117.5	qtz Ss, Sltst	ltgrbn	VF-F	F	SR								N			
120.0	qtz Ss, Sltst	ltgrbn	VF-F	F	SR								N			
													N			

AGE COMPOSITION IMAGE



Date 5-11-2000 Geologist L. CASEBOLT Drilling Co. BAYLES EXPLORATION, INC. Hole No. TW4-6

Property WHITE MESA MILL Project MW-4 PHASE 2 Unit No. ______ Sec. ______ Twp. ______ Rge. ______

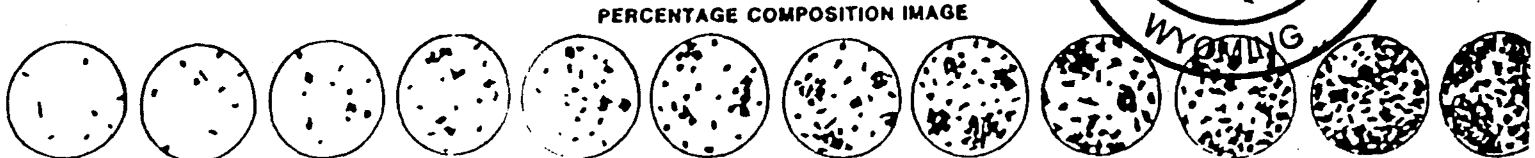
County SAN JUAN State UTAH Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 97.5 FEET
FLUID LEVEL DRY WELL

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																					
2.5						Sh, Sltst, Ss	dk rd bn	C-M	VP									S			Soil, very sparse clear qtz grains, plant frag
5.0						Sh, Sltst	dk rd bn - lt rd tn											VS			
7.5						Sltst	lt rd tn											VS			
10.0						Sh, qtz Ss	lt ywgy	C-M	P	R		SP						VS			Noteable color change
12.5						Sh, Sltst	lt ywgy											VS			
15.0						Sh, qtz Ss	lt ywgy	C-M	F	SR		SP						VS			Hematite as grains, and clusters, qtz grains
17.5						Sh, qtz Ss	lt ywgy	C-M	F	SR		SP						S			" Some sparse gypsum (selenite xls)
20.0						Sh, Sltst	lt ywgy											W			
22.5						Sh, Sltst	lt ywgy											W			Upper Burro Cyn Fm. contact at 22.5 ft.
25.0						Qtz Ss	lt gy tn		G	SR		SP						VW			Qtz grains clear, sparse hematite as grains, ch
27.5						Qtz Ss	lt gy tn	F	P	SA		SP						N			Sparse dk gy chert frag, some gy shale.
30.0						Qtz Ss	lt tn	[illegible]	[illegible]	SR		SP						N			
32.5						Qtz Ss.	lt gy tn	C-M	[illegible]	SA		A						N			Abund. hematite, abund. wh-dk gy chert frag.
35.0						Qtz Ss.	tn	C-M	[illegible]	SA		S						N			Some hematite abund. wh-dk gy chert frag
37.5						Qtz Ss.	tn	C-M				S						VW			" "
40.0						Sh, Qtz Ss	gy	C-M	[illegible]	A		SP						VW			
42.5						Qtz Ss	tn	M	G	R		SP						N			Nice clean sand.
45.0						Qtz Ss	tn	M				SP						N			
47.5						Qtz Ss, Sh	lt gy tn	F-M	F			SP						N			Sparse shale frag.
50.0						Qtz Ss	lt tn	F	G	A		SP						N			
52.5						Qtz, Ss	lt tn	F	G									N	SP	P	Sparse carbon (plant fragments)
55.0						Qtz Ss, Sh	lt gy	F	F									N	S	P	Some carbon (plant fragments) wh chert frag
57.5						Qtz Ss	gy	F	F	SA								N	VA	P	Abundant carbon, some wh chert frag.
60.0						Qtz Ss	gy	M-F	P	SA								N	A	P	
62.5						Qtz Ss	gy tn	M-F	F	SA								N	SP		
65.0						Qtz Ss	gy tn	M-F	F	SA								N	SP		wh-bk chert fragments
67.5						Qtz Ss	lt tn	M-F	F	SA		SP						N			wh-bk chert fragments
70.0						Qtz Ss	tn	M-F	G	SA								N			wh-bk chert frag.
72.5						Qtz Ss, Cgl	tn	C-F	P	SA								S			Coarse, multicolored chert & rock fragments poss. co
75.0						Qtz Ss	v lt tn	F	F	SA								N			very clean sand
77.5						Qtz Ss	v lt tn	F	F	SA								N			" " "
80.0						Qtz Ss	v lt tn	F	F	SA								N			" " "
82.5						Qtz Ss	v lt tn	F	F	SA			S					W			Some granular pyrite frag.
85.0						Qtz Ss	v lt gy tn	F	F	SA			SP					N			" " " "
87.5						Sh, qtz Ss	gy	M	P	SA			SP					N	SP		
90.0						Qtz Ss, Sh	gy	C-M	P	SA			SP					N	SP		Carbon & pyrite frag. with multi colored chert fr
92.5						Qtz Ss	lt or tn	M	G	SR								N			nice clean sand
95.0						Qtz Ss	lt or tn	M	G	SR								VW			Basal Burro Cyn. Fm contact @ 95.0 feet.
97.5 T.D.						Sh, Cgl	bl gy - tn	C	VP	SA			S					N			upper Brushy Basin contact, pyrite grains w/ gy chert fragments. noteable color change

PROFESSIONAL GEOLOGIST
LAWRENCE CASEBOLT
PG-3216
WYOMING

PERCENTAGE COMPOSITION IMAGE



Date 11-17-99 Geologist L Casebolt Drilling Co. BAYLES EXPLORATION, INC Hole No. #7

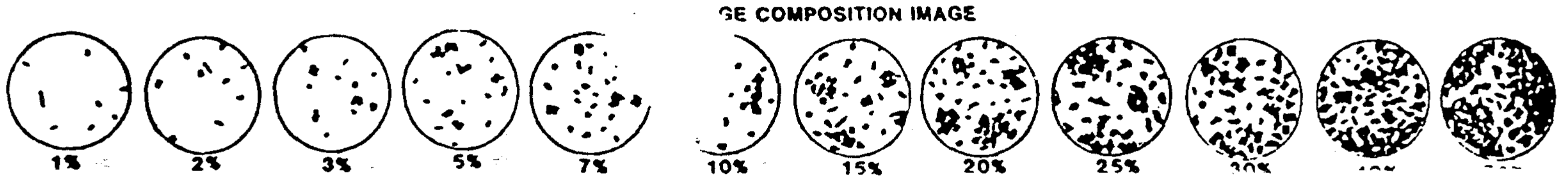
Property WHITE MESA MILL Project MW-4 PHASE 2 Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County SAN JUAN State UTAH Location ______ Elev. ______

PAGE 1 OF ______
T.D. PROBE ______
T.D. DRILL ______
FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0						Sltst, Sh	dkrdbn											N			Soil
2.5						sltst, sh	dkrdbn-ltpktn											VS			noteable color change
5.0						sltsh, sh	ltpktn											VS			
7.5						Sh	ywgy											VS			notecble color change, some manganese dend
10.0						Sh	ywgy											W			
12.5						Sh	ywgy					L						VS			sparse limonite
15.0						Sh	ywgy											S			gypsum (selenite) crystals
17.5						qtz Ss, Sltst	ywgy	VF	P	SA		L						S			20% gypsum (selenite) crystals
20.0						Sltst, sh	ywgy					L						N			20% gypsum (selenite) crystals
22.5						sltst, sh	ywgy					H						N			10% gypsum (selenite) crystals
25.0						Sltst, Sh	ywgy											N			
27.5						qtz Ss	lt tn	F-M	F	SA								N			Top of Burro Cyn. Fm.
30.0						qtz Ss	lt tn	F-M	F	SA								N			
32.5						qtz Ss	lt tn	M	G	SR		L						N			Sparse limonite
35.0						qtz SS	lt tn	M	G	SR		L						N			Sparse limonite
37.5						qtz Ss	lt tn	F-M	F	SA								N			
40.0						qtz SS	tn	F-M	F	SA								N			
42.5						qtz SS	ltgytn	F	F	SA								N			
45.0						qtz Ss	lt tn	F	F	SR								N			
47.5						qtz SS	lt tn	F-M	F	SR								N			
50.0						qtz Ss	vlttn	F	G	SR								N			
52.5						qtz SS	vlttn	VF-F	G	SA								N			
55.0						qtz Ss	lttn	VF-F	F	SA								N			
57.5						qtzSs, Sh	tnbn-gy	F-M	F	SA								N			
60.0						qtz Ss, Sh	dkgybn											N			
62.5						no cuttings															Lost circulation at this depth - no cuttings
65.0																–					" " " " " " "
67.5																					" " " " " " "
70.0																					" " " " " " "
72.5						qtzSs	ltbn	M	G	SA								N			Began H2O injection w/ foam
75.0						qtz Ss, Cgl	lt ywtn	M-CR	P	SA		H						N	S	P	Sparse carbon as plant frag. chert fragments
77.5						qtz SS, Cgl	lt gy-wh	M-CR	P	SA		H						N			Chert & qtzite rock fragments sparse hemati
80.0						qtz Ss, Cgl	lt tn	M-CR	P	A		H						N			" " " " " "
82.5						qtz ss, Cgl	tn-rdbn	M-CR	P	A		H						N			abundant rd & bk chert fragments
85.0						qtz Ss, Cgl.	tn-multicolor	CR	P	A		H						N			Very large & abundant chert fragments
87.5						qtz Ss, Sh	lttn-ltblgy	F-M	F	SA								N			lt bl shale fragments 5%
90.0						qtzSs, Sh	lttnbn-ltblgy	F-M	F	SA			SP	MTX				N			Sparse pyrite as cement/matrix around qtz grains
92.5						qtz Ss	lttn-ltorbn	F-M	F	SA		H	SP	MTX				N			" " " " " " " "
95.0						qtz Ss	vlttn	F-M	F	SA								N			Base of Burro Cyn Fm.
97.5						Sltst,	wh											N			
100.0						Sh, Sltst	ltblgy											N			
102.5						Sh, Sltst	dkrdbn-blgy											N			Shale frag, mottled, reduced from rdbn-blgy
105.0						Sh, Sltst	dkppbn-blgy											N			
107.5						Sltst, Cgl	ltblgy											N			Dark gray chert frag. & pebbles
110.0						qtz ss, Cgl, Sh	lt blgy	M-CR	P	A								N			coarse, clear qtz grains, large rock fragments & pebbl
112.5						Sh, Sltst	vlblgy											N			
115.0						Sh	ltblgy											N			
117.5						Sh	ltblgy											N			
120.0																					

GE COMPOSITION IMAGE



Date 11-17-99 Geologist L. CASEBOLT Drilling Co. BAYLES EXPLORATION INC. Hole No. #8

Property WHITE MESA MILL Project MW-4 PHASE 2 Unit No. ______ Sec. ______ Twp. ______ Rge. ______

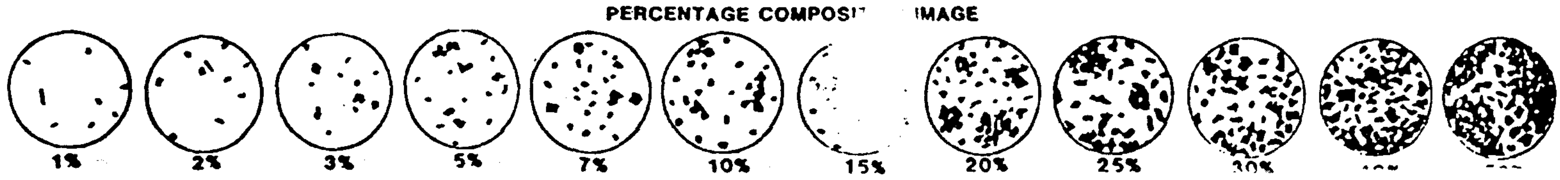
County SAN JUAN State UTAH Location ______ Elev. ______

PAGE 1 OF ____
T.D. PROBE ____
T.D. DRILL ____
FLUID LEVEL ____

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																					
2.5						Sltst-Sh	rdbn											S			Soil
5.0						sltst-sh	rdbn-ltpktn											S			
7.5						Sltst-Sh	rdbn-ltpktn											VS			
10.0						sltst-sh	lttn-rdbn											VS			noteable color change
12.5						Sh	dkywbn											S			
15.0						Sh	dkywbn											VS			manganese dendrites on surfaces
17.5						Sh	dkywbn					L						VS			trace selenite (gypsum) fragments
20.0						Sh	dkywbn					L						S			3% selenite fragments
22.5						Sltst-Sh	dkywbn					L						S			
25.0						sltst-sh	dkywbn					L						N			
27.5						sltst-Sh	ywbn					L/H						N			
30.0						qtz Ss	ltgytn	m-F	P	SR								N			Top of Burro Cyn Fm. @ 27.5'
32.5						qtz Ss	ltortn	F	G	R								N			
35.0						qtz Ss	lt tn	F-VF	P	SR		H						N			
37.5						qtz Ss, Congl	dktn	vc F	P	A		H						S			
40.0						qtz Ss, Congl	dktn	vc F	P	A		H						VS			Sparse shale fragments
42.5						qtz Ss, Sltst	dkgytn	F-VF	P	SR		L						N			
45.0						qtz Ss, Sltst	dktn	F-VF	P	SR		L						N			
47.5						qtz Ss	lt tn	VF	G	SR								N			
50.0						qtz Ss	lt tn	F	G	R								N			
52.5						qtz Ss	tn	VF	F	SR								N			
55.0						qtz Ss	lt tnbn	VF	F	SR		L						N			
57.5						qtz Ss	gybn	VF	F	SR								N	T		
60.0						qtz Ss	gybn	VF	F	SR								N	1%		
62.5						qtz Ss	gy bn	F-VF	P	SR								N	T		
65.0						qtz Ss	dk tn	VF	F	SR								N	T		
67.5						qtz Ss	gytn	F-VF	F	SR					-			N			
70.0						qtz Ss	gytn	m-VF	F	SR								N			
72.5						qtz Ss	gytn	F VF	F	SR								N			
75.0						qtz Ss	tn	F	W	SR								N			
77.5						qtz Ss	tn	F	W	SR								N			Trace dk chert fragments
80.0						qtz Ss	tn	m-F	P	SR		H						S			3% lt blgn shale fragments
82.5						sltst	lt blgn											N			
85.0						qtz Ss	lt tn	F	G	SR								N			
87.5						qtz Ss	ltgy	F	G	SR								N			
90.0						qtz Ss	ltgy	VF	F	SR								N			
92.5						slt st	lt blgy											N			
95.0						qtz Ss Sltst	lt blgn	m-F	F	SR								N			
97.5						qtz Ss	ltgy-lt blgn	m	W	R								N			15% blgn shale frag. &
100.0						qtz Ss, Congl	gy	vc-C	P	SR								N			50% multi colored rocks & chert fragments
102.5						qtz Ss,	ltgy	vc-m	F	SR								N			1% dkgy-wh rock fragments, Burrow Cyn/Brushy Basin
105.0						Sltst, Congl	gygn											N			sparse lttn-rd chert fragments
107.5						Sltst, Congl	gygn											N			sparse, colored chert fragments, pebble fragments
110.0						Sltst, Congl	gygn											N			Sparse colored chert fragments
112.5						Sltst, Congl	gygn	-										N			
115.0						Sltst, qtz Ss	gygn	VF										N			Sparse ltgy Ss fragments
117.0						Sltst, qtz Ss	gygn	VF										N			Sparse ltgy Ss fragments
120.0						Sltst, Congl	ltgygn											N			Sltst 75% tn chert fragments 25%
122.5						Sh	dkpprd-gygn											N			
125.0						Sh	dkpprd											N			

T.D.

PERCENTAGE COMPOSITION IMAGE



Date 12-15-99 Geologist L. CASEBOLT Drilling Co. BAYLES EXPLORATION INC. Hole No. 99-09-003-M-09
Property WHITE MESA MILL Project MW-4 PHASE 2 Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County SAN JUAN State UTAH Location ____ Elev. ____

PAGE ____ OF ____
T.D. PROBE ____
T.D. DRILL 120.0
FLUID LEVEL ____

DEPTH	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	REACT-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
2.5	SHst	dkrdbn							S			soil (plant fragments)
5.0	SHst, Ss	ltpkbn-ltpk	VF	P	A				VS			ltpk fragments caliche
7.5	SHst, Ss	ltpkbn-ltpk	VF	P	A				VS			" " "
10.0	SHst	ltrdbn							VS			
12.5	Sh	wh							VS			
15.0	Sh, Ss	ltywbn	F	P	SR				VS			
17.5	Sh	vltywgy							S			
20.0	Sh	vltywgy-gy							VS			sparse gypsum (selenite crystals)
22.5	Sh	ltywgy-gy							VS			" " " "
25.0	Sh	ywgy-gy							S			increasing gypsum (selenite crystals)
27.5	Sh	ywgy-gy							S			" " " "
30.0	Sh	ltywgy-gy							S			gypsum (selenite crystals 2%)
32.5	Sltysh	ltywgy-gy							W			selenite 1% sparse manganese dendrites
35.0	Sltysh	ywgy-gy bn				H			W			sparse hematite
37.5	Sltysh	ywgybn				H			W			hematite 2%
40.0	Sltysh, Ss	ywgybn	F	F	R	H			N			Upper Ct. Burro Cyn. Fm. @ 38.0 feet
42.5	qtz Ss	ltywbn	VF-F	F	R				N			
45.0	qtz Ss	lttn	F-m	F	SR	L			N			
47.5	qtz Ss	lttn	F-M	m	SR				N			
50.0	qtz Ss	lttn	VF-F	F	SA				N			
52.5	qtz Ss	lttn	VF-F	P	SA				N			
55.0	qtz Ss	lttn	VF-F	P	SA	H			N			Sparse hematite
57.5	qtz Ss, Sh	ltgybn	VF-F	P					N	SP	P	sparse carbon plant fragments
60.0	qtz Ss	vlttn	VF	F	SR				N			
62.5	qtz Ss	vltgy-wh	VF	F	SR				N			
65.0	qtz Ss	vltgy-wh	VF-F	F	SR				N			
67.5	qtz Ss	vltgy	VF-F	F	SR				N			
70.0	qtz Ss	ltgy	F	G	SR				N	SP	P	sparse carbon plant fragments
72.5	qtz Ss	gy	VF-m	F	SR				N			2% carbon plant fragments
75.0	qtz Ss	ltgybn	VF-m	P	SR				N			" " " "
77.5	qtz Ss, Cgl	ltgytn	F-CR	P	SR				N			dkgy-pk chert fragments
80.0	qtz Ss, Cgl	lttn	F-CR	P	SA				N			" " " "
82.5	qtz Ss, Cgl	lttn	F-CR	P	SA				N			" " " "
85.0	Sh, Ss, Cgl	vltblgy	m-CR	P	A				N			Sh 80% - Ss, Cgl 20% dkgy-tn chert frag.
87.5	Sh	lt blgy							N			
90.0	qtz Ss	lttn	m	F	SR				N			some dkgy chert fragments
92.5	qtz Ss, Cgl	tn	m-CR	F	SR				N			" " " "
95.0	qtz Ss, Cgl	tn	m-CR	F	SR				N			" " " "
97.5												No cuttings -
100.0	Cgl, qtz Ss	dkgy, rd, lttn	CR	P	A				N			chert fragments
102.5	qtz Ss, Cgl	lttn	m-CR	F	R				N			"
105.0	qtz Ss, Sltst	lttn-ltblgy	m	F	SR				N			Upper Ct. Brushy Basin Fm. @ 104.0 feet
107.5	Sltst	ltblgy							N			
110.0	Sltst	ltblgy					S	G	N			Sparse pyrite (granular)
112.5	Sltst, Cgl	ltblgy							N			dkgy chert fragments
115.0	Cgl, qtz Ss	wh-ltblgy	m-CR	P	R		S	G	N			Cgl unit in Brushy Basin Fm - high perm zone
117.5												no cuttings
120.0	qtz Ss	lttn	m	G	R				N			
TD												

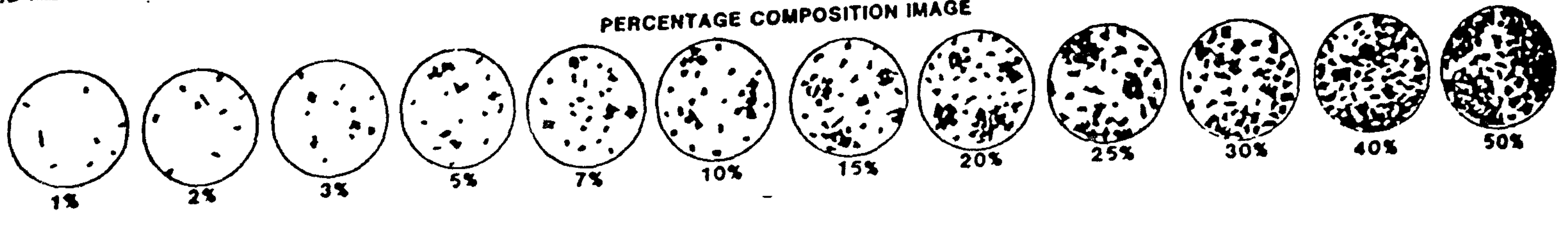
PERCENTAGE COM ON IMAGE

Date 12-20-2001 Geologist L. Casebolt Drilling Co. Bayles Exploration Inc. Hole No. TW4-10
Property White Mesa Mill Project MW-4 Phase 3 Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 110.0
FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0						sltst,sh	rdbn											S			soil
2.5						sltst,sh	rdbn											S			soil
5.0						sh, qtzss	vlttn	cr	p	sr								VS			
7.5						Sh	ltywtn											VS			manganese dendrites
10.0						sh	ltywtn											VS			" " selenite crystals
12.5						sh	ltywgy											VS			
15.0						Sh	ltywgy											S			selenite crystals
17.5						sh	lt ywgy											S			
20.0						sh	lt ywgy											VS			
22.5						sh	lt ywgy											S			
25.0						Sh	lt ywgy											VS			selenite crystals
27.5						Sh	lt ywgy											S			
30.0						Sh, sltst.	lt ywgy											W			abnt. selenite crystals
32.5						sh, sltst.	ywgy											VW			
35.0						sltst, sh	ywgy											N			
37.5						sltst, sh	dkgy - ywgy											N			Upper contact Burro Cyn Fm @ 40.0'
40.0						qtzss	tn	f-m	m	sr								N			
42.5						qtzss	tn	f-m	m	sr								N			
45.0						qtzss	tn	f-m	m	sr								N			
47.5						qtzss	tn	f-m	m	sr								N			
50.0						qtzss	tn	m	f	sa								N			
52.5						qtzss	tn	f-m	m	sa								N			
55.0						qtzss	tn	f-m	m	sa								N			
57.5						qtz ss	tn	vf-f	m	sr								N			
60.0						qtz ss	ltgytn	f	w	sr								N			
62.5						qtz ss	tn	f	w	sr								N			
65.0						qtzss	dkgy	f-m	p	sa								N	10%		abnt. 10% carbon wood frags sp. wh chert. frag.
67.5						qtzss	vdkgy		p	sa								N	20%		abnt. 20% carbon wood frag. " " " "
70.0						qtzss, sh	vlttn	f-m	f	sr								N			moisture first noted @ 72.5'
72.5						qtzss, sh	vlttn	f-m	f	sr								N			
75.0						qtzss, sh	vlttn	f-m	f	sr								N			Water injection begin @ 75.0 feet
77.5						ss, cgl	wh-blk	m-vc	p	sr								N			multi-colored chert frag. high perm.
80.0						sh, sltst cgl.	ltgy	vc	p	sr								N			" "
82.5						ss	wh	f-m	m	sr								N			clean sand
85.0						ss	wh	f-m	f	sa								N			" "
87.5						ss, cgl	wh	m-c	p	sr								N			
90.0						ss, cgl.	wh-multicolored	vc	p	sr								N			chert frag. (high perm zone)
92.5						ss, cgl	multicolored	vc	p	sr								N			chert pebble conglomerate (high perm zone)
95.0						ss, sh cgl	wh-lttn	m-vc	p	sr			tr	xls				N			abnt multicolored chert frag. tr. pyrite (high perm zone)
97.5						ss, slt, sh	wh-gygn	f-m	f	sr								W			chert frags.
100.0						ss	wh	f-m	f	sr								N			
102.5						ss	wh	f	w	sr			tr	xls				N			trace dkgy-pk chert frag. tr. pyrite
105.0						ss, sltst, sh	wh-gygn	vf-f	w	sr								N			Burro Cyn Fm / Brushy Basin Fm. Ct. @ 106 feet
107.5						sltst, sh	gygn											N			Total Depth -
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE

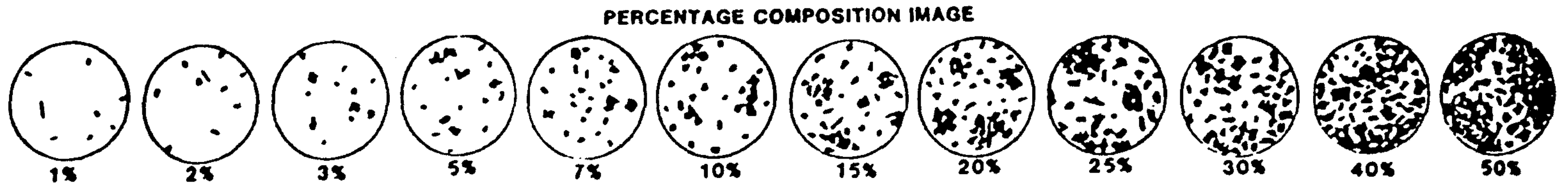


Date 12-19-2001 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TW4-11
Property W Project MW-4 Phase 3 Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 97.5
FLUID LEVEL 90

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						sltst, sh	ltpktn											VS			soil
5.0						sh	ltywtn											S			
7.5						sh	ltywtn											S			
10.0						sh	ltywtn											S			very abnt. selenite crystals
12.5						sh	ltywtn											S			
15.0						sh	ltywgy											S			
17.5						sh	ltywgy											S			
20.0						sh	ltywgy											S			Noteable selenite Crystals
22.5						sh sltst	ywgy											m			" " "
25.0						sh, sltst	ywgy											S			
27.5						sh, sltst	ywgy											W			selenite crystals
30.0						sh, sltst	ywgybn											N			
32.5						sh, sltst	dkywbn											N			
35.0						sltst, sh	vdkgybn											N			Dakota/Burro Cyn Fm. Contact @ 35.0 feet
37.5						qtz ss	tn	f-m	f	sr								N			
40.0						qtz ss	tn	f-m	f	sr								N			
42.5						qtz ss	tn	f-m	f	sr								N			
45.0						qtz ss	tn	f-m	m	sr								N			
47.5						qtz ss	tn	f-m	m	sr								N			
50.0						qtz ss	vltgy	m	w	r								N			
52.5						qtz ss	vltgy-wh	m	w	r								N			
55.0						qtz ss	vlttn	f-m	f	r								N			
57.5						qtz ss	tn	f-m	f	sr								N			
60.0						qtz ss	tn	vf-f	f	sr								N			
62.5						qtz ss	vdkgy	f	m	sr								N	10%		Noteable color change, abnt. carbon wood frags.
65.0						qtz ss	dkgy	f	m	sr								N	3%		some carbon wood fragments
67.5						qtz ss	gybn	m	w	r								N			
70.0						qtz ss	vltgytn	m	m	r								N			
72.5						qtz ss	vltgytn	f-m	F	r								N			
75.0						qtz ss	vltgytn-wh	f-m	W	r								N			Moisture first noted
77.5																		N			No Cuttings - Begin H2O injection
80.0						qtz ss	wh	m-cr	p	sa								N			chert frag.
82.5						qtz ss, cgl	wh-multicolor	m-vc	p	sr								N			" " (high perm zone)
85.0						qtz ss, cgl	wh-multicolor	c-vc	p	sa								N			" "
87.5						cgl, sltst	lttn, gn											N			Basal Contact Burro Cyn. Fm @ 86.0 feet
90.0						sltst, cgl	ltgn, multi color											N			
92.5						sltst	ppbn-ltgy											N			
95.0						sltst	ltgn											N			
97.5						sltst, ss cgl	ltgn	f-m										N			Total depth
100.0																					
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



Date 7-1-2002 Geologist L. Casebolt Drilling Co. Bayles Exploration Hole No. TW4-12

Property White Mesa Mill Project ____ Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 1

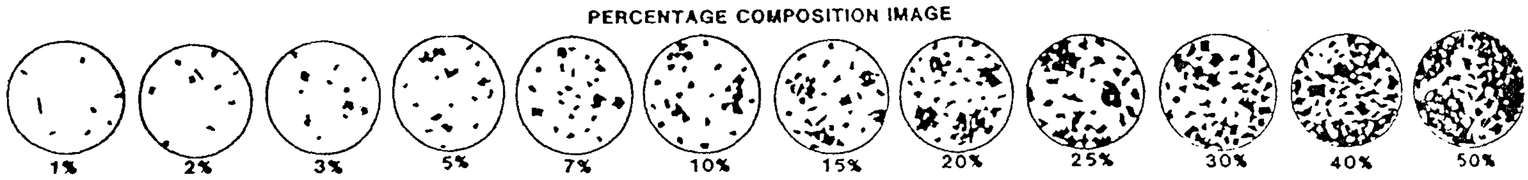
T.D. PROBE ____

T.D. DRILL 107.5

FLUID LEVEL 43.3 below casing

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																					
2.5						Sltst	rdbn	vf										S			Surface Soil
5.0						Sltst	rdbn	vf										S			
7.5						Sltst	rdbn	vf										S			
10.0						Sltst	rdbn	vf										S			
12.5						Qtst	rdbn-lttn	vf										S			
15.0						Sltst	rdbn	vf										VS			
17.5						Sltst	pktn	vf										VS			
20.0						Slty Sh	ywgybn	vf										VS			
22.5						Slty Sh	ywgybn	vf										VS			
25.0						Sndy Sltst	ltbn	f m	p	sa								m			
27.5						Qtz Ss, Sltst	bn	vf f	p	sa								W			
30.0						Sndy Sltst	bn	vf f	p	sa								N			
32.5						Qtz Ss	tn	vf m	p	sa								N			Ct. Top of Dakota Fm @ 31.0 feet
35.0						Qtz Ss	tn	f m	p	sa		H						N			hematite coating of quartz grains
37.5						Qtz Ss	tn	f m	p	sa								N			
40.0						Qtz Ss	pktn	m	p	sa		H						N			
42.5						Qtz Ss	tn	f	m	sa		H						N			
45.0						Qtz Ss, Sh	gy-pprd	f	m	sa		H						N			
47.5						Qtz Ss,	vltgy	f	f	sa								N			
50.0						Qtz Ss,	vltgy	f	f	sa								N			
52.5						Qtz Ss	vltgy	f	f	sa								N			
55.0						Qtz Ss	vltgy	f	f	sa								N			
57.5						Qtz Ss	ltgy-vdkgy	vf f	f	sa								N	3%	I	carbonaceous material
60.0						Qtz Ss	vltgy-lttn	vf m	p	sa		L						N	Tr	I	" "
62.5						Qtz Ss	ltgy-blk	vf m	p	sa								N	50%	I	" "
65.0						Qtz Ss, Cgl	dkgy-blk	vf vcr	p	a								N	50%	I	abund. white to dkgray chert frag.
67.5						Qtz Ss	vltgy-blk	vf m	f	sa			Tr					N			
70.0						Qtz Ss	dkgy-blk	vf m	f	sa			Tr					N			disseminated pyrite
72.5						Cgl, Qtz Ss	gy	m vcr	p	a			1%					N			" " multicolored chert frags.
75.0						Cgl, Qtz Ss	gy	m vcr	p	a			Tr					N			" " " "
77.5						Cgl, Qtz Ss	gy	m vcr	p	a								N			chert frag.
80.0						Qtz Ss, Cgl	gy	m vcr	p	sa								N			chert frags
82.5						Cgl, Qtz Ss	gy	m vcr	p	sa			Tr					N			chert frag.
85.0						Cgl, Qtz Ss	gy	m vcr	p	a								N			" "
87.5						Cgl, Qtz Ss	gy	m vcr	p	a								N			" "
90.0						Cgl, Qtz Ss	gy	m vcr	p	a			Tr					N			" "
92.5						Qtz Ss, Cgl	vltgy	vf vcr	p	a			Tr					N			" "
95.0						Qtz Ss,	vltgy-wh	vf cr	f	sa			1%					N			disseminated & massive pyrite, chert frag.
97.5						Qtz Ss, Cgl	wh	vf cr	f	sa								N			
100.0						Qtz Ss	wh	vf f	m	sa			Tr					N			
102.5						Qtz Ss, Sltst	ywbn-ppbr	vf-f	f	sa								N			Upper Brushy Basin Fm. contact @ 101.0 feet.
105.0						Qtz Ss, Sh	wh-ltgn	vf f	f	sa								W			
107.5						Qtz Ss, Sh	wh-ltgn ppbn	vf-f	p	sa			Tr					W			

PERCENTAGE COMPOSITION IMAGE



1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 7-1-02 Geologist L. Casebolt Drilling Co. Bayles Exploration Co Hole No. TW4-13

Property White Mesa Mill Project MW4 Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1

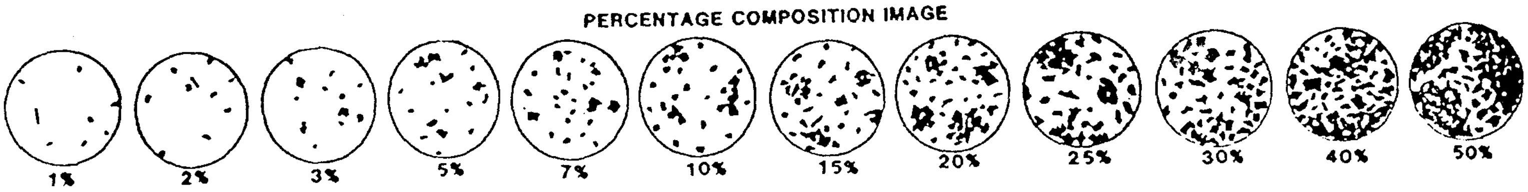
T.D. PROBE 102.5

T.D. DRILL 102.5

FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0–2.5						Slty Sh	dkrdbn	vf										W			Soil
2.5–5.0						Slty Sh	rdbn-pk	vf										S			
5.0–7.5						Slty Sh	rdbn-pk	vf										VS			
7.5–10.0						Slty Sh	rdbn	vf										VS			
10.0–12.5						Slty Sh	rdbn-ywbn	vf										S			
12.5–15.0						Sh	ywgybn	vf				tr						S			Noteable color change sparse hematite
15.0–17.5						Sh, Qtz Ss	ywgybn	f	p	sa								S			
17.5–20.0						Sh, Qtz Ss	ywgybn	f m	p	sa								S			
20.0–22.5						Sh, Qtz Ss	ywgybn	f m	p	sa								S			
22.5–25.0						Slty Sh	ywgybn	vf										S			
25.0–27.5						Slty Sh	ywgybn	vf										S			
27.5–30.0						Slty Sh	ywgybn	vf										W			
30.0–32.5						Qtz Ss	ortn	f m	m	sa		tr						N			Upper Dakota Fm. contact @ 30.6' limonite coating
32.5–35.0						Qtz Ss	ortn	f m	p	sa		tr						N			
35.0–37.5						Qtz Ss	tn	f m	f	sa		tr						N			
37.5–40.0						Qtz Ss	lt tn	f	f	sa								N			
40.0–42.5						Qtz Ss	tn	m	f	sa								N			
42.5–45.0						Qtz Ss	tn	f	f	sa								N			
45.0–47.5						Qtz Ss, Sh	tn-gy	vf f	p	sa								N			
47.5–50.0						Qtz Ss	wh	vf f	m	sr								N			Clean sandstone
50.0–52.5						Qtz Ss	lt tn	vf f	m	sr								N			
52.5–55.0						Qtz Ss	lt tn	vf f	m	sr								VW			
55.0–57.5						Qtz Ss	yw tn	vf f	f	sa								W			
57.5–60.0						Sh, Sltst	dkgy-blk	vf										N	5%		abund. carbonaceous material
60.0–62.5						Qtz Ss	ltgy	f m	m	sr			tr					N	1%		sparse carbon material, trace pyrite
62.5–65.0						Qtz Ss	ltgy	m	w	r								N	<1%		
65.0–67.5						Qtz Ss	lt gy	f m	m	r								N	<1%		
67.5–70.0						Qtz Ss, Sh	ltgy		m	r								N	<1%		
70.0–72.5						Qtz Ss	lt tn	vf f	m	r								N			
72.5–75.0						Qtz. Ss.	lttn-ltgn	f m	m	sr								N			some gray chert fragments
75.0–77.5						Qtz Ss	lttn	m-cr	f	sa								W			multi colored chert frag.
77.5–80.0						Sh, Qtz Ss	ltgygn	f vcr	p	sa			1%					S			pyrite, multi colored chert f[illegible]
80.0–82.5						Sh, Qtz Ss	ltgygn-wh	vf										N			some chert fragments
82.5–85.0						Sltst	ltgygn-wh	vf										N			
85.0–87.5						Sltst	ltgygn	vf										N			
87.5–90.0						Sltst	ltgygn	vf										N			
90.0–92.5						Sltst	ltgygn	vf										N			
92.5–95.0						Sltst	ltgygn	vf										N			
95.0–97.5						Qtz Ss	ltgy-wh	m	f	sr			3%					N			abund. pyrite fragments
97.5–100.0						Qtz Ss	ltgy-wh	m	f	sr			1%					S			Some pyrite fragments
100.0–102.5						Sh, Qtz Ss	gn-wh	m	f	sr			1%					N			Upper contact Brushy Basin Fm. @ 101.5'; some pyrite, occurs as cubes and granular

PERCENTAGE COMPOSITION IMAGE



Date 7-2-2002 Geologist L. Casebolt Drilling Co. Bayles Exploration Hole No. TW4-14
Property White Mesa Mill Project MW4 Unit No. Sec. Twp. Rge.
County San Juan State Utah Location Elev.

PAGE 1 OF 1
T.D. PROBE
T.D. DRILL 95.0
FLUID LEVEL

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Habit	Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Type	Remarks
0						Sndy Sltst. qtz	lt rd br-or	vf	p	sa								S			Surface soil.
.5						sndy Sh-qtz	lt pk-wh	vf	p	sa								VS			trace of plant fragment:
.0						Sh-sltysh	wh-pk	vf	p	sa								VS			
5						Sndy sh	ywgybn	vf-f	p	a		tr						VS			limonite/hematite coating on qtz grains
.0						Slty Sh	ywgybn	vf	p	sa		tr						S			
2.5						Slty Sh	ywgybn	vf	p	sa		tr						W			hematite coating on qtz
5.0						Slty Sh	ywgybn	vf	p	sa								N			
7.5						sltySh-qtzSs	ltgy-orbn	vf f	p	sa		tr.						N			Contact upper Dakota Fm. @approx. 18.0 feet.
0.0						Qtz Ss	tn	f-m	f	sr		tr.						N			Clean sandstone
2.5						Qtz Ss	tn	m	g	sr		tr.						N			
5.0						Qtz Ss	lt tn	m	g	sr		tr.						N			
7.5						Qtz Ss	lt tn	m-cr	f	sr								N			
0.0						Qtz Ss.	lt tn	f-cr	f	sr								N			
2.5						Qtz Ss	lt tn	m-cr	f	sr		tr.						N			
5.0						Qtz Ss	tn	m-vcr	p	sa								N			hematite coating on sand grains, white chert frag.
7.5						Qtz Ss-cgl	vlt tn	vf-cr	p	sa		3%						N			lt-dk gy quartz fragments.
40.0						Qtz Ss	lt tn	f-cr	f	sa		1%						N			
42.5						Qtz Ss	vlt tn	f	w	sr								N			very clean sandstone
5.0						Qtz Ss	lt tn	f	w	sr								N			" " "
47.5						Qtz Ss.	lt pk tn	vf m	f	sr								N			
50.0						Qtz Ss	lt pk tn	m cr	f	sr								N			sparce chert frag.
2.5						Qtz Ss.	lt tn	m	f	r								N			
5.0						Qtz Ss.	lt tn	m	w	r								N			very clean sandstone
57.5						Qtz Ss-Cgl	lt tn	vf-m	p	sa								N			dk gy to wh chert & qtz frag.
0.0						Qtz Ss	lt pk tn	f m	f	sa								N			
2.5						Qtz Ss.	lt pk tn	f	w	sr								N			
5.0						Qtz Ss.	lt tn	f	w	sr								N			
7.5						Qtz Ss	lt gy tn	f m	f	sa								N			
70.0						Qtz Ss-Cgl	gy tn-wh	f vcr	p	sa								N			20% chert & quartz fragments-multicolor
2.5						Qtz Ss-Cgl	gy tn-wh	m-vcr	p	sa								N			20% chert & quartz fragments.
75.0						Qtz Ss-Cgl	tn	m cr	p	sr								N			
7.5						Qtz Ss-Cgl	multicolor	m vcr	p	sa								N			50% grit (wh-rd-blk chert frag.)
80						Qtz Ss	lt tn	m	w	r								N			clean sandstone
2.5						Qtz Ss	lt tn	m	f	sr								N			2% dk gy quartz frag.
5.0						Qtz Ss	lt tn	f m	f	r								N			
7.5						Qtz Ss-Cgl.	lt gy tn	f vcr	p	sr								S			tr. lt gn shale
0.0						Sh-Qtz Ss	lt gy gn	vf f	p	sa								N			Upper cont. Brushy Basin Fm @ 91.0 feet.
2.5						Slty Sh	lt gn	vf										N			
5.0																					
0.																					

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 7-2-2002 Geologist L. Casebolt Drilling Co. Bayles Exploration Co Hole No. TW4-15
Property White Mesa Mill Project MW4 Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 122.5
FLUID LEVEL ____
REMARKS 12¼" bit To 50.0 ft. 6¾" bit 50 To T.D.

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React. 10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						QtzSs.	tnbn	vf f	f	sa								S			Surface Soil.
5.0						Sh, QtzSS	dkbn	vf m	p	sa								VS			
7.5						SltySh	ltrdbn	vf f										S			
10.0						Slty Sh	ltrdbn											S			
12.5						SltySh	ltrdbn											S			
15.0						Slty Sh	ywgybn											VS			
17.5						SltySh	ywgybn											VS			
20.0						SltySh	ywgybn											S			
22.5						Sh	ywgybn											N			
25.0						Sh	ywgybn											W			
27.5						SndySh	ywgybn	vf m	p	sa								N			
30.0						QtzSs, Sh	orbn	f m	f	sa								N			Upper contact Dakota Fm @ 28.0 feet.
32.5						QtzSs	orbn	m Cr	p	a		L						N			limonite, chert frags
35.0						QtzSs	orbn	m cr	p	a								N			
37.5						QtzSs, Sh	gy	m cr	p	a								N			
40.0						QtzSs	tn	f m	f	sa								N			
42.5						QtzSs, Sh	ywtn-ltgy	f m	f	sa								N			
45.0						QtzSs	tn	f	f	sa								N			
47.5						QtzSs	tn	f	f	sr								N			
50.0						QtzSs	tn-ltgy	f	f	sr								N			
52.5						QtzSs	tn-dkgy	vf f	p	sa								N			
55.0						QtzSs, Cgl	tn	vf cr	p	sa								N			multicolored chert frags
57.5						QtzSs, Cgl	ltpktn	m vcr	p	Sa								N			" " " "
60.0						QtzSs	ltpktn	M vcr	p	Sa								N			
62.5						QtzSs	lttn	f m	f	sa								N			
65.0						QtzSs	lttn	m cr	f	sr								N			
67.5						QtzSs	lttn	m	w	r								N			
70.0						QtzSs	lttn	f	w	r								N			
72.5						QtzSs	lttn	f m	w	r								N			
75.0						QtzSs	lttn	vf m	p	sa								N			
77.5						QtzSs, Cgl	vlttn	vf m	p	sa								N			brown chert fragments.
80.0						QtzSs Cgl	white	f m	m	sr								N			
82.5						QtzSs Cgl	lttn-ltgy	f m	m	sr			TR					N			disseminated pyrite
85.0						QtzSs, Sh	vltgy-ltgn	vf f	f	sa								N			
87.5						QtzSs, Sh	vltgy-ltgn	vf f	f	sa			Tr					N			
90.0						QtzSs, Sh	vltgy-ltgn	vf f	f	sa			Tr					N			
92.5						QtzSs, Sh	vltgy-ltgn	vf f	f	sa			1%					N			
95.0						QtzSs, Sh	wh-ltgn	vf f	f	sa			Tr					N			
97.5						QtzSs, Sh	wh-ltgn	vf f	f	sa			tr					N			
100.0						QtzSs, Sh	wh-ltgn	vf m	f	sa			Tr					N			
102.5						QtzSs, Sh	wh-ltgn	f m	f	sr								N			
105.0						QtzSs	wh	f m	f	sr								N			
107.5						QtzSs	wh	f m	f	sr								N			
110.0						QtzSs, Cgl	vltgn	f vcr	p	sa								N			gray-brown chert fragments.
112.5						QtzSs	wh-ltgn	vf f	f	sa								N			
115.0						QtzSs	wh-ltgn	vf f	f	sa								N			
117.5						QtzSs, Sh	wh-ltgn	vf m	p	sr			Tr					N			
120.0						Sh, QtzSs	gn-wh	vf m	p	sr								N			Upper contact Brushy Basin Fm. @ 118.0 feet
122.5						Sh.	gn-ppbn											N			
T.D.																					

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 7-2-2002 Geologist L. Casebolt Drilling Co. Bayles Exploration Hole No. TW4-16

Property White Mesa Mill Project TW4 Unit No. Sec. Twp. Rge.

County San Juan State Utah Location Elev.

PAGE 1 OF 2

T.D. PROBE 149.0

T.D. DRILL 147.5

FLUID LEVEL 97.5

12¼" bit to 50'

6¾" bit 50-147.5

DEPTH	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	HABIT	ALTER.	METALLIC	NON-METALLIC	REACT. 10% HCL	CARBON AMOUNT	TYPE	REMARKS
2.5	Sh, Sltst.	ywgybn											VS			Surface soil.
5.0	Qtz Ss	ltpkor	vf f	p	sa								S			
7.5	Sltst, Sh	ltrdbn											S			
10.0	Sh, Sltst	ywgybn											VS			some chert frag.
12.5	Sh	ywgybn											VS			
15.0	Sh	ltgytn											VS			
17.5	Sndy Sh	ltgytn	vf f	p	sa								VS			
20.0	Sh	ywgybn											VS			
22.5	Sh	ywgybn											VS			gypsum crystals (selenite)
25.0	Sh	ywgybn											VS			very abund gyp xls.
27.5	Sh	ywgybn											S			" " " "
30.0	Sh	ywgybn											M			" " " "
32.5	Sh	ywgybn											M			" " " "
35.0	Qtz Ss, Sh	ywgybn	vf f	f	sa								S			Upper contact Dakota Fm. @ 33.0 feet
37.5	Qtz Ss	ltywbn	vf f	f	sa								W			
40.0	Qtz Ss	lt bn	vf	p	sa								W			
42.5	Qtz Ss	ltywbn	f m	p	sa								N			
45.0	Qtz Ss	lttnbn	f m	f	sr		L						N			some limonite coating.
47.5	Qtz Ss	tn	m	m	sr		L						N			
50.0	Qtz Ss	tn	f m	f	sr								W			
52.5	Qtz Ss	tn	f	f	sa								N			
55.0	Qtz Ss	tn	f	f	sa								N			
57.5	Qtz Ss	tn	f	f	sa								N			
60.0	Qtz Ss	tn	vf f	p	sa								N			
62.5	Sndy Sh	gybn	f m	p	sa								W			gypsum crystals as selenite
65.0	Qtz Ss	gybn	f m	f	sa								N			some chert frag. as sand grains
67.5	Qtz Ss, Sh	ltgytn	vf f	m	sr								N			
70.0	Qtz Ss	tn	f	w	r								N			
72.5	Qtz Ss	gy	vf f	m	sr								N	1½	I	
75.0	Qtz Ss, Cgl	lt bn	f vcr	p	sa								N			white to dk gray chert fragments
77.5	Qtz Ss, Cgl	ltgytn	f cr	p	sa								N			" " " " " "
80.0	Qtz Ss, Sh, Cgl	ltgytn	f m	p	sa								N			
82.5	Qtz Ss, Cgl	tn	m vcr	p	a								N			chert fragments, white to bn to rd
85.0	Qtz Ss Cgl	tn	m vcr	p	a								N			multi colored chert frags.
87.5	Qtz Ss, Cgl.	Tn	m vcr	p	sa								N			multi colored chert frags wh-or-blk
90.0	Qtz Ss, Cgl	vlttn	vf m	p	sr								N			
92.5	Qtz Ss	vlttn	vf f	f	sr								N			Clean sandstone
95.0	Qtz, Ss	vlttn-wh	vf f	w	sa								N			
97.5	Qtz Ss, Cgl	multicolor	m vcr	p	a			2%					W			pyrite desseminated around sand grains, chert frag.
100.0	Qtz Ss, Sh, Cgl	multicolor,	vf vcr	p	a								N			Clean white sandstone.
102.5	Qtz Ss	wh	f m	m	sr								N			
105.0	Qtz Ss	wh-vltgn	f m	m	sr								N			
107.5	Qtz Ss	wh-vltgn	f m	m	sr								N			
110.0	Qtz Ss	wh-vltgn	f m	f	sr			Tr					N			
112.5	Qtz Ss, Sh, Cgl	wh-vltgn	f m	f	sr			Tr					N			
115.0	Qtz Ss Sh, Cgl	bn-ltgn	f m	f	sr			Tr					N			
117.5	Qtz Ss, Sh, Cgl	tn-ltgn	f m	f	sr								N			
120.0	Qtz Ss, Sh, Cgl	wh-ltgn	vf vcr	p	sr								N			
122.5	Qtz Ss, Sh	wh-ltgn		f	f	sr							N			
125.0	Qtz Ss, Cgl	wh-gy	f vcr	p	sr								N			

PERCENTAGE COMPOSITION IMAGE

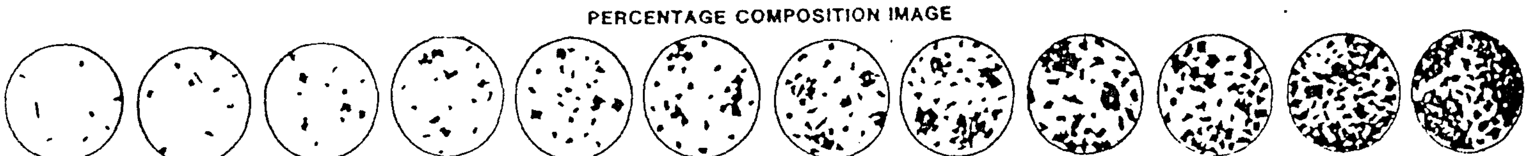
1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 7-2-2002 Geologist L. Casebolt Drilling Co. Bayles Exploration Hole No. TW4-16
Property White Mesa Mill Project MW4 Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 2 OF 2
T.D. PROBE 149.0
T.D. DRILL 147.5
FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
125.0																					
127.5						Qtz Ss, Cgl	wh-multi color f	cr	f	sa							N				multi color chert fragments
130.0						Qtz Ss, Cgl	wh-multi Color	m	p	sa							N				" " " "
132.5						Qtz Ss, Cgl	wh-multicolor	m	p	sa							N				" " " "
135.0						Qtz Ss Cgl	wh. f	vcr	p	sa							N				" " " "
137.5						Qtz Ss	wh vf	f	f	sr							N				
140.0						Qtz Ss	wh	f	f	sr							N				
142.5						Sh, Qtz Ss	wh-gn	f	f	sr							N				Upper Contact Brush Basin Fm @ 141.0 feet
145.0						Sh	gn										N				clean shale
147.5 T.D.						Sh	gn-rdgybn										N				clean shale

PERCENTAGE COMPOSITION IMAGE



1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

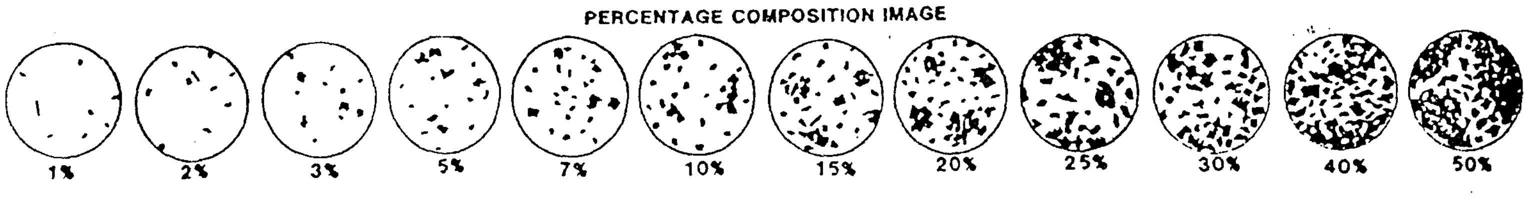
Date 7-2-02 Geologist L Casebolt Drilling Co. Bayles Exploration Hole No. TW4-17
Property White Mesa Mill Project MW4 Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 2
T.D. PROBE 132.9
T.D. DRILL 132.5
FLUID LEVEL 115.5

REMARKS 12 1/4" bit to 52.5, 6 3/4" 52.5 to T.D.

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						Qtz Ss, caliche	wh-tn bn	f cr	p	sa								VS			caliche, surface soil
5.0						Qtz Ss, caliche	wh-tn	f m	p	sa								VS			caliche, surface soil
7.5						Sltst, Sh	ltrdbn	vf f	f	sa								VS			
10.0						Sltst	ltrdbn	vf f	f	sa								S			
12.5						Sltst.	ltpkrd											S			
15.0						Slty Sh	ltpkbn											S			
17.5						Slty Sh	ltpkbn-ltywgy											VS			
20.0						Sh	ywgybn											VS			
22.5						Sh	ywgybn											VS			
25.0						Sh	ywgybn											S			
27.5						Sh	ywgybn											S			gypsum crystals as selenite
30.0						Sh	ywgybn											S			abund. gypsum crystals.
32.5						Sh	ywgybn											W			" " "
35.0						Sh	ywgybn											W			
37.5						Sh	ywgybn											W			
40.0						Slty Sh	ywgybn					L						VW			Limonite
42.5						Slty Sh, Qtz Ss	ywgybn	vf f	p	sr		L						VW			Contact Dakota Fm approx 42.0 ft.
45.0						Qtz Ss, Sh	ltortn	f m	p	sr								N			
47.5						Qtz Ss	ltortn	f m	p	sa								N			
50.0						Qtz Ss	ltgytn	f m	p	sa		L						N			
52.5						Qtz Ss	tn	f m	f	sr		L						N			
55.0						Qtz Ss	tn	f	f	sr		L						N			
57.5						Qtz Ss	tn	vf f	f	sr								N			
60.0						Qtz Ss	tn	vf f	p	sa								N			
62.5						Qtz Ss	tn	f m	f	sr								N			
65.0						Qtz Ss	vlttn	f m	f	sa								N			
67.5						Qtz Ss	vlttn	f m	f	sr								N			
70.0						Qtz Ss, Sh	vlttn-vltgn	f m	f	sr								m			
72.5						Qtz Ss	lttn	m cr	f	sr								N			some ltgy chert grains
75.0						Qtz Ss	vlttn	f m	m	sr								N			
77.5						Qtz Ss	lttn	f m	m	sr								N			gray to tn chert fragments.
80.0						Qtz Ss, Cgl	lttn	m vcr	m	sr								N			multi chert fragments
82.5						Qtz Ss	lttn	f m	f	sr								N			
85.0						Qtz Ss Cgl	lttn	f vcr	f	sr								S			multi color chert fragments
87.5						Sh	ltgn											N			
90.0						Qtz Ss	lttn	f	m	sr								N			clean sandstone
92.5						Qtz Ss	lttn	vf f	m	sr								N			
95.0						Qtz Ss	wh	vf	f	sr								N			
97.5						Sh, Qtz Ss	wh-vltgy	vf	m	sr								N			
100.0						Qtz Ss, Sh	vltgy	vf	m	sr								N			
102.5						Qtz Ss	wh	f m	m	sr								N			clean sandstone
105.0						Qtz Ss, Cgl	wh-gy	f m	m	sr			tr					N			chert fragments
107.5						Qtz Ss, Cgl	wh-gybn	m cr	f	sr			tr					N			" "
110.0						Qtz Ss	wh	m	w	r								N			
112.5						Qtz Ss, Cgl	wh-ltgy	f cr	p	sr								N			
115.0						Qtz Ss, Cgl	wh-multicolor	f cr	p	sr								N			multi color chert frag.
117.5						Qtz Ss, Cgl	ltgy-multico.	m cr	f	sr								N			" " " "
120.0						Qtz Ss, Cgl	ltgy	m cr	f	sr								N			" " " "
122.5						Qtz Ss, Cgl	ltgy-wh	m cr	f	sr								N			" " " "
125.0						Qtz Ss Cgl	wh	f m	f	sr								N			" " " "

PERCENTAGE COMPOSITION IMAGE



Date 7-2-2002 Geologist L. Casebolt Drilling Co. Bayles Exploration Hole No. TW4-17

Property White Mesa Mill Project MW4 Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ______

PAGE 2 OF 2

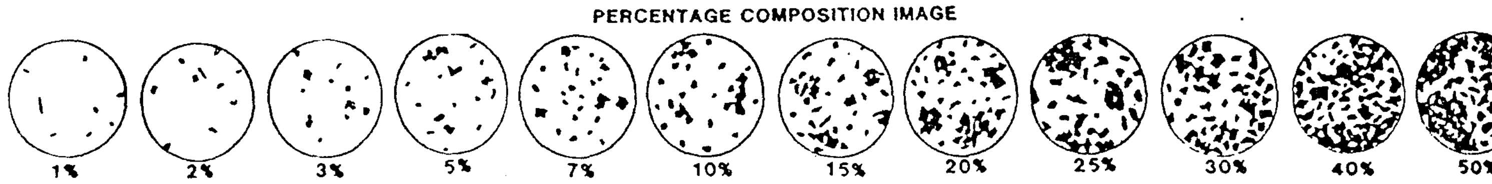
T.D. PROBE 132.9

T.D. DRILL 132.5

FLUID LEVEL 115.5

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
125.0						Sh, Qtz SS, Cgl	gn-wh m	vcr	p	sr											Upper Brushy Basin Ct @ 126.0 feet
127.5						Sh	gn-pp bn														Clean shale
130.0						Sh	gn-pp bn														Clean shale
132.5																					
T.D																					

PERCENTAGE COMPOSITION IMAGE



Date 7-8-2002 Geologist L. Casebolt Drilling Co. Bayles Exploration Hole No. TW4-18

Property White Mesa Mill Project MW4 Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 2

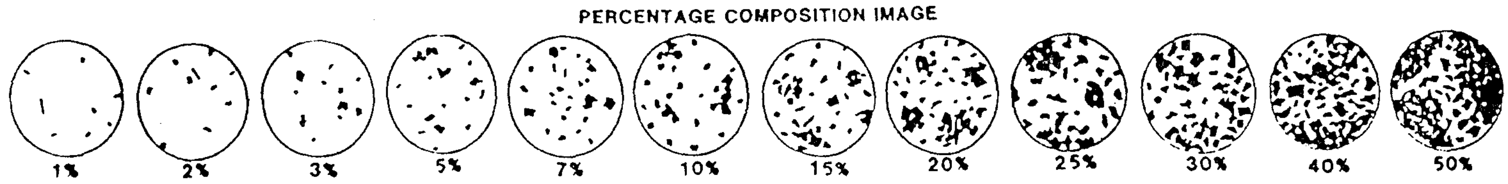
T.D. PROBE ______

T.D. DRILL 142.5

FLUID LEVEL 62 Feet

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks 7⅞" bit, collar to T.D.
0																					
2.5						Sltst	rdbn	vf										S			Surface soils
5.0						Sltst	rdbn	vf										VS			
7.5						Sltst	rdbn-lt pk bn	vf										VS			
10.0						Sh	ltpktn											VS			
12.5						Sh	ltywtn											S			
15.0						Sh	ywgy											S			
17.5						Slty Sh	ywgy	vf										S			
20.0						Slty Sh	ywgy	vf										VS			
22.5						Slty Sh	ywgy	vf										m			
25.0						Slty Sh	ywgy	vf										VS			
27.5						Slty Sh	ywgy	vf										VS			gypsum as selenite crystals
30.0						Qtz Ss, Sltst	ywgybn	vf f	p	sa								VS			
32.5						Sltst	orbn					L						VS			limonite
35.0						Sltst	orbn					L						S			limonite
37.5						Sltsh	orbn					L						N			limonite
40.0						Sltst, QtzSs	orbn	m cr	p	sa		L/H						N			limonite/hematite, Upper Dakota Fm contact @ 39.5'
42.5						Qtz Ss	orbn	m cr	p	sa		L						N			limonite coating qtz grains
45.0						Qtz Ss	or-bn	m cr	f	sr								N			" " " "
47.5						Qtz Ss	or-bn	m cr	f	sa								N			" " " "
50.0						Qtz Ss	ortn	f m	f	sa								N			" " " "
52.5						Qtz Ss.	tn	m	f	sr								N			
55.0						Qtz Ss	tn	m	m	sr								VW			
57.5						Qtz Ss	tn	f m	f	sr								VW			
60.0						Qtz Ss, Sh	tn, ltgy	f m	f	sa								N			
62.5						Qtz Ss	tn	vf f	f	sa								N			
65.0						Qtz Ss	tn	vf f	f	sa								N			
67.5						Sltst	dkgy-blk	vf f	p	sa								N	30%	I	abund carbon frag.
70.0						Sltst, QtzSs	dkgy-blk	f m	P	sa								N	30%	I	" " "
72.5						Qtz Ss.	dkgybn	m	m	sr								N	2%	I	
75.0						Qtz Ss, Cgl	dkgybn	vcr	p	sr								N			chert, quartz frag. & pebbles
77.5						Qtz Ss	dktn	f m	m	sr								N			
80.0						Qtz Ss	dktn	f m	m	r								N			
82.5						Qtz Ss, Sh	tn-ltgygn	f m	f	sr								N			
85.0						Sh	ltgygn											N			
87.5						Sh	ltgygn											N			
90.0						Sh, Qtz Ss	ltgygn-ltortn	vf	m	sr								N			
92.5						Qtz Ss	lttn	vf f	m	sr								N			
95.0						QtzSs, Cgl, Sh	lttn-gygn	f m	p	sa								N			
97.5						Sltst	ltgygn	vf										N			
100.0						Sltst, Qtz Ss	ltgygn	vf f	m	sa								N			
102.5						Sltst, Qtz Ss	ltgygn-lttn	vf f	f	sa								N			
105.0						Qtz Ss	lttn	f	m	sa								N			
107.5						Qtz Ss	lttn	f	f	sa								N			
110.0						Qtz Ss	lttn	f	f	sa								N			
112.5						Qtz Ss	lttn	f m	f	sr								N			
115.0						Qtz Ss	lttn	f m	f	sr								N			
117.5																					no cuttings from this interval
120.0																					
122.5																					
125.0						Qtz Ss	lttn	m	m	sa								N			

PERCENTAGE COMPOSITION IMAGE

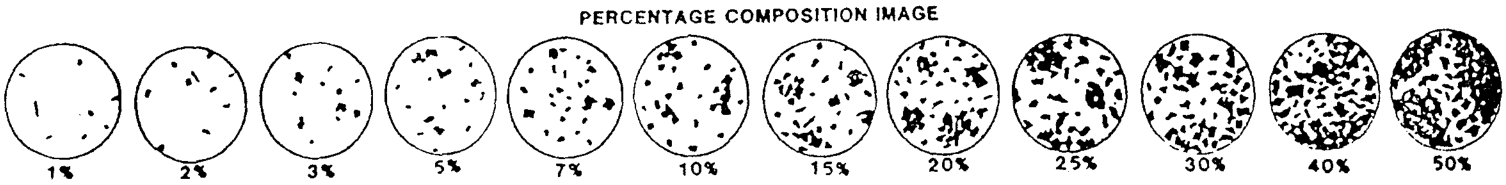


Date 7-8-2002 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. TW4-18
Property White Mesa Mill Project MW4 Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 2 OF 2
T.D. PROBE ____
T.D. DRILL 142.5
FLUID LEVEL 62 Feet

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
125.0																					
127.5						Qtz Ss, Sltst	lt tn - lt gy f	m	f	sr								N			
130.0						Qtz Ss	lt tn f	m	p	sr								N			
132.5						Qtz Ss	lt tn f	m	f	sr								N			
135.0						Qtz Ss	lt tn f	m	p	sr								N			
137.5						Qtz Ss, Sh	lt tn - ppbn f	m	p	sr								N			Upper Brushy Basin Fm. Contact @ 137.5'
140.0						Sh	ppbn-gn											N			
142.5						Sh	pp bn.											N			
T.D.																					

PERCENTAGE COMPOSITION IMAGE



Date 7-9-02 Geologist L. Casebolt Drilling Co. Bayles Exploration Hole No. TW4-19
Property White Mesa Mill Project TW4 Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location Next to office complex Elev. ____

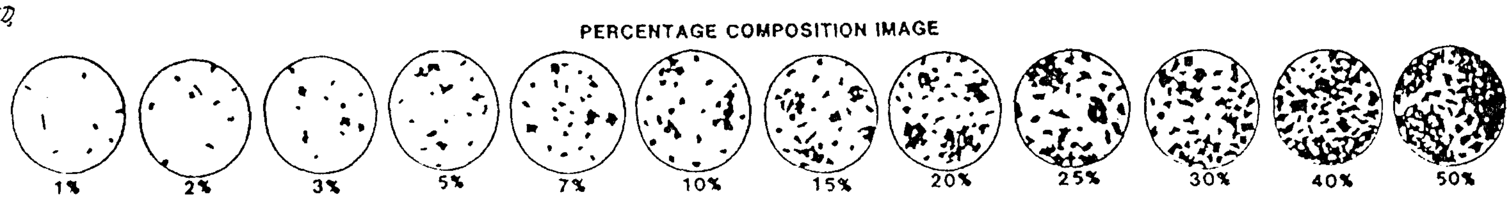
PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 125.0
FLUID LEVEL ____

REMARKS 7 7/8 ...

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite: Amount	Pyrite: Habit	Pyrite: Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon: Amount	Carbon: Type	Remarks
2.5						Slty Sh	ltrd bn	vf										S			Soil
5.0						Slty Sh	ltpk tn	vf										VS			
7.5						Sh	ltpk tn	vf										VS			
10.0						Sh	lt tn	vf										S			
12.5						Slty Sh	ltyw gy	vf										S			sparse qtz grains
15.0						Qtz Ss-Sltst	yw-ybn	f	p	sa		tr						S			limonite and hematite coating on qtz grains
17.5						Slty Sh	gybn	vf										N			
20.0						Slty Sh	gybn	vf										N			
22.5						Qtz Ss Sltst	ltorbn	f-m	f	sa		1%						N			Upper Dakota Fm. Ct. @ approx 21.0 ft. limonite coating
25.0						Qtz Ss	ltorbn	m	f	sa		1%						N			limonite coating on qtz grains
27.5						Qtz Ss	ltorbn	m	f	sa		1%						N			
30.0						Qtz Ss	lt tn	m cr	f	sa								N			
32.5						Qtz Ss	lt tn	f m	f	sr								N			
35.0						Qtz Ss	lt tn	f	f	sr								N			
37.5						Qtz Ss	ltpk.tn	f	M	sr								N			
40.0						Qtz Ss	lt tn	vf f	p	sa								N			
42.5						Qtz Ss	ltpk tn	vf f	m	sa								N			Clean sandstone
45.0						Qtz Ss	ltpk tn	vf f	m	sa								N			
47.5						Qtz SS-Sh	tn-wh	m vcr	p	sa								N			
50.0						Qtz Ss-Sh	lt tn ltgy	f cr	p	sa								N			
52.5						Qtz Ss-	ltpk tn	f m	w	sr								N			Clean sandstone
55.0						Qtz Ss	ltpk tn	f m	M	sr								N			
57.5						Qtz Ss	ltpk tn	m	w	sr								N			
60.0						Qtz Ss	vltpk tn	f m	m	sr								N			
62.5						Qtz Ss	vltpk-wh	f m	m	sr								N			
65.0						Qtz Ss	vltpk-wh	f m	m	sr								N			
67.5						Qtz Ss	wh	f m	f	sa								N			
70.0						Qtz Ss, Cgl	lt tn	f vcr	p	sa		tr						W			multi color chert & qtz frag.
72.5						Qtz SS, Cgl	tn	f vcr	p	sa		tr						W			hematite coating on qtz & chert frag.
75.0						Qtz Ss, Cgl	tn	f vcr	p	sa		tr						W			
77.5						Sh	ltblgy											N			
80.0						Qtz Ss	vlttn	vf f	f	sa								N			
82.5						Qtz Ss, Sh	vlttn-ltgygn	vf f	f	sa								N			
85.0						Sh-Qtz Ss	ltblgy-lttn	f	f	sa								N			
87.5						Sh	ltgy-ltppbn	vf										N			Mottled shale frags.
90.0						Sh	ltgy-ltppbn	vf										N			" " "
92.5						Qtz Ss	vltgy	vf f	f	sa								N			
95.0						Qtz Ss, Sh	lttn-ltgy	vf	f	sa								N			
97.5						Qtz Ss, Sh	lttn-ltgy	vf	f	sa								N			
100.0						Qtz Ss, Cgl	ltgy-wh	f cr	p	sa		tr						N			
102.5						Qtz Ss, Cgl, Sh	ltgy	m cr	f	sa		tr						N			
105.0						Qtz Ss, Cgl	vltgy-orbn	m cr	f	sa		tr						VW			
107.5						Qtz Ss	ltpk tn	m	m	sr		tr						N			
110.0						Qtz Ss, Sltst	lttn-ltgy	m	m	sa								N			
112.5						Qtz Ss	ltgy	f	f	sr								N			
115.0						Qtz Ss	wh-ltgy	vf f	f	sa								N			
117.5						Qtz Ss, Sh	wh-ltgy	vf f	f	sa								N			
120.0						Qtz Ss Cgl	wh-ltgy-or	f vcr	p	sa								N			
122.5						Sh, Qtz Ss	pprdbn, gy-wh	m	f	sa								N			Upper Brushy Basin Fm. Ct @ approx 121.0 feet
125.0						Sh	pprdbn-gygn											N			

T.D.

PERCENTAGE COMPOSITION IMAGE



Date 4-9-05 Geologist L. Casebolt Drilling Co. Boyles Exploration Co. Hole No. TW4-20

Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ≈ 5627

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 107.5
FLUID LEVEL ______

DEPTH	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	IRON OXIDE	REACT.-10% HCL	REMARKS
2.5	sltysh	ywbn					S	Surface soil
5.0	sltysh	dkrdbn					m	
7.5	sltysh	dkrdbn-rdbn					VS	
10.0	Sh	ywtn					VS	
12.5	Sh	ywbn					VS	
15.0	Sh	yw bn					VW	
17.5	Sltst	yw bn					VW	
20.0	Sndysltst	gybn	vf	m	sr		M	
22.5	Sndysltst	dkbn-dkgybn	vf	p			N	Upper Dakota Fm Ct. @ Approx 22.0ft.
25.0	qtz ss	ltpktn	vf-m	p	sr		N	
27.5	qtz ss	ywtn	vf-f	f	sr		N	
30.0	qtz ss	lttn	vf-f	f	sr		N	
	qtz ss	lttn	f-cr	p	sr		N	
35.0	qtz ss	lttn	m-cr	m	sr		N	
37.5	qtz ss	ltpktn	M	m	r	SP	N	Sparse Hematite, clay cement?
40.0	qtz ss	lttn	M	w	r		N	
42.5	qtz ss	lttn	f-m	m	r		N	
45.0	qtz ss	vlttn	vf-f	M	r		N	
47.5	qtz ss	vlttn	vf-f	M	sr		N	
50.0	qtz ss, sh	ltln-ltgy	vf-f	p	sr		N	
52.5	qtz ss	vltgy	vf-f	p	sa		N	
55.0	qtz ss	vlttn	f-cr	w	sr		N	dk chert frags.
57.5	qtz ss	vlttn-wh	m-cr	w	r		N	" " "
60.0	qtz ss	vlttn-wh	m-vcr	p	a		N	
62.5	qtz ss	vlttn-wh	m-vcr	p	a		N	30% dk multi colored chert frags
65.0	qtz ss	wh-vlttn	m-vcr	p	a		N	
67.5	qtz ss	wh-vlttn	m-vcr	p	sa		N	
70.0	qtz ss; cgl	lttn-gy	m-vcr	p	a		N	60% multi colored chert frags & peb
72.5	qtz ss cgl.	ortn-gy	vcr	p	sr		N	80% " " " " "
75.0	cgl, qtz ss	or gy	vcr	p	sa		N	80% " " " " "
77.5	cgl, qtz ss	or gy	vcr	p	sa		N	80% " " " " "
80.0	qtz ss	vlttn-wh	vf-f	m	sr		N	
82.5	qtz ss	vltln-wh	vf-f	m	sr		N	
3	50% sh, 50% qtz ss	wh-ltbl	vf-f	p	sr		N	
37.5	sh, sltst	wh-ltbl	vf	p	sr		N	
90.0	sh, sltst	wh-ltbl	vf	p	sr		N	
12.5	qtz ss	vltn-wh	vf	w	r		N	
5.0	qtz ss	vlttn-wh	vf	w	r		N	
17.5	qtz ss	vlttn-wh	vf	w	r		N	
00.0	qtz ss	vlttn-wh	vf	w	r		N	
02.5	qtz ss	wh-vlttn	f-m	w	sr		N	
05.0	90% qtz ss, 10% sh	wh-gn	vf-m	p	sr		N	upper Brushy Basin Ct @ 104.0
07.5	Sndy sh	gn-dkgygn	vf	p	sa		N	Brushy Basin Mbr
D								

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 4-19-05 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. TW4-21

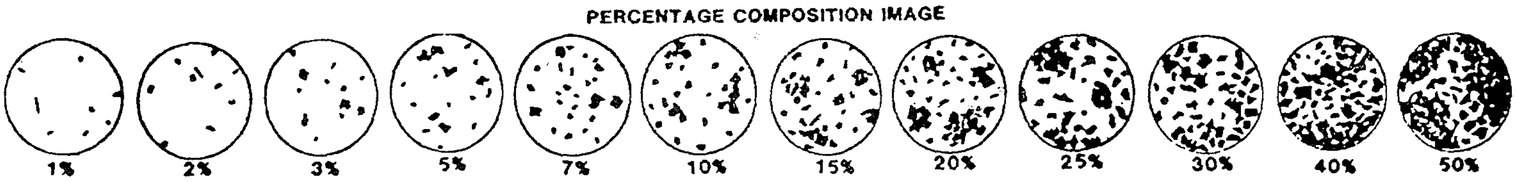
Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 125.0
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5						Sndy Sltst	rd bn	vf-f	P	sa								VS			Surface soil (mill yard - near change room)
5.0						Sndy sltst	rd bn-lt tn	vf-f	P	sa								VS			mancos sh.
7.5						Sltst	lt pk tn											VS			
10.0						sh	yw gy											VS			
12.5						sh	yw gy											S			
15.0						sh	yw gy											S			abnt. selenite xls. (gyp)
17.5						Sh	yw gy											m			" " " "
20.0						Sh, sltst	yw gy											W			
22.5						sltst, sh	yw gy											N			abnt. selenite xls.
25.0						sltst, sh	yw gy											N			
[illegible]						sltst, sh	yw gy											N			
[illegible]						qtz ss	tn	f-m	w	sa								N			Upper Cr Dakota Fm @ 27.5'
32.5						qtz ss	or tn	f-m	w	sr		L	M					N			chert frags.
35.0						qtz ss	or tn	m	w	sr								N			
37.5						qtz ss	tn bn	m	w	sa								N			abnt. chert grains
40.0						qtz ss	tn bn	m-cr	w	sr								N			
42.5						qtz ss	tn	m-cr	w	sr								N			
45.0						qtz ss	tn	m cr	w	sr								N			Moisture first noticed in cuttings
47.5						qtz ss	tn	f m	w	sr								N			
50.0						qtz ss, sh	tn-gy	f-m	w	sr								N			
52.5						qtz ss, sltst	vdk gy-lt gy	vf-f	f	sa								N			
55.0						sltst, sh, ss	vdk gy-vlt gy	vf-m	f	sa								N			
57.5						qtz ss	lt pk tn	m	w	sr								N			
60.0						sndy sltst	lt gy bn	f-vcr	f	sa								N			
62.5						qtz ss-grit	lt gy	m-vcr	p	sr								N			abnt. light colored chert frags.
65.0						qtz ss	lt gy tn	m-cr	f	sr								N			
67.5						qtz ss	lt gy tn	m	w	r								N			
70.0						qtz ss	lt gy tn	m	w	r								N			
72.5						qtz ss-grit	lt gy tn	m-vcr	w	r								N			
75.0						qtz ss-grit	lt gy tn	m-vcr	w	r								N			
77.5						qtz ss-cgl	gy bn	m-peb	p	sr								N			cgl. zone, abnt chert frag. & pebbles
[illegible]						qtz ss-grit	gy tn	m-vcr	p	sa								N			
[illegible]						qtz ss-cgl	dk gy tn	f-peb	p	sa								N			
85.0						qtz ss-sltst	dk gy	vf-cr	p	sa								N			Silty fg ss @ 84.0 ft.
87.5						qtz ss	gy	vf-f	f	sa								N			
90.0						qtz ss	gy	vf-f	f	sa								N			
92.5						qtz ss	gy	vf-f	f	sa								N			
95.0						qtz ss	gy-wh	vf-f	f	sa								N			
97.5						qtz ss	wh	f-m	f	sa								N			
100.0						qtz ss	wh	f-m	w	sr								N			
102.5						qtz ss	vlt tn-wh	f-m	w	sr								N			
105.0						qtz ss	wh	f-m	w	sr								N			
107.5						qtz ss	wh-lt gn	m-vcr	f	r								N			sparse dk gy chert frag.
110.0						qtz ss	wh	f-m	w	r								N			
[illegible]						qtz ss	wh	f-m	w	sr			T	c				N			
115.0						qtz ss-sh	wh-lt gn	f-m	w	sr								N			sparse gn sh frag.
117.5						qtz ss-sh	wh-gn	f-m	w	sr								N			Upper Brushy Basin Cf @ approx 117.0 ft. (116 from video)
20.0						sh	pp-gy gn											N			
22.5						Sh	pp-gy gn											N			
25.0						Sh	pp bn-dk gy gn											N			TD

PERCENTAGE COMPOSITION IMAGE



Date 4-9-05 Geologist L. Casebolt Drilling Co. Boyles Exploration Co. Hole No. TW4-22

Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1

T.D. PROBE ______

T.D. DRILL 115.0

FLUID LEVEL ______

REMARKS cored from 20'-115.0'

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCl	Carbon Amount	Carbon Type	Remarks
2.5	sndysltst	or bn	f m	p	sa								M			Surface soil
5.0	qtz ss	or bn	vf-cr	p	sa								VS			
7.5	qtz ss, sltst	tn bn	vf m	f	sa								VS			
10.0	sltst, qtz ss	vltrdbn	vf f	f	sa								VS			
12.5	sltst, qtz ss	vltrdbn	vf f										VS			
15.0	sltst, sh	vltrdbn											VS			
17.5	sltst, sh	lt yw gy											vw			
20.0	sndy sltst	lt or tn	vf-f	f	sa								W			
22.5	qtz ss	ywtn	f m	f	sa								N			upper Dakota Fm. ct @ approx 20.0 ft.
25.0	qtz ss	ywtn	f m	f	sr								N			
27.5	qtz ss	tn	m	w	sr								N			
[illegible]	qtz ss	tn	f-m	f	sr								N			
[illegible]	qtz ss	lttn	f-m	w	sa								N			
35.0	qtz ss	lttn	f-m	f	sa								N			
37.5																No Cuttings
40.0	qtz ss	tn	f-m	f	sa								N			
42.5	qtz ss	tn	f-m	f	sr								N			
45.0	qtz ss	tn	m	w	sa								N			
47.5	qtz ss	tn	f-m	f	sa								N			
50.0	qtz ss	tn	m	w	sr								N			
52.5	qtz ss	ywtn	m	f	sr								N			
55.0	qtz ss	tn	m	f	sr								N			
57.5	qtz ss	gytn	m-cr	f	sa								N			
60.0	qtz ss	gytn	f	w	sr								N			
62.5	qtz ss	lt bn	m-vcr	p	sa								N			
65.0	qtz ss	gytn	f	f	sa								N			
67.5	qtz ss	lt bn	m	w	sr								N			
70.0	qtz ss	lt gybn	m-cr	f	sr								m			
72.5	qtz ss	or bn	m-vcr	p	sa								S			
75.0	qtz ss, cgl	tn	m-grit	p	a								N			multi colored chert frags. and pebbles
77.5	qtz ss, cgl	tn	m-vcr	p	sa								N			
80.0	qtz ss	tn	f-cr	p	sr								N			
[illegible]	qtz ss	tn	f-m	f	sr								M			
[illegible]	qtz ss	lttn	f-m	f	sr								N			
87.5	qtz ss	lttn	f-m	f	sr								N			
90.0	qtz ss	lttn	f-m	f	sr								W			
92.5	qtz ss, sh	tn-gybl	f-m	f	sr	L		Tr	C	L			W			sparse shale frags.
95.0	qtz ss.	tn	f-m	f	sr								N			
97.5	qtz ss	tn	f-m	w	sr								N			
00.0	qtz ss.	vlttn-wh	f-vcr	p	sa								N			
102.5	qtz ss, cgl	vlttn-wh	f-grit	p	sa								N			Some multi colored chert pebbles and rock frags.
05.0	qtz ss, cgl	tn	f-grit	p	sa			Tr	C	T			N			
107.5	qtz ss, cgl	dk gytn	m-grit	p	sa								N			abunt multicolored chert pebbles
10.0	qtz ss, cgl	dk gytn	m-grit										N			
12.5	sndy sh, cgl	bl gy gn-rdbn	m-cr										N			upper Brushy Basin Ct @ approx 111.5 ft.
1[illegible]	sndy sh	bl gy	m	p	sa								N			

PERCENTAGE COMPOSITION IMAGE

Date 5-1-07 Geologist Casebolt Drilling Co. Boyles Exploration Hole No. TW4-23

Property White Mesa Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1

T.D. PROBE ______

T.D. DRILL 120.0

FLUID LEVEL ______

REMARKS CORE ZONE 100-120

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5						Sndy sltst	ltrdbr	f	P									S			Surface soil
5.0						Sh	ltrdbr											VS			Mancos Sh
7.5						Sh	ltpktn											VS			
10.0						sh	ltpktn											VS			
12.5						Sh	lt ywgy											VS			
15.0						Sh	ltywgy-gy											VS			abnt selenite xls
17.5						sh	ltywgy											VS			some selenite xls
20.0						sndysh	ltywgy	vf	P									S			very abnt selenite xls
22.5						Sh	ltywgy											M			sparce selenite xls.
25.0						sndysh	ywgy	vf	P									W			very large & abunt selenite frags.
27.5						sndysh	ywgy-dkgy	vf	P									N			abunt selenite
30.0						sndysh	gy	vf	P			L						N			some selenite
32.5						qtzss/sh	orgy	f-M	P	r		L						N			Upper Dakota Fm contact approx 31.0ft.
35.0						qtz ss	lt tn	f-cr	P	r		L						N			
37.5						sh	gy					L						N			shale lens
40.0						qtz ss	lt tn	vf	W	R								N			
42.5						qtz ss	lt tn	vf	W	R								N			
45.0						qtz ss	lt tn	vf	W	R								N			
47.5						qtz ss	lt tn	vf	W	R								N			
50.0						qtz ss	lt tn	vf	W	R								N			
52.5						qtz ss	lt tn	vf	W	R								N			
55.0						qtz ss	lt tn	vf	W	R								N			
57.5						sltysh	vdkgy-blk											N	S		carbon plant frag-
60.0						qtz ss/cgl	wh-dkgy	f peb	N	A								N			chert peb/frags.
62.5	X																				No sample
65.0						qtz ss	lt tn	f cr	P	a								N			
67.5						qtz ss/cgl	lt orgy	f peb	N	A								N			abnt multicolored chert frag & peb
70.0						qtz ss/cgl	tn	f cr	N	A								N			Some muti colored chert frag.
72.5						qtz ss	tn	f-m	M	R								N			
75.0						sndy sltst	lt blgy	vf-f										N			
77.5						sltst/sh	lt blgy											N			
80.0						sltst	lt blgy											N			
82.5						sltst	lt gy											N			
85.0						qtz ss	vlt tn	f	W	WR								N			Moisture first noted
87.5						qtz ss	vlt tn	f	W	WR								N			
90.0						qtz ss	vlt tn	f	W	WR								N			
92.5						qtz ss	vlt tn	m	W	WR								N			
95.0						qtz ss	vlt tn	m	W	WR			T	A				N			
97.5						qtz ss	vlt tn	m	W	WR								N			Trace blgy shale., sparce chert grains
100.0						qtz ss	lt tn/sh	m	M	WR								N			Begin core run
102.5	X																				No sample
105.0						qtz ss	lt bn	f-m	M	R											
107.5						qtz SS	vlt tn	f-m	M	R											
110.0						qtz ss/sh	lt tn-vlt blgy	f-CR	P	S											
112.5						qtzss/sh	tn-ywgr-lt bl	mc	P	S											Upper Brushy Basin Ct @ 111.5, from core
115.0						Sh-sltst	ywgr-bl-ppbr														
117.5						Sh-qtzss	ppbr-bl	m cr	P	A											
120.0						Sh-qtz ss	ppbr-bl	m cr	P	A											Bottom in Brushy Basin TD 120.0

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Core Log of Well No. TW4-23

Cored Interval 100.0 ft. to 120.0 ft. T.D

Depth	Description
100.0 - 110.0	Core recovery 26%, 100.0 ft. - 105.5 ft. no recovery. 105.5 108.5 ft. quartz sandstone / gritstone, very light yellow-tan, fine to grit size quartz grains. Oxidized, some low angle partings occur along crossbeds and concentrations of grit sized grains. Coarse material consists of chert and shale fragments, no high angle fractures or joints observed. 108.5-110.0 ft. quartz sandstone / conglomerate, light gray - reduced, sparse pyrite grains, some low angle partings. Quartz sandstone / gritstone with abundant chert grains and fragments. No high angle fractures or joints observed. Competent core.
110.0 - 120.0	Core recovery 85%, 110.5-111.5 ft. No core recovery, upper Brushy Basin contact selected at 111.5 ft. 111.5-113.5 ft. Mottled green shale, some low angle partings, Brushy Basin Fm. 113.5-120.0 ft. Purple - brown shale, some low angle partings, no high angle fractures or joints observed, core consists of broken fragments and 2 to 4 inch long unbroken pieces. Core began to air slake soon after retrieval.

Date 5-2-07 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. TW4-24

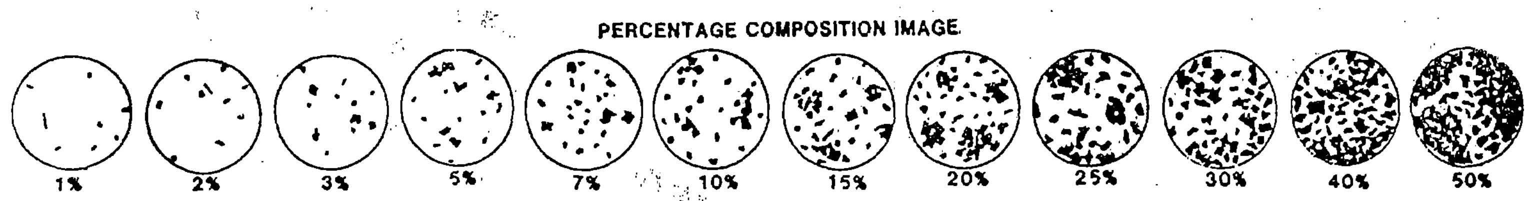
Property White Mesa Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ≈ ______

PAGE ____ OF ____
T.D. PROBE ______
T.D. DRILL ______
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite: Amount	Pyrite: Habit	Pyrite: Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon: Amount	Carbon: Type	REMARKS CORE ZONE 100'-120'
0																					
2.5						Sndy Sltst	rd br	vf-CR	P	A		h						S			Surface soil - Some wh chert frags.
5.0						Sndy Sltst	rd br	vf-f	m	SA		h						VS			" " tr. selenite xl's
7.5						Sltst	rd br											N			
10.0						Sndy sltst	lt br	vf-f	m	SA		h						VS			
12.5						Slty sh	lt br											S			
15.0						Shale	lt ywbr											S			Mancos Shale
17.5						qtz Ss	tn	f-m	m	SR		l						N			Upper Dakota Fm contact at approx 15.0'
20.0						qtz Ss	lt gy tn	m-CR	m	SA		l						N			some wh chert frags.
22.5						qtz Ss	tn	m-CR	m	SA								N			
25.0						qtz ss	lt tn	f-m	m	SA		l						N			
27.5						qtz ss	lt tn	f-m	m	SA								W			
30.0						qtz ss, sh	lt tn-gy	f-m	m	SA		l						N			some lt gy shale frags. (2%)
32.5						qtz ss, sh	lt tn-gy	f-m	m	SA		l						N			" " " " (10%)
35.0						qtz ss, sh	lt tn gy	f	m	SA		l						N			ss/sh 50%/50%
37.5						qtz Ss, sh	wh-tn, gy	f	m	SA		l						N			ss/sh 50%/50%
40.0						qtz Ss, Sh	wh-tn, gy	f-m	m	SA		l						N			ss/sh 80%/20%
42.5						qtz Ss, Sh	wh-tn, gy	f-m	m	SA		l						N			ss/sh 90%/10%
45.0						qtz ss	tn	vf-m	P	SA		l						N			Clean Ss, sparse wh chert grains
47.5						qtz Ss	wh	vf-m	P	SA		l						N			some white chert grains
50.0						qtz Ss	wh	f-m	m	SR		l						N			Some wh+rd chert grains, surface casing point
52.5						qtz Ss, Cgl	lt tn	m-peb	P	SA		l						S			white chert frags, conglomerate zone
55.0						qtz Ss, cgl	tn	m-peb	P	SA		l						N			white to gray chert frags
57.5						qtz ss	tn	m-CR	P	R		l						N			multi colored chert grains
60.0						qtz Ss, cgl	tn	m-peb	P	SR		l						W			" " " "
62.5						qtz Ss	tn	f-m	P	SA		l						N			" " " "
65.0						qtz SS	tn	f-m	m	SR		l						N			" " " "
67.5						qtz SS	tn	m	w	R		l						N			
70.0						qtz Ss	tn	m-peb	P	SR		l						N			chert pebble frags. w/ tr limonite after pyrite
72.5						qtz Ss	lt tn	m-CR	m	SR		l						N			
75.0						qtz ss	v lt tn	m-CR	m	SR								N			
77.5						qtz Ss	wh	m-CR	m	SR								N			
80.0						qtz Ss, sh	wh-lt gy gn	m-CR	m	SR								N			ss/sh 60%/40%
82.5						slty sh	tn-gy											N			
85.0						qtz Ss	wh-lt gy	f-m	m	SA								W			
87.5						qtz ss, sltst	wh-lt gy	f-m	m	SA								VS			
90.0						qtz ss, sltst	lt tn-lt gy	f-m	m	SA								W			
92.5						qtz ss	v lt tn	f-m	w	SR								W			
95.0						qtz ss	v lt tn	f-m	m	SA								W			
97.5						qtz ss	v lt tn	f-m	m	SA								W			
100.0						qtz ss	v lt tn	m	w	R		l						N			some rounded chert grains - begin coring
102.5																					no cutting recovered below 100.0'
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					

PERCENTAGE COMPOSITION IMAGE



Core Log of Well No. TW4-24

Cored Interval 100.0 ft. to 120.0 ft. T.D

Depth	Description
100.0 - 110.0	Core recovery 54%, 100.0 ft. - 104.8 ft. no recovery. 104.8- 108.4 ft. quartz sandstone / conglomerate, light tan, fine to grit size sub angular quartz and chert grains. Some very low angle crossbeds. Core is oxidized with limonite staining. Non calcareous. 108.4-110.0 ft. Quartz sandstone / conglomerate, some low angle partings.
110.0 - 120.0	Core recovery 100%, 110.0-110.2 ft. Quartz sandstone / conglomerate, very light tan to white to yellow, oxidized contact, contact is not gradational. Contact is approx. 15 to 20 degrees from horizontal. Chert pebbles to 1/4". 110.2-115.8 ft. Quartz sandstone / siltstone, some shale fragments, very fine to fine grained with occasional chert grains. Low angle partings. 115.8-118.2 ft. Purple-brown siltstone / shale, mottled appearance, high angle (45 degree) slickensided partings at 116.4 ft. and 118.2 ft. Striations indicate some normal movement. 118.2-120.0 ft. Light green siltstone / shale, some low angle partings.

Date 4-30-07 Geologist L. Casebolt Drilling Co. Boyles Exploration Co. Hole No. TW4-25

Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ≈

PAGE 1 OF 2

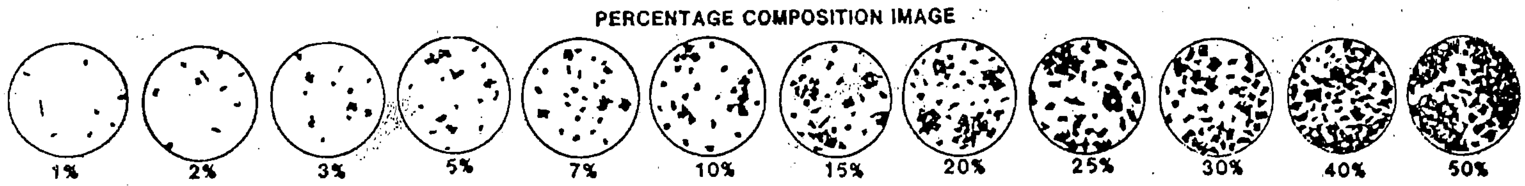
T.D. PROBE ______

T.D. DRILL 140.0

FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	React.-10% HCL	REMARKS CORE ZONE 110.8'-140'
2.5	Sndy Sltst	rdbr	vf	P	SA		h		S	Surface Soil.
5.0	Sndy Sltst	rdbr	vf	P	SA		h		S	" "
7.5	Slty sh	lt br					l		VS	Mancos Shale Fm.
10.0	Slty sh	lt br					l		VS	
12.5	Shale	lt br - ltywgn					l		VS	
15.0	Shale	lt br - ltywgy					l		VS	
17.5	Shale	lt br - lt ywgy					l		S	
20.0	Sndy Sh	lt gy br	vf				l		S	
22.5	Sndy Sh	ltgybr	vf				l		W	
25.0	Sndy Sh	ltgybr	vf				l		VW	
27.5	sndy Sh	ltgybr	vf				l		N	Upper Dakota Fm contact at approx 27.5 ft.
30.0	qtz SS	lt tn	f	m	SR		h		N	
32.5	qtz SS	lt tn - lt gy	f-m	m	SR		h		N	
35.0	qtz SS	lt tn	f-m	m	SR		l		N	
37.5	qtz ss	lt tn	f-m	m	SR		l		N	
40.0	qtz SS	lt tn	f-m	m	SR		l		N	
42.5	qtz SS	v lt tn	f-m	m	SA		l	Tr?	N	trace diss. pyrite
45.0	qtz ss	v lt tn	f-m	m	SR		l		N	
47.5	qtz ss	v lt tn	f-m	m	SR		l		N	
50.0	qtz Ss	v lt tn - v lt gy	f-m	m	SR		l		N	
52.5	qtz ss	ltgytn	f-m	P	SA	A			N	
55.0	qtz Ss	wh - lt gy	f-m	P	SA	A			N	Some multi colored chert frags.
57.5	qtz Ss	v lt tn	m	m	SR				N	Some gy chert frags.
60.0	qtz Ss	v lt tn	f-cr	P	SR				N	dkgy chert frags.
62.5	qtz Ss	wh	f-m	P	SR				N	clean ss.
65.0	qtz Ss	wh	vf-cR	P	SA		l	Tr	N	abnt dk chert frags
67.5	qtz Ss	wh - lt tn	vf-grnl	P	SA		l	tr	N	" lt chert frags
70.0	qtz Ss	v lt tn	vf-m	m	SR		l	tr	N	
72.5	qtz Ss-Chert	wh - tn	m-cR	m	SR		l	Tr	N	
75.0	qtz Ss-Grit	wh - lt tn	m-cR	P	SA		l	Tr	N	abnt multi colored angular chert frags.
77.5	qtz Ss-Cgl	tn	vCR-Cgl	P	A				N	" " " " " "
80.0	qtz Ss-Cgl	gy tn	vCR-cgl	P	A				N	" " " " " "
82.5	qtz Ss-Cgl	gytn	vCR-Cgl	P	A				N	" " " " " "
85.0	qtz Ss-Cgl	gytn	vCR-Cgl	P	A				N	" " " " " "
87.5	qtz Ss-Cgl	gytn	vCR-Cgl	P	A				N	" " " " " "
90.0	qtz Ss Cgl	lt tn	vCR-Cgl	P	SA				N	Some multi colored angular chert frags.
92.5	qtz Ss	v lt tn	m-cR	m	SR				N	" " " " " "
95.0	qtz Ss	v lt tn	f-cR	P	SR				N	" " " " " "
97.5	qtz Ss-Sh	v lt tn - v ltgn	vf-f	m	SR				N	Sparse shale frags.
100.0	Slty Sh	v ltgn							N	
102.5	qtz Ss-Sh	lt tn - ltgygn	vf-f	m	SA				N	sparse shale frags.
105.0	qtz Ss	lt tn	f-m	m	SR				N	sand size chert grains
107.5	qtz Ss-Sh	lt tn - ltgn	vf-f						N	some ltgn shale frags.
110.0	qtz Ss-Sh	lt tn - ltgn	vf-f						N	" " " " Begin Coring @ 110.8'
112.5	qtz Ss.	lt tn —	vf	W					N	
115.0	qtz Ss	lt tn	vf	W					N	
117.5										No Cuttings recovered below 115.0'
120.0										
122.5										
125.0										

PERCENTAGE COMPOSITION IMAGE



2742

Date 4-30-07 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. TW4-25

Property White Mesa mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ______

PAGE 2 OF 2

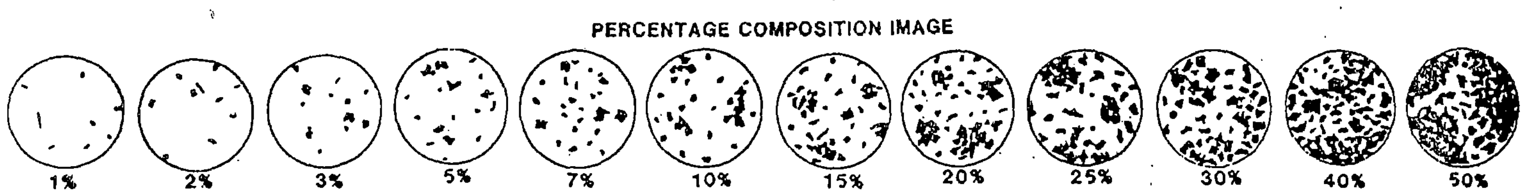
T.D. PROBE ______

T.D. DRILL 140.0

FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
125.0		X																			
127.5		X																			cored interval - no cuttings ↓
130.0		X																			
132.5		X																			
135.0		X																			
137.5		X																			
140.0																					
T.D.																					

PERCENTAGE COMPOSITION IMAGE



Core Log of Well No. TW4-25

Cored Interval 110.8 ft. to 140.0 ft. T.D.

Depth	Description
110.8 - 120.0	Core recovery 100%, 110.8 - 116.0 ft. very light gray quartz sandstone, very fine grained, some low angle partings, mottled appearance, some light green shale fragments. Competent core, no high angle fractures or joints. 116.0-120.0 ft. quartz sandstone, fine to coarse grained, some low angle partings, no high angle fractures or joints. Grit sized material occurs along bedding planes, competent core.
120.0 - 130.0	Core recovery 100%, 120.0-127.8 ft. clean white quartz sandstone, fine to medium grained, well sorted and rounded, competent core. Low angle cross-bedded with gray green shale fragments concentrated at bedding planes. 127.8-128.5 ft. quartz sandstone / grit, coarse, poorly sorted, very light gray, sparse disseminated pyrite, some chert fragments and light green shale fragments. 128.5-130.0 ft. clean quartz sandstone, fine to medium grained, white, no high angle fractures or joints, competent core.
130.0 - 140.0	Core recovery 75%, 130.0-131.9 ft., Dakota sandstone, fine to medium grained quartz, well sorted, rounded grains, low angle cross-bedding, accessory grains include multi colored chert grains and shale fragments. Three inch zone of disseminated pyrite mineralization occurs from 130.7 to 130.9 ft. Core is white with dark gray patch of pyrite. Numerous low angle partings occur at bedding planes. No high angle fractures or joints are observed. Sandstone / Shale contact occurs at 131.9 ft. Upper Brushy Basin contact. 131.9-134.5 ft., core is missing, no recovery, presumed to be Brushy Basin. 134.5-135.0 ft., core material consists of fragments of light gray green shaly siltstone. 135.0-137.8 ft., light gray green siltstone, with some mottling, competent core. 137.8-139.5 ft., purple brown siltstone / shale, competent core. 139.5-140.0 ft., light gray green siltstone, no high angle fractures or joints. T.D.

Date 5-25-2010 Geologist [redacted] Casebolt Drilling Co. Boyles Exploration Hole No. TW4-26

Property White Mesa Mill Project Chloroform Investigation Unit No. ______ Sec. 33 Twp. 37S Rge. 22E

County San Juan State Utah Location 4154276 632571 Elev. ≈5602

PAGE 1 OF 1
T.D. PROBE 100.5
T.D. DRILL 100.0
FLUID LEVEL 63.5 @ 8:30 AM ON 5-26-2010

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Habit	Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Type	Remarks
0																					
2.5						Mdst	dkrdbn											S			Surface soil/mudstone
5.0						Sh	ltpktn											VS			Mancos Shale Fm.
7.5						Sndy sltst	ywbn											VS			" " "
10.0						Sndy sltst	ywbn											VS			" " "
12.5						Sltst	ywbn											VS			" " "
15.0						Sltst/qtz ss	gybn	f-cr	p	r		H						W			Upper contact Dakota Fm @ 13.0 ft.
17.5						qtz ss	gybn	m-cr	m	r								N			
20.0						qtz ss	gybn	m-vcr	p	s								N			abundt. dkgr chert grains
22.5						qtz ss	gybn	m-vcr	p	s								VW			abundt. white chert grains.
25.0						qtz ss	tn	f-m	w	r								N			clean sand
27.5						qtz ss	tn	f-m	w	r								N			clean sand
30.0						qtz ss/sh	tn - ltblgy	f-m	m	r								N			Shale layer
32.5						qtz ss	tn	f-m	w	r		L						N			clean sand
35.0						qtz ss	tn	f-cr	w	a								N			some dkgy-wh chert fragments.
37.5						qtz ss	lt tn	m	w	R								N			clean sand
40.0						qtz ss	lt tn	f	w	R								N			clean sand
42.5						qtz ss	lt tn	f-m	m	r								N			
45.0						qtz ss	lt tn-gy	f-m	m	r								N			
47.5						qtz ss	tn	m-cr	m	r								N			
50.0						qtz ss, sh	tn-gy	f-m	m	r								N			Shale layer
52.5						qtz ss	lt tn	f-m	m	r		L						N			
55.0						qtz ss	lt tn	f	w	R								N			
57.5						qtz ss	lt ywtn	f-m	m	r								N			abundt chert grains
60.0						qtz ss	lt tn	m-cr	m	a								N			
62.5						qtz ss	tn-dkgy	m-peb	p	a								N			multi colored chert frags or grains
65.0						qtz ss	tn-dkgy	m-peb	p	a								N			Moisture first noted, abund chert grains
67.5						qtz ss	tn-gy	m-peb	p	r								N			
70.0						qtz ss, sh	tn-ltblgy	m-vcr	m	r								S			Shale layer.
72.5						sltst, ss	ltgy	f	w	r								VW			
75.0						qtz ss, sltst	ywtn-ltgy	vf-m	m	r								N			
77.5						qtz ss, sh	vltbn	vf-m	m	r								N			
80.0						qtz ss	ywtn	vf-m	m	r		L						N			cuttings very damp, abunt. lim.
82.5						qtz ss	tn bn	m-peb	p	r								N			Begin H_2O injection - increased permeable
85.0						Sh, qtz ss	blgn-tn	m-cr	m	r								N			Brushy Basin Contact @ 83.0 ft. chert frags
87.5						Sh	blgn											N			
90.0						Sh	blgn											N			
92.5						Sh, sltst	blgn-blgy											N			
95.0						Sh, sltst	blgn-blgy											N			
97.5						Sh	blgy											N			
100.0						Sh	blgn-ppbn											N			mottled frags.
T.D.																					

Date 10-18-11 Geologist L. Casebolt Drilling Co. Bayles Exploration Inc Hole No. TW4-27

Property White Mesa Mill Project chloroform investigation Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 1
T.D. PROBE 100.0
T.D. DRILL 100.0
FLUID LEVEL ____

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React. 10% HCl	Carbon Amount	Carbon Type	Remarks
0–2.5	CL w/sand	rdbn	slt-vf	m	a								S			Surface soil. CL (Lean Clay w/ sand
5.0	CL w/sand	lt pk bn	slt-vf	m	a								S			Mancos Sh fm @ 6.0' CL
7.5	slty sh	lt gy bn											VS			
10.0	slty sh	lt gy bn											VS			
12.5	sndy sh	gy bn	vf-f	m	a								VS			
15.0	slty ss	yw bn	vf-f	m	a								S			
17.5	sndy sh-qtz ss	yw bn	f	m	a								W			Dakota Ct. @ 17.0'
20.0	qtz ss	lt tn	m	w	r								N			
22.5	qtz ss	lt or tn	m	w	r		lim						N			
25.0	qtz ss	lt gy tn	m	w	r		hem						N			tr hem. as cement
27.5	qtz ss, sh	lt gy tn	m-cr	m	r								N			
30.0	qtz ss	lt tn	m	w	r								N			
32.5	qtz ss	lt tn	m	w	r								N			
35.0	qtz ss	tn	f-m	m	r								N			moisture noted @ 35.0 ft.
37.5	qtz ss, sh	tn-gy-pk	f-cr	m	r								N			some bright pink-red clay min as cement
40.0	qtz ss	v lt gy	f-m	w	r								N			
42.5	qtz ss, sh	v lt gn	m-cr	m	r								N			
45.0	qtz ss	tn	m-cr	m	r								N			
47.5	qtz ss	tn	m	w	r								N			
50.0	qtz ss	tn	m-cr	m	r		lim						N			
52.5	qtz ss	lt or tn	m	w	r								N			
55.0	qtz ss	lt gy bn	m-cr	m	r								N			some light colored chert frags and grains
57.5	qtz ss	lt gy bn	m-cr	m	r								N			abund. light colored chert frags.
60.0	qtz ss	tn	m	w	R								N			
62.5	qtz ss	tn	f-m	m	R								N			
65.0	qtz ss	tn	f-m	m	R								N			
67.5	qtz ss	tn	f-m	m	R								N			light and dark chert frags.
70.0	qtz ss	tn	m	w	R								N			sparse dk gray chert frags.
72.5	qtz ss	or tn	m	m	R								N			some multi colored chert frag.
75.0	qtz ss, cgl	tn-gy bn	m-peb	w	A								N			abund. chert frags and pebbles. moisture noted.
77.5	qtz ss	tn	m-cr	m	r								N			
80.0	qtz ss	tn	f	w	r								N			
82.5	qtz ss	tn	f	w	r								N			
85.0	qtz ss	yw tn	m-vcr	p	a								N			abund chert frags.
87.5	qtz ss	yw tn	m-cr	m	r								N			
90.0	qtz ss	yw tn	m-vcr	p	a								S			some chert pebbles
92.5	qtz ss, cgl, sh	or tn-blgn	m-peb	p	a			<1%	c				VW			Brushy Basin Ct @ 91.0 ft. sparse sulfides
95.0	sndy sh	blgn	m	m	r		LT						N			sparse chert peb.
97.5	sndy sh	blgn	m	m	r								N			
100.0	sh	lt blgn-v lt bn											N			T.D. no free water observed
102.5																
105.0																
107.5																
110.0																
112.5																
115.0																
117.5																
120.0																
122.5																
125.0																

PERCENTAGE COMPOSITION IMAGE

Date 3-4-2013 Geologist L. Casebolt Drilling Co. Bayles Exploration Hole No. TW4-28

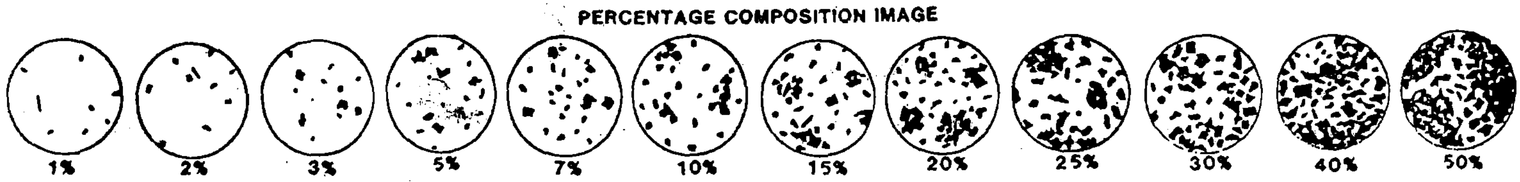
Property White Mesa Mill Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location White Mesa mill Elev. ____

PAGE 1 OF 1
T.D. PROBE 114.0
T.D. DRILL 112.5
FLUID LEVEL ____

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5						Clay w/sand	rd bn	slt-vf	m	a								S			Surface Soil
5.0						Clay w/sand	rd bn-lt rd bn	slt-vf	m	a								S			Surface Soil
7.5						clay w/sand	lt rd bn	slt-vf	m	a								VS			Surface Soil
10.0						clay w/sand	lt rd bn	slt-vf	m	a								VS			Surface Soil
12.5						Sh	pk-lt yw bn											VS			Mancos Sh Ct. @ 11.0'
15.0						sh	yw bn											S			
17.5						sndy sh	yw bn	f-m	m	r								N			
20.0						sndy sh	yw bn	f-m	m	r								W			
22.5						sndy sh	yw bn	f-m	m	r								W			
25.0						sndy sh	yw bn	f-m	m	r								N			
27.5						sndy sh	yw bn	f-m	m	r								N			Dakota Fm ct @ 27.5'
30.0						qtz ss	lt tn	m-cr	m	r								N			
32.5						qtz ss	lt or tn	m	w	a								N			
35.0						qtz ss	lt or tn	m	w	a								N			
37.5						qtz ss	lt or tn	m	w	a								W			
40.0						Sh	blk											N	Tr		
42.5						Sh	vdk gy											N			moisture first noted @ 40.0'
45.0						sndy sh	lt gy	f-m	m	a								S			
47.5						sh-sndy sh	lt gy-dk gy	f-m	m	r								N			begin H_2O injection @ 45.0'
50.0						qtz ss/sndy sh	lt gy-dk gy	f-m	m	r								N			
52.5						qtz ss w/sh	lt gy-dk gy	m	m	a								N			
55.0						sndy sh	vdk bn	vf-m	p	a								N			
57.5						qtz ss, sh	lt gy-blk	f-m	m	a								N			
60.0						qtz ss, sh	gy-blk	f-m	m	a								N	20%		Carbonaceous plant frag. abund.
62.5						qtz ss, cgl	dk gy	m-peb	p	A								N	10%		Some chert pebbles and frags.
65.0						cgl/qtz ss	lt gy-vdk gy	m-peb	p	A								N	10%		
67.5						cgl/qtz ss	dk gy	m-peb	p	A								N	1%		abund. dk gy chert pebbles and frags.
70.0						cgl/qtz ss	vdk gy	m-peb	p	A								N	1%		" " " " " " "
72.5						cgl/qtz ss	vdk gy	m-peb	p	A								N			" " " " " " "
75.0						cgl/qtz ss	vdk gy	cr-peb	p	A								N			
77.5						qtz ss/cgl	vlt gy	cr-peb	p	A								VW			
80.0						slty sh	vlt gy-vlt bl gy											N			
82.5						sndy sh	vlt bl gy	vf-f	m	a			tr	c				N			
85.0						slty sh	lt bl gy											N			
87.5						sh	lt gy gn											N			
90.0						sh	lt gy gn											N			
92.5						slty sh	vlt gy						tr	I				N			some disseminated pyrite xls.
95.0						slty sh	vlt gy gn											N			
97.5						sltst	vlt gy											N			
100.0						sltst	vlt gy-vlt gy gn											N			
102.5						slty sh	vlt gy gn						Tr					N			
105.0						sh	bl gn											N			Brushy Basin Ct. @ 102.5' small rd chert pebbles
107.5						slty sh	bl gn											N			
110.0						slty sh	bl gn											N			
112.5						slty sh	bl gn-bl gy											N			
114.0						slty sh	bl gn-bl gy											N			T.D. 114.0'

PERCENTAGE COMPOSITION IMAGE



Date 3-4-13 Geologist L CASEBOLT Drilling Co. Boyles Exploration, Inc. Hole No. TW4-29

Property White Mesa Mill Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ≈ 5605

PAGE 1 OF 1

T.D. PROBE 101.5'

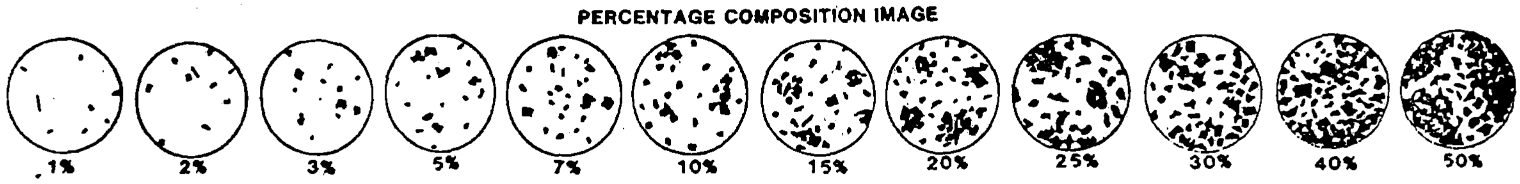
T.D. DRILL 100.0'

FLUID LEVEL ____

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5	clay w/slt	rdbn											W			Surface soil.
5.0	clay w/slt	rdbn-ltpktn											VS			Surface soil
7.5	clay w/slt	lt pktn											VS			Surface soil
10.0	sh	yw gy											S			Mancos Sh. ct. @ 7.5'
12.5	sh	yw bn											S			
15.0	sh/qtz ss	yw bn	f-cr	p	A								W			
17.5	qtz ss/sh	yw bn	f-m	m	a								N			
20.0	qtz ss/sh	yw bn	f-m	m	a								N			
22.5	qtz ss/sh	yw bn	f-m	m	a								N			
25.0	sndy sh	yw bn	f	w	a								N			
27.5	sndy sh	yw bn	f	m	a								N	Tr		
30.0	qtz ss	tn	m	m	a								N			Upper Dakota Ct @ 27.5'
32.5	sndy sh	or tn	vf-cr	p	a		L						N			
35.0	Sh	lt gy											N	1%		carbonaceous matter
37.5	qtz ss	or tn-rdbn	f-m	p	a								N	Tr		" "
40.0	qtz ss	or tn	m-cr	m	A		L						N	Tr		
42.5	qtz ss	tn	m	w	r								N			
45.0	qtz ss	lt gytn	m	w	r								N			
47.5	qtz ss	lt gytn	m	w	r								N			Moisture first noted @ 47.5'
50.0	qtz ss	tn	m	w	a								N			
52.5	qtz ss	dk pktn	m	w	r								N			
55.0	qtz ss	dk tn	m	w	r								N			Some light colored chert frags.
57.5	qtz ss	lt bn	f-m	m	a								N			
60.0	qtz ss/cgl	ltgy-wh	m-peb	p	A								N	Tr		abund. chert pebbles and frags.
62.5	cgl/qtz ss	dkgy-tn	m-peb	p	A								N			" " " " "
65.0	cgl/qtz ss	tn-ltgy	m-peb	p	A								N			" " " " "
67.5	cgl/qtz ss	tn-gy	cr-peb	p	A								N			" " " " "
70.0	cgl/qtz ss	tn-gy	cr-peb	p	A								N			" " " " "
72.5	cgl/qtz ss	tn-dkgy	cr-peb	p	A								N			" " " " "
75.0	qtz ss/cgl	gy tn	m-peb	p	A								N			
77.5	qtz ss/cgl	tn	m-peb	p	a								N			
80.0	qtz ss	tn	m-cr	m	r								N			
82.5	qtz ss	tn	m-cr	m	r								N			Begin H2O injection
85.0	cgl/qtz ss	tngy	m-peb	p	A			Tr	I				N			limonite after pyrite, rare pyrite xls in shale frag.
87.5	cgl/qtz ss	tn-dkgy	m-peb	p	A			Tr	C				N			
90.0	Sh/qtzss/cgl	tn-blgn	m-peb	p	A								N			Brushy Basin ct. @ 88.0 ft.
92.5	Sndy Sh	blgn	f-m	m	a								N			Sparse rd chert pebbles.
95.0	Sndy Sh	blgn	f-m	m	a								N			Some rd chert pebbles
97.5	Sndy Sh	gygn	f-m	m	a								N			
100.0	Sndy Sh	lt blgn	f-m	m	a								N			T.D. @ 101.5' small (½-1mm) rd chert pebbles
102.5																and qtz grains in matrix of bl gy sh.

General Note: The fractured and fragmented condition of the chert and quartz pebbles may have resulted from the crushing action of carbide buttons of the tricone roller bits used to drill these wells.

PERCENTAGE COMPOSITION IMAGE

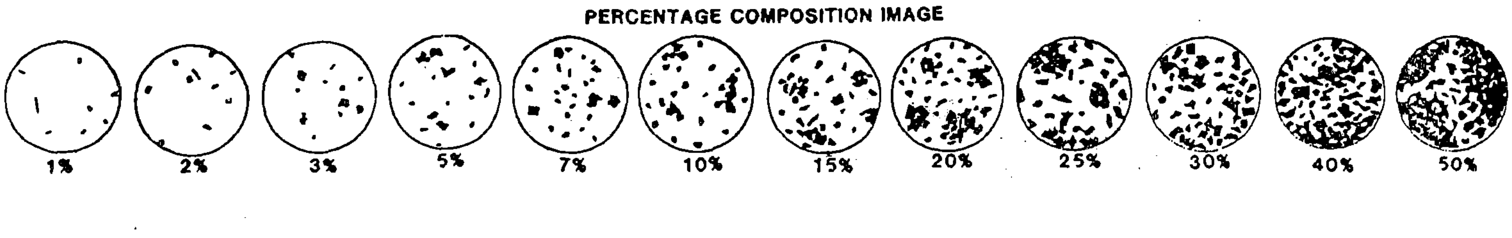


Date 3-5-13 Geologist L. Casebolt Drilling Co. Bayles Exploration Inc. Hole No. TW4-30
Property White Mesa Mill Project Nitrate Study Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE 96.0'
T.D. DRILL 95.0'
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5						cl w/sand	rdbn	slt-vf	m	a								W			Surface soil.
5.0						cl w/sand	rdbn-lttn	slt-vf	m	a								W			Surface soil
7.5						slty sh	rdbn-ltywbn	slt-vf	m	a								VS			Macos Sh Ct @ 5.0'
10.0						sndy sh	ltywbn	slt-vf	m	a								VS			
12.5						snd sh	ywbn	f	m	r								VS			abund. selenite (gypsum xls.)
15.0						sndy sh	ywbn	f	m	r								N			some selenite xls.
17.5						qtz ss w/sh	ywbn	f	m	r								N			
20.0						qtz ss w/sh	ywbn	f	m	r								W			
22.5						qtz ss w/sh	ywbn	f	m	r								W			
25.0						sh	ywbn-gy											W			
27.5						sndy sh	ywgybn	f	m	r			tr	I				W			
30.0						sndy sh	ywbn	f	m	a								N	tr		
32.5						qtz ss/sh	ltortn	f	m	a								N	tr		Upper Dakota Ct @ 31.0'
35.0						qtz ss	ltgy-tn	f-m	m	r								N			
37.5						qtz ss/sh	gy-ortn	f-m	m	r		L						N			
40.0						qtz ss	tn	m	m	a								N			moisture 1st noted @ 37.5'
42.5						qtz ss	ltgytn	m-cr	p	a								N			
45.0						qtz ss	tn	m	w	a								N			Begin H_2O injection @ 45.0'
47.5						qtz ss	ywtn-rd	m-cr	m	a								N			
50.0						qtz ss/sh	ywtn-gy	m-cr	m	a								N			
52.5						qtz ss	tn-gyblk	f-m	m	a								N	15%		
55.0						qtz ss/cgl	tn-blk-rd	m-peb	p	A								N	15%		abund carbon as plant frags./chert frags.
57.5						qtz ss/cgl	tn-rdtn	m-peb	p	A								N			abund chert/qtz pebble frags.
60.0						qtz ss/cgl	tn-rdtn	m-peb	p	A								N			" " " " "
62.5						cgl/qtz ss	gy-tn	cr-peb	p	A								N			approx 80% chert frags.
65.0						qtz ss/cgl	tn	m-cr	p	a								N			
67.5						qtz ss/cgl	tn	m-peb	p	a								N			abund chert pebble frags
70.0						cgl/qtz ss	tn-dkgy	m-peb	p	a								N			
72.5						cgl/qtz ss	ortn-gy	m-peb	p	a								N			abund multi colored chert frags.
75.0						cgl/qtz ss	orgytn	cr-peb	p	a								N			" " " " "
77.5						cgl/qtz ss	orgytn	m-peb	p	A								N			
80.0						cgl/qtz ss	orgytn	cr-peb	p	A								N			mostly chert pebbles and frags.
82.5						qtz ss/cgl	tn-gy	f-peb	p	A								N			
85.0						qtz ss/cgl	tn	m-peb	p	A								N			
87.5						qtz ss/sh	ywtn-blgn	m-cr	m	R								N			Brushy Basin Ct @ 86.0'
90.0						qtz ss/sh	blgn	m	w	R			tr					N			tale tell rd chert grains
92.5						sh/qtz ss	blgn	f-m	m	a			tr					N			" " " " "
95.0						sh/qtz ss	blgn-ltgy	f-m	m	a			tr					N			T.D. @ 96.0'
97.5																					
100.0																					
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE

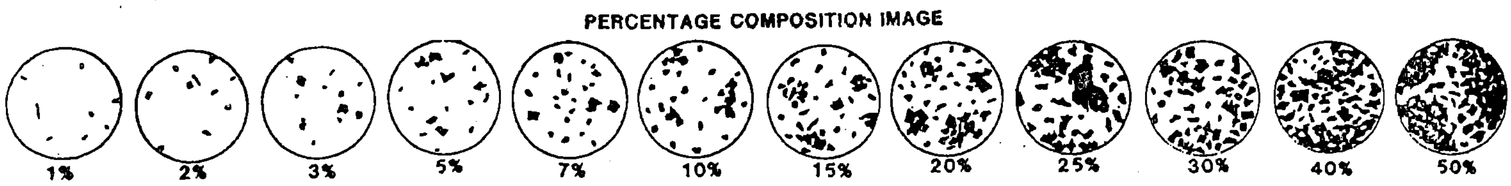


Date 3-5-13 Geologist L. Casebolt Drilling Co. Boyles Exploration, Inc. Hole No. TW4-31
Property White Mesa Mill Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 1
T.D. PROBE 111.0
T.D. DRILL 110.0
FLUID LEVEL ____

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0–2.5						CL w/sand	rdbn	slt-f	m	a								VS			Surface Soil. CL (lean clay w/ sand
2.5–5.0						CL w/sand	vlt tn-wh	slt-vf	m	a								VS			Surface Soil CL (lean clay w/ sand
5.0–7.5						sltysh	ltgybn	slt-vf	m	a								VS			Mancos sh Ct @ 5.0'
7.5–10.0						sndysh	lt ywbn	f-m	m	a								S			
10.0–12.5						sndysh	lt ywbn	vf-m	m	a								VS			
12.5–15.0						qtzss w/sh	lt ywbn	f-m	m	a								S			
15.0–17.5						qtzss w/sh	ltywbn	f-m	m	r								N			
17.5–20.0						qtzss w/sh	ltywbn	f-m	m	r								N			
20.0–22.5						qtzss	lt tn	f	w	r								W			Upper Dakota ct @ 20.0'
22.5–25.0						qtzss	lt tn	f	w	r								N			
25.0–27.5						qtzss	lt tn	f-m	m	r								S			
27.5–30.0						qtz ss	lt tn	f-m	w	r								S			some muscovite sheets as accessory minerals
30.0–32.5						sh	lt gy											N	<1%	I	sparse carbon material
32.5–35.0						sh-qtzss	or bn-gy	f-m	w	r		L						N	Tr	I	abund. limonite as cementing agent.
35.0–37.5						qtzss-sh	lt or bn-gy	f-cr	m	a								N			
37.5–40.0						qtz ss	lt tn	f-m	m	a								N			
40.0–42.5						qtz ss	ltgytn	m-cr	m	a								N			
42.5–45.0						qtzss	lt tn	m-cr	w	r								N			
45.0–47.5						qtz ss	lt tn	f-m	m	a								N			
47.5–50.0						qtzss-sh	lt bn-dkgy	m-cr	m	r								N	5%	I	some carbon fragments
50.0–52.5						qtzss	bn	m	w	r								N	<1%	I	some carbonaceous material; sparse chert frags.
52.5–55.0						qtz ss	bn	m	w	r								N			some chert frags.
55.0–57.5						qtzss	bn	m	w	r								N			
57.5–60.0						qtz ss	bn	m-cr	m	a								N			Moisture 1st noted @ 60.0'
60.0–62.5						qtzss	lt pk bn	f-m	m	a								N			
62.5–65.0						qtzss	lt tn	f-m	m	a								N			
65.0–67.5						qtzss	tn	m-vcr	p	A								N			abund. light colored chert frags.
67.5–70.0						qtz ss	tn	m-cr	p	A								N			abund. multi colored chert frags.
70.0–72.5						qtz ss	tn	m-cr	p	a								N			
72.5–75.0						qtzss/cgl	tn-dkgy	m-peb	p	A								N			pebble cgl w/ abund. chert pebbles and frags.
75.0–77.5						qtzss/cgl	tn-dkgy	m-peb	p	A								N			" " " " " " "
77.5–80.0						qtz ss	tn	m	m	r								N			
80.0–82.5						qtzss	tn	m	m	r								N			
82.5–85.0						qtzss	tn	m-cr	m	r								N			abund. multi colored chert frags
85.0–87.5						qtzss	tn	m	w	r								N			
87.5–90.0						qtzss/cgl	tn	m-peb	p	r								N			Some chert pebbles and frags.
90.0–92.5						qtz ss/cgl/sh	gy tn	m-peb	p	r								N			abund. chert and qtz. pebbles and frags.
92.5–95.0						qtz ss	gytn	m-peb	p	a								N			" " " " " " "
95.0–97.5						qtzss	tn	m	w	r								N			clean sand
97.5–100.0						qtz ss/cgl.	tn	m-peb	m	a								N			sulfides (marcasitic habit)
100.0–102.5						qtzss-sh	gy-blgn						2% c/mt					N			Brushy Basin Ct @ 101.0 Began H_2O injected @ 100.0'
102.5–105.0						sh	gy-rd											N			shale frag. mottled gray w/ ppbn, Sharp contact
105.0–107.5						sh / cgl	gygn-ppbn											N			large chert frag.
107.5–110.0						sh	ppbn-blgn											N			
110.0–112.5																		N			T.D. @ 111.0
112.5–115.0																					
115.0–117.5																					
117.5–120.0																					
120.0–122.5																					
122.5–125.0																					

PERCENTAGE COMPOSITION IMAGE



Date 9-9-2013 Geologist L. CASEBOLT Drilling Co. Bayles Exploration Co. Hole No. TW4-32
Property White Mesa Mill Project ____ Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 1
T.D. PROBE 119.5
T.D. DRILL 117.5
FLUID LEVEL 43.4 8.45 AM, 9-11-13

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5						CL w/sand	rd bn	slt vf	m	a								N			Surface soil. CL (Lean clay w/ Sand)
5.0						CL w/sand	rd bn	slt vf	m	a								VS			Surface soil CL (Lean clay w/ sand)
7.5						CH w/sand	rd bn	slt vf	m	a								VS			Surface soil CH (Fat Clay w/ sand)
10.0						CH w/ sand	lt rdbn-ywbn	slt vf	m	a								VS			Mancos Sh fm @ 9.0'
12.5						CL w/sand	lt rdbn-pk	slt-f	m	a								S			small sandstone pebble
15.0						qtz ss/sh	lt ywbn	f-m	m	a								VS			
17.5						qtz ss/sh	lt ywbn	f-cr	p	a								M			
20.0						qtz ss	tn	f-cr	p	a								VW			Upper Dakota Ct. @ 17.5' white chert frag - 1CM
22.5						qtz ss	tn	m	m	a		lim						VW			
25.0						qtz ss	tn	m-cr	m	a		lim						N			
27.5						qtz ss	tn	m	w	r		lim						N			
30.0						qtz ss	ywtn	m-cr	m	a		lim						N			
32.5						Sh	lt ppbn											N			
35.0						Sh/qtz ss	dk ppgy	cr	w	r								N			
37.5						qtz ss/sh	tn-gy	vf-f	m	r								N			
40.0						qtz ss	tn	f-m	m	r								N			
42.5						qtz ss/sh	tn	f-m	m	a								N			moisture first noted @ 42.5'
45.0						qtz ss	tn	m-cr	m	a								N			
47.5						qtz ss	tn	m	w	r								N			
50.0						qtz ss	tn	m-cr	m	r								N			well began producing H2O @ 50.0'
52.5						qtz ss/sh	tn-lt gy	m	m	r								N			
55.0						qtz ss/sh	gy	f-peb	p	A								N	3%	I	abund. chert pebbles and frags.
57.5						sh/qtz ss	dk gy	m-cr	p	a								N	15%	I	some chert peb. and frags
60.0						sndy sh	gy	m-cr	p	a								N		I	Began H2O injection @ 60.0' Some chert frags.
62.5						cgl/qtz ss	orgy	m-peb	p	a								N			Abund. multi colored chert peb. and frags.
65.0						cgl/qtz ss	orgy	m-peb	p	a								N			
67.5						qtz ss/cgl	tn gy	m-peb	p	a			3%	C/A				N			Abund. chert frags, abund sulfides as cement a disse[minated]
70.0						qtz ss/sltst	v lt gygn	vf-f	w	a								N			
72.5						qtz ss	v lt gygn	vf-f	w	a								N			
75.0						qtz ss/sh	v lt gygn	vf-f	w	a								N			
77.5						qtz ss/sh	v lt gygn	vf-f	w	a								N			
80.0						slty qtz ss	lt gygn	slt-vf	w	a								N			rd chert frag.
82.5						qtz ss/sh	lt gygn	vf-f	m	a								VW			
85.0						qtz ss/sh	lt gygn	vf-f	m	a								N			
87.5						qtz ss	lt gygn	f-m	m	a			1%	C/A				N			sparse sulfides
90.0						qtz ss	wh	f	w	a								VW			very hard/slow drilling beginning @ 87.5'
92.5						qtz ss	wh	f	w	a								N			
95.0						qtz ss/sh	wh-lt blgn	f-m	m	a								N			
97.5						qtz ss	wh	f-m	m	a			1%	C/A				N			Some chert frags. sulfides present.
100.0						qtz ss	v lt gy	cr-grit	m	r								N			some chert frags.
102.5						qtz ss	v lt gy	cr-grit	m	R								N			water flow increased to approx. 5gpm. chert pebbles & fr[ags]
105.0						qtz ss	v lt gy-wh	m-cr	w	R								N			
107.5						qtz ss	v lt gy-wh	m	w	r								N			
110.0						qtz ss	lt gy	cr	w	R								N			some chert frags.
112.5						qtz ss/sh	lt gy-gn-pprdbn	cr	m	r								S			Brushy Basin Ct. @ 111.0 mottled shale
115.0						sh	lt gn-pprdbn											S			mottled shale
117.5						sh	lt gn-pprdbn											N			T.D. 117.5

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 9-11-13 Geologist L. Casebolt Drilling Co. Boyles Exploration Co. Hole No. TW4-33
Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE 90.0
T.D. DRILL 90.0
FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5	CL	rdbn											m			Surface soil CL (lean clay)
5.0	CL/CL w/ ss	rdbn-ywbn	f-m	m	a								VS			Surface soil CL / Mancos shale @ 4.0'
7.5	Sndy sh	ywbn	f-m	f	a								VS			
10.0	Sndy sh	ywbn	f-m	f	a		L						VS			
12.5	qtz ss/sh	ywbn-tn	m	w	a		L						N			Upper Dakota Ct. @ 11.0'
15.0	qtz ss	lt or tn	m-cr	m	A		L						N			
17.5	qtz ss/sh	lt or gy	m-cr	f	A								W			
20.0	qtz ss/sh	lt or tn-gy	m-cr	f	A		L						N			
22.5	qtz ss	lt or tn	cr	m	A		L						N			
25.0	qtz ss	lt or tn	m	m	a								N			
27.5	qtz ss	lt tn	m	w	a								N			
30.0	qtz ss	tn	m	w	r								N			
32.5	qtz ss	tn	m	w	r		L						N			
35.0	qtz ss	lt tn	m	w	r								N			
37.5	qtz ss	lt or tn	m	w	r								N			
40.0	qtz ss	vlt bn	f-m	m	a								N			Some chert grains and frags
42.5	qtz ss	dk tn	m-cr	m	r								N			Some chert grains and frags.
45.0	qtz ss	dk gy bn	m	w	r								N	T	I	
47.5	qtz ss	lt gy tn	f-m	m	r								N			
50.0	qtz ss	gy tn	f-grt	p	a								N			some chert grains and frags.
52.5	cgl/qtz ss	gy tn	m-peb	p	a								N			abund. chert frags.
55.0	qtz ss	gy tn	m-grt	p	a								N			
57.5	qtz ss	gy tn	m-grt	p	a		L						N			
60.0	qtz ss	tn	f-m	m	a		L						N			
62.5	qtz ss	lt gy tn	m	w	r								N			
65.0	qtz ss	lt or tn	m-grt	p	r		L						N			Moisture first noted @ 65.0' abund. chert frags.
67.5	qtz ss	tn	m	w	r								N			
70.0	qtz ss	lt tn	m	w	R								N			
72.5	qtz ss	lt tn	m-cr	m	r								N			
75.0	qtz ss/cgl	lt or tn	m-peb	p	r								N			
77.5	qtz ss/cgl	lt tn	m-peb	p	r								N			
80.0	qtz ss/cgl		m-peb	p	r								N			
82.5	qtz ss/sh	lt tn-bl gn					L	1%					VW			Brushy Basin Ct. @ 82.0' Sharp contact
85.0	sh	gy gn											N			
87.5	sh	gy gn											N			
90.0	sh	gy gn											N			TD @ 90.0'

PERCENTAGE COMPOSITION IMAGE

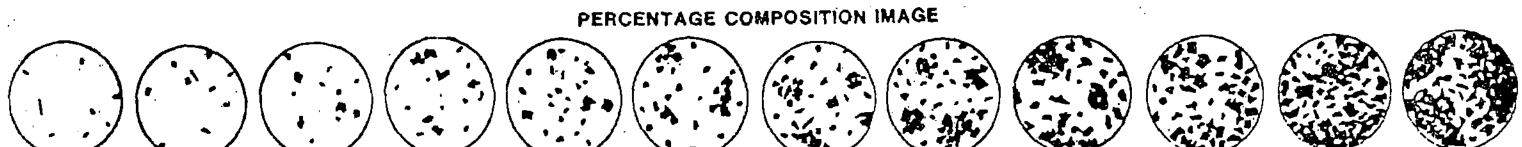
1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 9-11-13 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. TW4-34
Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE 97.9
T.D. DRILL 97.5
FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
2.5						CL	rdbn											S			Surface soil CL (lean clay)
5.0						CL	rdbn-ltpktn											VS			surface soil CL (lean clay)
7.5						Sndy sh	yw tn	m	m	a								VS			Mancos Shale @ 5.0'
10.0						Sndy sh	ywbn	f-m	m	a								VS			
12.5						Sndy sh	ywbn	f-m	m	a								VS			some selenite
15.0						Sndy sh	yw bn	f-m	p	a		L						S			abund selenite (gypsum crystals)
17.5						qtz ss/sh	ywbn	f-m	m	a		L						S			friable ss
20.0						sndy sh	ywbn	f-m	m	a								m			
22.5						sndy sh	ywbn	f-m	m	a								M			
25.0						Sndy sh	ywbn	f-m	m	a		L						N			
27.5						Sndy sh	ywbn	f-m	m	a		L						N			
30.0						qtz ss	tn	m	w	r								N			Upper Dakota Ct @ 27.5'
32.5						qtz ss	tn-orbn	m	w	r		L						N			
35.0						qtz ss	tn-or bn	m	w	r		L						N			
37.5						qtz ss	tn	m	w	a		L						N			
40.0						qtz ss	tn	m	w	a								N			
42.5						qtz ss	lt tn	m	w	a								N			abund. chert grains
45.0						qtz ss	ltgytn	m	w	a								N			
47.5						qtz ss	tn	m	w	r								N			moisture first noticed @ 47.5'
50.0						qtz ss	dktn	f-m	m	r								N			
52.5						qtz ss	dktn	f-m	m	a								N	5%	I	
55.0						qtz ss	tn-dkgy-blk	m	m	a								N	40%	I	Begin H_2O injection @ 52.5'
57.5						cgl/qtz ss	wh-pkbn	m-peb	p	A								N			abund. multi colored chert grains and peb.
60.0						cgl/qtz ss	wh-gybn	m-peb	p	A								N			" " " " " " "
62.5						cgl/qtz ss	wh-tn-dkgy	m-peb	p	A		H						N	10%	I	" " " " " " "
65.0						cgl/qtz ss	tn-dkgy	m-peb	p	A		H						N			" " " " " " "
67.5						cgl/qtz ss	tn-dkgy	cr-peb	p	A								N			" " " " " " "
70.0						cgl/qtz ss	tn-gy	cr-grt	p	A								N			" " " " " " "
72.5						cgl/qtz ss	tn-gy-wh	cr-peb	p	A								N			" " " " " " "
75.0						cgl/qtz ss	tn-gy	m-peb	p	A		L						N			" " " " " " "
77.5						cgl/qtz ss	tn-gy	m-peb	p	A								N			" " " " " " "
80.0						cgl/qtz ss	tn	m-peb	p	A								N			" " " " " " "
82.5						qtz ss/cgl	tn	f-grt	p	A								N			" " " " " " "
85.0						qtz ss/cgl	tn-ortngy	m-peb	p	A								N			" " " " " " "
87.5						cgl/qtz ss	tn-dkgy	m-peb	p	A								N			" " " " " " "
90.0						cgl/qtz ss	tn-gy	m-peb	p	A								N			" " " " " " "
92.5						qtz ss	tn	m-grt	m	a								S			
95.0						Sh/cgl/qtz ss	rdbn-blgn-tn	m-peb	p	A								S			Brushy Basin Ct. @ 93.0'
97.5						sh	blgy											N			T.D.

PERCENTAGE COMPOSITION IMAGE



1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

SAMPLE DESCRIPTION KEY

DEPTH SCALE
Scale is 1"-50' for drill samples and 1"-5' for core.

SAMPLE TAKEN
Mark through interval which special chip sample is saved, with an "X" mark through core interval with shading.

GRAPHIC LOG
Standard rock symbol for interval.

ALTERATION
| Reduction
+ Dissolution
o Oxidation

GAMMA ANOMALY (Probe)

T	3xBG - .009	Trace
1	.010 - .049	Low Mineral
2	.050 - .199	High Mineral
3	.200 >	Ore

BRECCIA PIPE
| Definate
| Unsure

LITHOLOGY
Standard abbreviation for rock type.

COLOR
GSA Rock-Color Chart of wet samples.

GRAIN SIZE

Sandstone		Carbonates
Peb	Pebble	
vc	Very Coarse	vc
c	Coarse	c
m	Medium	m
f	Fine	f
vf	Very Fine	vf

SORTING
W Well-sorted
M Moderately-sorted
P Poorly-sorted
U Un-sorted

ANGULARITY
VA Very Angular
A Angular
a subangular
r Subrounded
R Rounded
WR Well Rounded

CEMENT-MATRIX
A Argillaceous
C Carbonate
D Dolomite
S Silica
F Ferruginous

IRON OXIDE

H	Hematite	A	Abundant
L	Limonite	M	Moderate
G	Geothite	T	Trace

PYRITE-MARCASITE
Amount - In percent.

Habit
A Aggregate
C Interangular cement
G Globules
I Individual
M Massive
MT Marcasitic texture
O Organic replacement

Alteration
F Fresh
T Tarnished
P Pseudomorphs after pyrite

METALLIC MINERALS
Mark with an "X" and clarify in remarks and metallic minerals observed.
(MoS_2, NiS, PbS, UO_2, CU_2O, etc.)

NON-METALLIC MINERALS
Mark with an "X" and clarify in remarks any non-metallic minerals observed. (Barite, Anhydrite, Gypsum, Calcite, etc.)

REACTION -10% HCL
VS Very Strong
S Strong
M Moderate
W Weak
VW Very Weak
N None

CARBON MATERIAL
Amount - In percent

Type
C Coal
F Distinct woody fragments
H Humic
HY Hydrocarbon
I Interbedded trash
L Lignitic

BRECCIA NOMENCLATURE
See sample manual - use grain size, sorting and angularity columns for classification and description.

REMARKS
Use to clarify and expand on the columnar data. Explain anything not evident or any special characteristics such as: heavy minerals, tuffaceouness, cyclic sedimentation, fossils, sedimentary structures, formation picks, etc.

energy fuels

Date 5-6-14 Geologist L. Casebolt Drilling Co. Boyles Exploration Co. Hole No. TW4-35

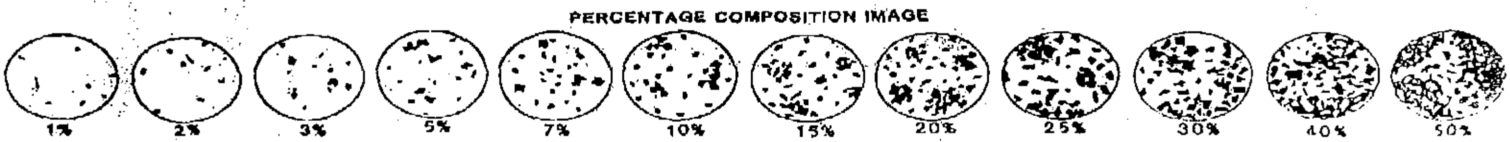
Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 90.0
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						CL w/sand	rdbn	slt-vf	m	a							W				Surface soil. CL (lean clay w/ sand)
5.0						CL w/ss-sh	rdbn-ltpktn	vf	f	a							S				Surface soil CL (lean clay) Mancos Shale at @ 4.
7.5						sh	ltywbn										VS				
10.0						sh	ltywbn										VS				
12.5						sh	ltywbn										VS				
15.0						sh	ltywbn										S				
17.5						sh	ltywbn										m				
20.0						sndy sh	ywbn	f-m	f	a							W				
22.5						sndy sh	ywbn	f-m	f	a							W				
25.0						sndy sh	ywbn	slt-f	f	a							VW				
27.5						sh	ltbn										m				
30.0						sh/sltst	dkgybn										S				
32.5						sh/sltst	gy										m				
35.0						sh	gy										m	tr	L		
37.5						sh	gy				L						VW				
40.0						sh	dkgybn										N				
42.5						qtz ss	ltortn	m-cr	m	r	L						N				Upper Dakota Fm. at @ 40.0' large chert frag.
45.0						qtz ss	lttn	m-cr	m	r	L						N				
47.5						qtz ss	tn	m-cr	m	r							N				moisture first noticed
50.0						sh/qtz ss	lttn-gy	m-cr	m	a							N	1%	L		
52.5						qtz ss/sh	gybn	m-cr	m	a							N	5%	L		
55.0						qtz ss/sh	gy-ortn	f-cr	p	a							VW	tr	L		
57.5						qtz ss/cgl	gy-ltortn	m-peb	p	a							N	tr	L		abund. white-gy chert pebbles + frags.
60.0						qtz ss	lttn-ortn	f-vcr	p	a							N				abund. white-gy chert pebbles + frags.
62.5						qtz ss/sltst	ltortn	slt-f	f	a							N				
65.0						qtz ss/sh	gy-ltortn	f	m	a		tr	c				N				
67.5						sh/qtz ss	lttn-ltgy	m-cr	f	a							N				
70.0						qtz ss	tn	cr	w	r							N				
72.5						qtz ss	tn	cr	w	r							N				
75.0						qtz ss	tn	cr	w	r							N				
77.5						qtz ss	tn	m-cr	m	a											Begin H_2O injection @ 77.5
80.0						qtz ss/cgl	tn-vdkbn	m-peb	p	a											abund dk bn-gy chert peb. + frags.
82.5						qtz ss/sh	lttn-ltgn	m	f	a											Brushy Basin at @ 82.0'
85.0						sh	gn														
87.5						sh	gn					tr	m								
90.0						sh/sltst	gn-wh					tr	m								T.D. 90.0'
92.5																					
95.0																					
97.5																					
100.0																					
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



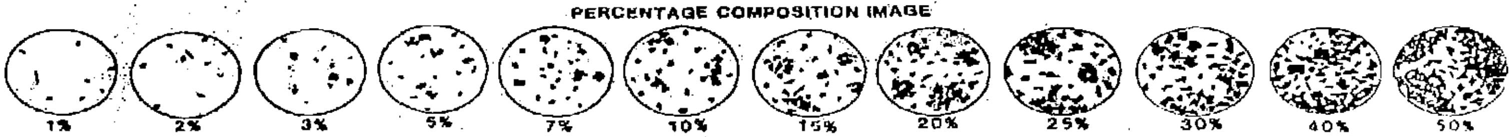
energy fuels

Date 5-5-14 Geologist L. Casebolt Drilling Co. Bayles Exploration, Co. Hole No. TW4-36
Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE 120.0
T.D. DRILL 117.5
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Amount	Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						CL w/sand	rd bn	slt-vf										N			Surface Soil. CL (lean clay w/ sand)
5.0						CL w/sand	rd bn	slt-vf										S			Surface Soil CL (lean clay w/ sand)
7.5						sh	lt rd bn-lpk tn											S			Mancos Shale ct. @ 5.0 ft.
10.0						sh	lt rd bn-lpk tn											VS			
12.5						sh	lt yw bn											VS			
15.0						sh	lt yw bn											VS			
17.5						sh	yw gy bn											VS			
20.0						sh	yw gy bn											S			
22.5						sh/qtz ss	yw gy bn	f-m	p	a								S			
25.0						sh/qtz ss	gy bn	f-m	p	a								S			
27.5						qtz ss/sh	or gy bn	f-m	p	a	L							S			
30.0						qtz ss/sh	or gy bn	f-m	p	a	L							m			
32.5						qtz ss/sh	or gy tn	m-cr	m	a	L							w			Upper Dakota Ct. @ 31.0 ft. Hard drilling
35.0						qtz ss	tn	f-cr	p	A	L							vw			Hard drilling
37.5						qtz ss	tn	f-cr	p	a	L							vw			
40.0						qtz ss	tn	f-m	f	a								vw			
42.5						sh	dk gy-or				L							N			
45.0						sh/qtz ss	dk gy-lt tn	m-cr	m	r								N			
47.5						qtz ss/sh	lt gy tn-gy	m-cr	m	R								N			
50.0						qtz ss	vlt tn	m-cr	m	R								N			
52.5						qtz ss	lt tn	f-m	m	r								N			
55.0						qtz ss	tn	m	w	r								N			
57.5						qtz ss/sh	dk gy-tn	f-cr	p	a								N			
60.0						qtz ss/sh	tn-gy	m-cr	m	R								N			
62.5						qtz ss	gy	m-cr	m	r								N	3%	L	some white chert frags
65.0						qtz ss/cgl	gy	m-peb	p	r		Tr C						N			Moisture first noted at 65.0 ft. abund. gy chert p
67.5						qtz ss	vlt bn	m	w	R								N			
70.0						qtz ss	lt bn	f	w	r								N			
72.5						qtz ss	gy	m-vcr	p	a								N			
75.0						qtz ss/sh	vlt gy gn	f-vcr	p	a		Tr C						M			abund chert grains & frag.
77.5						sltst/sh	lt gy-vlt gn											N			
80.0						sltst	vlt gy											N			
82.5						qtz ss/slt	lt gy	vf-m	p	a								N			
85.0						qtz ss/sltst	vlt gy	slt-vf	m	r								N			
87.5						qtz ss/sltst	vlt gy	slt-vf	m	a								N			
90.0						qtz ss	lt gy	vf-f	m	a								N			
92.5						qtz ss/sh	vlt gy gn	vf-f	m	a		Tr C						N			
95.0						qtz ss	vlt gy-wh	f	m	a								N			Began H_2O inject after 92.5' Brushy Basin Ct. @ 95.0'
97.5						sh/sltst	lt gn-gn					Tr C						N			
100.0						sndy sh	lt gy-lt gn	f	m	a								N			
102.5						sndy sh	lt gn	m-cr	m	r								N			
105.0						sndy sh	lt gn	m	m	r								N			
107.5						sndy sh	lt gy	m	m	r								N			
110.0						sndy sh	lt gy	f	m	r								N			
112.5						sndy sh	lt gy-gn	f	m	r								N			
115.0						sh	gy-gn-pp bn											N			mottled purple brown-green shale
117.5						sh	gn-pp bn											N			T.D. 117.5'
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



Date 3-23-2015 Geologist L. CASEBOLT Drilling Co. BAYLES EXPLORATION INC Hole No. TW4-37

Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County SAN JUAN State Utah Location ______ Elev. ______

PAGE 1 OF ______
T.D. PROBE 116.6
T.D. DRILL 115.0
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCl	Carbon Amount	Carbon Type	Remarks
0 – 2.5						CL w/snd	rdbn	slt-vf		a								S			Surface Soil CL - lean clay with sand
5.0						CL w/snd	rdbn	slt-vf		a		H						N			Surface Soil CL - lean clay with sand
7.5						sh/qtz ss	ltrdbn-gytn											VS			Mancos shale ct @ approx 7.0'
10.0						sh/qtz ss	ltgybn	f-m		a								VS			
12.5						sh/qtz ss	ltywbn	vf-m		a		l						S			
15.0						sh/qtz ss	lt gybn	f-m	p	a								VW			
17.5						sh/qtz ss	lt ywbn	vf-f	p	a								N			
20.0						qtz ss/sh	lt tn	m	w	r		l						N			Dakota Fm Ct. @ 18 ft.
22.5						qtz ss	gytn	m-cr	m	a		l						N			
25.0						qtz ss	tn	m-cr	m	a		l						N			sparse chert frag.
27.5						qtz ss	tn	m-cr	m	a								N			
30.0						qtz ss	ortn	m-cr	m	a		l						N			
32.5						qtz ss	lt tn	m	w	r								N			
35.0						qtz ss	lt tn	m-cr	m	r								N			some dark colored chert grains
37.5						qtz ss	lt tn	m	w	r								N			
40.0						qtz ss	ltgytn	m	w	r								N			
42.5						qtz ss	lt tn	m	w	r								N			
45.0						qtz ss	lt tn	m-cr	p	a								N			moisture first noted @ 44.0 ft. some wh chert grain
47.5						qtz ss	ltgytn	m	w	r								N			abund. wh chert grains
50.0						qtz ss	tn	m cr	m	a								N			
52.5						qtz ss	tn	m-cr	m	a								N			
55.0						qtz ss	wh-vlt tn	m	W	R								N			
57.5						qtz ss	wh-vlt tn	m-vcr	m	r								N			some wh chert grains
60.0						qtz ss	wh-lt tn	f-vcr	p	a								N			abund multi colored chert grains
62.5						qtz ss	wh-tn	m-cr	m	r								N			Well began producing < ½ gpm @ ≈ 62.5 ft.
65.0						qtz ss/cgl	wh-vltgy	m-peb	p	r								N			abund. chert peb. + frag.
67.5						qtz ss/cgl	pktn-bn	m-peb	p	a								N			" " " "
70.0						qtz ss/cgl	pkgy	m-peb	p	a								N			" " " "
72.5						cgl/qtz ss	wh-rdgy	m-peb	p	a								N			chert pebbles + frags. > 50%
75.0						cgl/qtz ss	tn-gy	m-peb	p	a		l						N			" " " > 50%
77.5						qtz ss/cgl	tn-gybn	m-peb	p	a								N			abund chert grains + fragments.
80.0						qtz ss/cgl	ltpktn	f-peb	p	a								N			Begin H_2O / foam injection @ 80.0 ft.
82.5						qtz ss/cgl	lt pktn	f-peb	p	a								N			
85.0						cgl/qtz ss	wh-lt tn	m-peb	p	a								N			
87.5						qtz ss	wh-vlt tn	m-vcr	p	a		l						N			
90.0						qtz ss/cgl	wh-pk tn	m-peb	p	a								N			
92.5						qtz ss/sh	wh-lt blgn	f-cr	p	a								N			
95.0						qtz ss/sh	ltgy-ltgn	m-vcr	p	a		l						N			
97.5						qtz ss/sh	ltgygn	m-cr	p	a		l						N			
100.0						qtz ss/sh	wh-lt ywgn	m-cr	p	a		l						VW			
102.5						qtz ss/sh	lt bn-ltgn	m-vcr	p	a		l						W			

12.5	qtz ss/sh	lt tn-lt gn	m-vcr	p	a	l	W	
05.0	qtz ss	vlt tn	m	w	r		N	
07.5	qtz ss	vlt tn	m	w	r		N	
10.0	qtz ss/sh	vlt tn-gy gn	m	m	a		N	Brushy Basin Cr @ 109.0 (sharp contact)
12.5	sh/sltst	lt gy-lt pp gy					N	
15.0	Sh	lt gn-lt pp gy					N	T.D. 116.0'
17.5	sh	lt gn-lt pp gy						
20.0								
22.5								
25.0								

PERCENTAGE COMPOSITION IMAGE

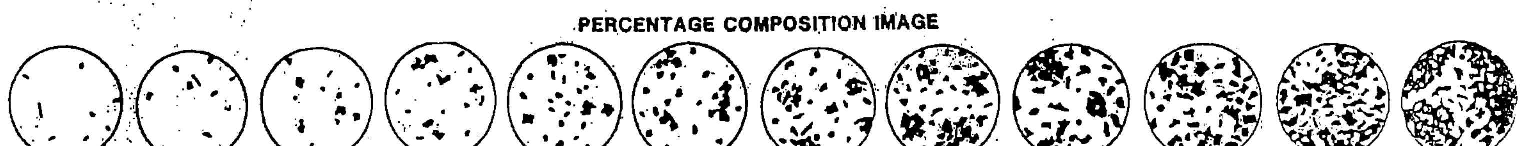
energy fuels

Date 10-17-16 Geologist L Casebolt Drilling Co. Bayles Exploration Hole No. TW4-38
Property White Mesa Mill Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State UT Location ______ Elev. ≈5647

PAGE 1 OF 1
T.D. PROBE 115.5
T.D. DRILL 117.5
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5						Sltst-sh	rdbn											W			Surface soil - lean clay w/ snd
5.0						Sltst-sh	rd bn											S			Surface soil - lean clay w/snd
7.5						Sh	rdbn											VS			
10.0						Sh	ltpk tn											VS			Mancos Shale @ 7.5'
12.5						Sh	ltpk tn											VS			
15.0						sh	lt yw bn											S			abund selenite (gyp.) x/s.
17.5						sh	yw bn											S			Some selenite x/s.
20.0						sh	ywbn											S			
22.5						sh	ywbn											VS			
25.0						sh	lt bn											VS			
27.5						sh	lt bn											S			
30.0						sh-qtz ss	lt bn	f-m	m	a		L						S			
32.5						Sh-qtz ss	lt bn	f	m	a		L						VW			
35.0						sh-qtz ss	lt bn	f-m	m	a		L						N			
37.5						sh-qtz ss	lt bn	m-cr	m	a		L						N			
40.0						qtz ss	vlt bn	m-peb	p	a								N			Upper Dakota Contact @ 38.0' some chert peb.
42.5						qtz ss	v lt bn	m-vcr	p	A								N			light colored chert frags.
45.0						qtz ss	tn	m	m	a								N			Moisture first noted @ 45.0'
47.5						qtz ss	tn	m	m	r		L						N			
50.0						qtz ss	tn	m-peb	p	A		L						N			
52.5						qtz ss/sh	lt or tn	m-cr	m	a								N			Some lt colored chert pebbles and frags.
55.0						qtz ss/sh	tn-gy	m-cr	m	a								N			dk gy sh frags.
57.5						qtz ss/sh	lt gy tn	f-cr	p	a								N			
60.0						qtz ss	lt gy tn	m-cr	m	r		L						N			Begin H_2O injection @ 60.0'
62.5						qtz ss	lt tn	m	w	R								N			
65.0						qtz ss/sltst	lt tn gy	slt-m	m	r		L						N			
67.5						qtz ss	lt ln gy	f-m	m	r		L						N			
70.0						qtz ss	vltgy	m	w	r								VW			
72.5																		X			Lost circulation - no sample
75.0																		X			Lost circulation - no sample
77.5						qtz ss/cgl	vltgy-bn	m-peb	p	r								N			abund. dk colored chert pebbles & frag.
80.0						qtz ss/cgl	wh-dk gy	f-peb	p	a								N			v abund. dk colored chert pebbles & frag.
82.5						sh/qtz ss	wh-vltgy	vf-f	m	a								N			
85.0						qtz ss/sh	tn-vltgy	vf-f	m	a								N			
87.5						cgl, qtz ss	ltgy-or tn	f-peb	p	a								N			v abund. multi colored chert pebbles & frags.
90.0						cgl	lt or bn	peb	w	A								N			multi colored pebbles & frags.
92.5						cgl/qtz ss	orrdgy	cr-peb	p	A								N			multi colored chert pebbles & frags.
95.0						cgl/qtz ss/sh	orrdgy	cr-peb	p	A								N			" " " " " w/sh frags.
97.5						sh/qtz ss	vltgygn	f-cr	p	a								N			
100.0						snd sh/qtz ss	vltgygn	vf-f	m	r								N			
102.5						sltst	vltgy-wh											N			
105.0						sltst	vltgy-wh											N			
107.5						sltst	vltgy-wh											N			
110.0						sltst	ltgn-wh											N			Brushy Basin Ct. @ 110.0'
112.5						sltst	ltgn											N			
115.0						sltst	ltgn											N			
117.5						sltst	ltgn						T	A	T			N			T.D. @ 117.5' trace of pyrite noted
120.0																					probed to 115.5'
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

energy fuels

Date 10-18-16 Geologist L. Caselott Drilling Co. Bayles Exploration Hole No. TW4-39
Property White Mesa Project ______ Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE 125.0
T.D. DRILL 125.0
FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5	Clay w/qtz ss	rdbn-bn											W			This sample consists of compacted millyard mtl.
5.0	Sh	rdbn											S			Surface soil - lean clay
7.5	sh	rdbn											W			Surface soil - lean clay
10.0	Sh	rdbn-ltywbn											W			Mancos Shale Ct @ 9.0'
12.5	sh	ltywbn											S			
15.0	sh	ltywbn											S			abund. selenite (gyp.) xls
17.5	sh	ywbn-gybn											m			abund. selenite xls.
20.0	sndy sh	ywbn	m-cr	m	a								m			
22.5	sndy sh	ywbn	f-m	m	a								w			
25.0	sndy sh	ywbn	f-m	m	a								N			
27.5	qtz ss	lt or tn	m-cr	m	a		L						N			Upper Dakota Fm contact @ 25.0'
30.0	qtz ss	tn	f-m	m	r		L						VW			
32.5	qtz ss	tn	f-m	m	a		L						VW			
35.0	qtz ss	tn	vf-m	p	a								W			
37.5	qtz ss	tn	vf-m	p	a								W			
40.0	qtz ss	tn	f-m	m	a								m			
42.5	qtz ss	tn	m	w	r								N			Moisture first noted @ 42.5'
45.0	qtz ss	tn	vf m	p	a								N			
47.5	qtz ss	tn	m	m	a								N			Begin H_2O injection @ 45.0'
50.0	qtz ss	tn	m-cr	p	a								N			
52.5	qtz ss	lt tn-wh	m-cr	m	A								N			
55.0	qtz ss	vlt tn-wh	m	w	a								N			
57.5	qtz ss	lt tn	m-peb	p	a								N			some wh-ltpk chert grains & frags.
60.0	qtz ss	lt tn	f-m	w	r								N			
62.5	qtz ss	lt tn	m	w	r								N			some dk gy chert grains
65.0	qtz ss	lt tn	m-vcr	p	a								N			
67.5	qtz/cgl	tn-ltgy	f-peb	p	A								N			abund. multicolored chert frags. & grains
70.0	cgl	lt orgy	peb	p	A								N			" " " " " & pebbles
72.5	cgl	orgy	peb	p	A								N			" " " " " "
75.0	cgl	orgy	peb	p	A								N			" " " " " "
77.5	cgl/qtz ss	orgy	cr-peb	p	A								N			" " " " " "
80.0	qtz ss/cgl	orgy	m-peb	p	A								N			" " " " " "
82.5	qtz ss/cgl	orgy	m-peb	p	a								N			" " " " " "
85.0	cgl	or bn	-peb	p	a								N			" " " " " "
87.5	cgl	orgy	peb	p	a								N			" " " " " "
90.0	cgl/qtz ss	ltgybn	f-peb	p	a								N			" " " " " "
92.5	cgl/qtz ss	lt blgy-bn	f-peb	p	a								N			" " " " " "
95.0	cgl/qtz ss	lt blgy-tn	f-peb	p	a								N			" " " " " "
97.5	qtz ss	wh	f-cr	p	a								N			
100.0	qtz ss/sh/cgl	lt blgy-wh	f-peb	p	a								N			
102.5	sh/qtz ss	ltgn-wh	f-peb	p	a								N			
105.0	qtz ss	wh	M	w	r								N			
107.5	qtz ss, cgl	wh	m-peb	m	a								N			
110.0	qtz ss, sh	wh-gn	m	m	a								N			some chert grains and frags.
112.5	qtz ss, sh	wh-gn	M	M	r								N			
115.0	qtz ss, sh	wh-gn	m-cr	m	a								N			
117.5	sh	gn-pprdbn											N			Brushy Basin Ct. @ 115.0'
120.0	sh	gygn-pprdbn						T	A	F			N			Trace of pyrite noted
122.5	sh	gygn-pprdbn											N			
125.0	Sh	gy-rdbn											N			TD @ 125.0'

PERCENTAGE COMPOSITION IMAGE

APPENDIX A.5

TWN - SERIES

Date 2-6-09 Geologist L. Casebolt Drilling Co. Bayles Exploration Hole No. TWN-1
Property WHITE MESA MILL Project NITRATE INVESTIGATION Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE 112.5
T.D. DRILL 112.5
FLUID LEVEL ______

Depth	Lithology	Color of wet sample	Grain size	Sorting	Angularity	Cement matrix	Iron oxide	React.-10% HCL	Remarks
2.5	Sndy Sltst	lt rdbn	vf	P	a	A		VS	well collared near old sample plant, old pad material
5.0	sndy sltst	lt rdbn	vf	P	a	A		VS	
7.5	sltysh	rdbn						S	
10.0	sltysh	rdbn						S	
12.5	Sh	lt rdbn						VS	
15.0	Sh	lt ywbn						S	Mancos shale contact @ 12.5 ft.
17.5	sh	lt ywbn						m	
20.0	sh	ywbn						N	
22.5	sh	ywbr						N	
25.0	sh	ywbr						N	
27.5	sh, qtz ss	ywbn	f-cr	P	r		L	VW	Upper Dakota Contact @ 27.0 ft.
30.0	qtz ss	ywtn	m-cr	P	r		L	N	
32.5	qtz ss	tn	vf-f	f	r		L	N	1% wh chert grains
35.0	qtz ss	tn	vf-f	f	r		L	N	" " " "
37.5	qtz ss	tn	f-m	P	a		L	N	" " " "
40.0	qtz ss	tn	f-m	P	a		L	N	" " " "
42.5	qtzss, sh	tn-blgy	f-m	f	r	A	L	N	
45.0	qtz ss, sh	tn-blgy	f-m	f	r		L	N	
47.5	qtz ss	tn	m	f	a		L	N	
50.0	qtz ss	vlt tn	f	m	r	a	L	N	
52.5	qtz ss	tn	f-m	m	a			N	
55.0	qtz ss	tn	f-m	m	a			N	
57.5	qtz ss	tn	f-m	m	a	A	L	N	
60.0	qtz ss	tn	f-m	m	a			N	
62.5	qtz ss	tn	m	m	r			N	multicolored chert grains and frags 2%
65.0	qtz ss	tn	m-cr	m	a		L	N	" " " " " " "
67.5	qtz ss	tn	m-cr	P	a			N	chert content increasing to 5%
70.0	qtz ss/chert	tn	vcr-grit	P	A			N	" " 40%
72.5	qtz ss	tn	m-vcr	P	a			N	" " 25%
75.0	qtz ss	tn	m-vcr	P	a			N	" " 30%
77.5	Sh, qtz ss	vlt blgy	f-cr	P	a			N	some chert frags & grains
80.0	sh, cgl	lt blgy-dk tn	m-peb	P	a			N	Chert pebbles & frags
82.5	Cgl, qtz ss	tn	vcr-peb	P	a			N	multicolored chert pebbles
85.0	Cgl, qtz ss	tn	vcr-peb	P	a			N	multicolored chert grains and frag.
87.5	qtz ss, cgl	tn	m-peb	P	a			N	multicolored chert grains & pebbles
90.0	qtz ss	tn	m-vcr	P	a			N	chert fragments and grains 10%
92.5	qtz ss/sh	tn-lt gn	vf-cr	P	a			N	shale frags 30%
95.0	qtz ss	vltgy	vf-f	f	r	A		N	
97.5	qtz ss, sh	vltgy	vf-m	m	r	A		N	
100.0	qtz ss sh	vlt tn-lt bl	vf-m	m	r	A		N	
102.5	qtz ss, sh	tn-lt bl	f-cr	m	r	A		M	Brushy Basin contact @ 102.0
105.0	sh	lt blgy						N	
107.5	sh	lt blgy-ppbn						N	
110.0	sh	lt blgy-ppbn						N	
112.5	sh	lt blgy-ppbn						N	T.D.

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 2-4-09 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-2
Property White Mesa Mill Project Nitrate Investigation Unit No. ______ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ______________________ Elev. ______

PAGE 1 OF 1
T.D. PROBE 95.0
T.D. DRILL 95.0
FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0 – 2.5						sndy sh	gybn-blk	vf-cr	f	a								S	>1	C	surface material derived from mill yard-con-
5.0						sndy sh	gybn-dkgy	vf-cr	f	a								M			tains fragments of coal and clinker fragments
7.5						sndy sh	ltorbn —	vf-f	f	a								M			left from coal burning steam plant. (abrupt
10.0						slty sh-sh	ltorbn-dk gy											M			color change) Mancos shale contact @ 9.5'
12.5						slty sh-sh	ltbn-vdkgy											S			color 50%/50%
15.0						sh	dkgy											W			
17.5						qtz ss-sh	lttn-gy	f-m	f	r	A							VW			Upper Dakota contact @ 16.0 ft' some chert grns.
20.0						qtz ss	tn-yw	f-m	f	r	A							VW			
22.5						qtz ss	wh-ltywtn	vf-f	f	r	A							N			
25.0						qtz ss	wh-vlttn	vf-f	f	r	A							N			some multi colored chert frags & grains.
27.5						qtz ss	lttn	f-m	f	R	A							N			some white chert frag. and grains
30.0						qtz ss	lttn	m-cr	m	R	A							N			abun. white chert frags & grains.
32.5						qtz ss	tn	m-cr	m	R	A							N			
35.0						qtz ss	tn	m-cr	m	r								N			
37.5						qtz ss	tn	m-cr	m	r								N			
40.0						qtz ss	tn	f-m	m	r								N			
42.5						qtz ss	lttn	f-m	m	r								N			
45.0						qtz ss	lttn	m-cr	m	r								N			sparse chert pebbles & frag.
47.5						qtz ss	wh-lttn	f-cr	p	r	A							N			" " " " "
50.0						qtz ss	wh-lttn	vf-cr	p	r	A							N			
52.5						qtz ss	wh-lttn	vf-f	m	r	A							N			
55.0						qtz ss	ywtn	f-m	m	r	A	L						N			some chert grains and frags.
57.5						qtz ss	ywtn	vf-peb	p	r	A	L						N			abund chert pebbles & frags.
60.0						qtz ss	ywtn	vf-peb	p	r	A	L						N			" " " "
62.5						qtz ss	ltgygn	vf-cr	p	r	A							N			abrupt color change red/ox contact.
65.0						qtz ss	ltgygn	vf-cr	p	r	A							N			
67.5						qtz ss	ltgygn	vf-m	p	r	A							N			
70.0						qtz ss	lttn	vf-f	f	r	A							N			
72.5						qtz ss	lttn	vf-f	f	r	A							N			
75.0						qtz ss	ltgygn	vf	f	r	A							N			
77.5						qtz ss	ltgygn	vf	f	r	A							N			
80.0						qtz ss	ltgygn	vf	f	r	A							N			
82.5						qtz ss	ltgygn	vf	f	r	A							N			
85.0						qtz ss	wh	f-m	f	r	A		<1	c				N			
87.5						qtz ss	wh	f-m	f	r	A		<1	c				N			
90.0						qtz ss	wh	f-m	f	r	A		<1	c				N			
92.5						qtz ss, sh	wh, gn-ppbn	f-m	f	r	A							N			Brushy Basin Contact @ 92.0 ft.
95.0						sh	ppbn											N			TD

PERCENTAGE COMPOSITION IMAGE

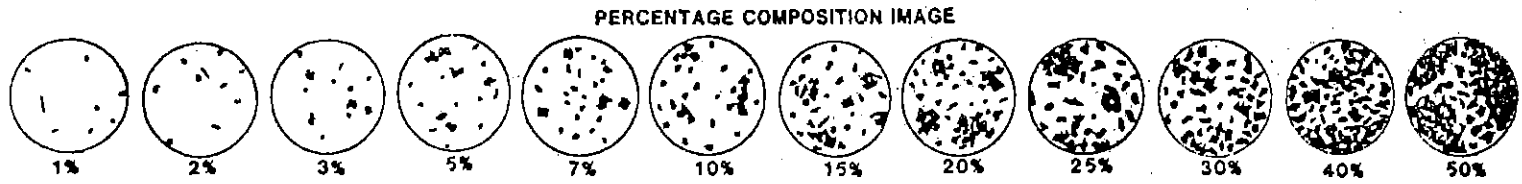
1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 2-3-09/2-4 Geologist L. Casebolt Drilling Co. Bayles Exploration Hole No. TWN-3
Property White Mesa Mill Project Nitrate Investigation Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE 110.0
T.D. DRILL 110.0
FLUID LEVEL ______

DEPTH	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	REACT.-10% HCL.	REMARKS
2.5	sndy sh	ywtn-ltrdbn	vf-f	p	a				VS	Surface soils
5.0	sndy sh	ywtn-ltrdbn	vf-f	p	a				VS	Mancos shale @ 4.0 ft
7.5	sndy sh	ywtn	vf-f	p	a				VS	
10.0	sndy sh-ss	ywtn	f-m	f	a		H		N	Color change @ 8.5' Upper Dakota Ct. sp. hem.
12.5	qtz ss	ywtn	f-m	p	a		L		M	
15.0	qtz ss	ywtn	f-m	p	a		L		W	
17.5	qtz ss	ywtn	f-m	f	s		L		N	
20.0	qtz ss	tn	f-m	f	s		L	S	N	sparse pyrite agg. within hematite cemented
22.5	qtz ss	tn	f-m	f	p		L		N	sandstone frags.
25.0	qtz ss	tn	f-m	f	s		L		N	
27.5	qtz ss	lt tn	f-m	f	s		L		N	
30.0	qtz ss	lt tn	f-m	f	s		L		N	
32.5	qtz ss	lt tn	f-m	f	s		L		N	
35.0	qtz ss	vlt tn	vf-f	f	s		L		N	Trace limonite
37.5	qtz ss	vlt tn	f-m	f	a		L		N	" "
40.0	qtz ss	vlt tn	vf-m	p	a		L		N	
42.5	qtz ss	vlt tn	f-m	f	r				N	
45.0	qtz ss	vlt tn	f-m	p	r				N	sparse chert frags as sand grains 1-2%
47.5	qtz ss	lt tn	f-cr	p	a				N	
50.0	qtz ss-sltst	ltgy tn	vf-f	p	a				N	
52.5	sndy sh	vltgy-vltgn	vf	f	a	a			N	
55.0	sndy sltst	vltgygn	vf	f	a	a			N	
57.5	sndy sltst	vltgygn	vf	f	a	a			N	
60.0	slty qtz ss	vltgygn	vf	f	a	a			N	
62.5	slty qtz ss	vltgygn	vf-f	f	a	a			N	
65.0	qtz ss-sh	ltgygn	f-m	f	a	a			N	
67.5	qtz ss	ltgygn	f-m	f	a	a			N	
70.0	qtz ss	ltgygn	vf-f	f	a	a			N	trace of chert frags.
72.5	qtz ss	ltgygn	vf-f	f	a	a			N	
75.0	qtz ss	ltgygn	vf-m	p	a	a			N	
77.5	qtz ss	ltgygn	vf-f	f	a	a			N	
80.0	qtz ss	vltgy	vf-f	f	a	a			N	
82.5	qtz ss	vltgy	f-m	f	a	a		S	N	Trace dissem. pyrite
85.0	qtz ss-sh	lttn-ltgn	f-m	f	R				N	noted increase in grain size, some chert frags
87.5	qtz ss	wh-ltgn	vf-f	f	r				N	
90.0	qtz ss-sh	wh-ltgn	f-m	f	r				N	
92.5	qtz ss-sh	wh-ltgygn-ppbn	f-m	f	r				N	Brushy Basin Contact @ 92.0 ft.
95.0	sh-qtz ss	ppbn, ltgn-wh	f-m	p	r				N	
97.5	sh	rdbn-ltgn							N	
100.0	sh-qtz ss	ltgn-vltgy	vf-m	p	r	a			N	
102.5	sndy sltst	ltgy-ltgn	vf-f	f	r	a			N	
105.0	sndy sltst	ltgy-ltgn	vf-f	f	r	a			N	
107.5	sndy sltst	ltgy-gn-rdbn	vf-f	f	r	a			N	
110.0	sndy sltst	gy-gybl	vf-f	f	r	a			N	T.D.

PERCENTAGE COMPOSITION IMAGE

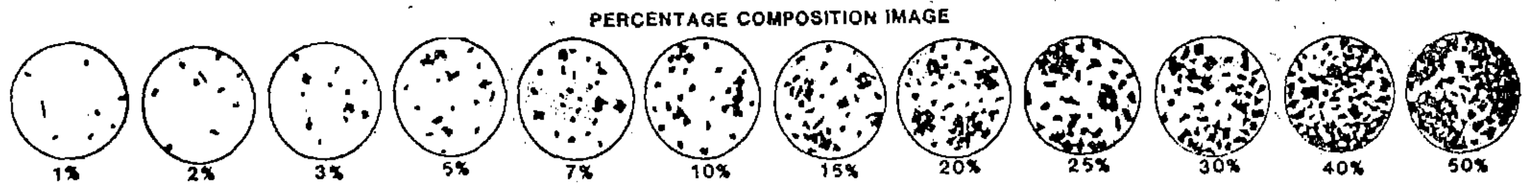


Date 2-3-09 Geologist L. Casebolt Drilling Co. Boyles Exploration, Inc. Hole No. TWN-4
Property WHITE MESA MILL Project NITRATE Investigation Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 2
T.D. PROBE 136.0
T.D. DRILL 136.0
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						Sltst-Sh	lt rdbr-lt tn					H						S			
5.0						Sltst-Sh	lt rdbr-lt tn					H						VS			
7.5						Sltst-Sh	lt rdbr-lt tn					H						VS			
10.0						Sltst-Sh	lt tn-lt rdbr					H						VS			Bottom of surface casing @ 9'4"
12.5						Sndy Sltsn	lt pktn-lt ywgr					H						VS			Mancos Shale Ct @ 12.5'
15.0						Sndy Sh	lt ywgr					L						S			
17.5						Sndy Sh	lt ywgr					L						W			
20.0						Sndy SA	lt ywgr					L						M			
22.5						qtz Ss	ywgy	f-m	m	sr		L						N			Upper Dakota Fm. contact @ 20.0 ft.
25.0						qtz Ss	gytn	m	m	sr		L						N			
27.5						qtz ss	gytn	m	w	sr		L						N			
30.0						qtz ss-sh	dktn-tn	f-m	m	sa		L						N			
32.5						qtz ss	tn	f-m	m	sr		L						N			
35.0						qtz ss	tn	f-m	m	sr								N			
37.5						qtz ss	tn	f-m	m	sr								N			
40.0						qtz ss	tn	f-m	m	sr								N			
42.5						qtz ss	tn	m	m	sr								N			
45.0						qtz ss	tn	m	m	sr								N			
47.5						qtz ss	tn	m	m	sr								N			
50.0						Sh-qtz ss	gy-gytn	m	m	sa		H						N			
52.5						Sh-qtz ss	gy-gytn	m	P	sa		H						N			
55.0						qtz ss-sh	lt tn-gy	m	m	sa								N	T	I	
57.5						qtz ss-cgl	lt gytn	m	m	sa								N			abun wh chert frags.
60.0						qtz ss-cgl	lt tn	m-cr	m	sr								N			abun multi colored chert grains and frag.
62.5						qtz ss-cgl	lt gytn	m-vcr	P	sa								N			abun multi colored chert grains and frags.
65.0						qtz ss-peb	lt gy	m-Peb	P	sa		L						N			abun multi colored chert pebbles and frags
67.5						qtz ss-Peb	lt gy	m-Peb	P	sa		L						N			abund multi colored chert pebbles and frag.
70.0						qtz ss	lt gy	m-vcr	P	sa								N			abund chert frag.
72.5						qtz ss-sh	lt gy	vcr-Peb	P	sa								N	T	I	abund chert frag.
75.0						qtz ss-Cgl	lt gy or	vcr-Peb	P	sa								N			abund multi colored chert frags.
77.5						qtz ss-Cgl	lt gy or	vcr-Peb	P	r								N			qtz grains well rounded, chert frag angular
80.0						qtz ss-Cgl	lt gy or	vcr-Peb	P	r								N			" " " " " " "
82.5						qtz ss-cgl	lt gy or	vcr-Peb	P	r								N			" " " " " " "
85.0						qtz ss-Grit	lt tn	m-vcr	P	r								N			" " " " " " "
87.5						qtz ss-grit	lt tn	m-vcr	P	r								N			" " " " " " "
90.0						qtz ss-sh	lt gytn	m-vcr	P	sr								N			" " " " " " "
92.5						qtz ss	vlt tn	vf-cr	P	sa								N			abund multi colored chert grains
95.0						qtz ss	vlt tn	m-cr	P	sr								N			" " " " "
97.5						qtz ss	vlt tn	f-m	P	sr								N			sparse chert frags
100.0						qtz ss	lt tn	f-m	m	sa								N			sparse chert grains and frags
102.5						qtz ss	lt tn-lt gn	vf-m	P	sa								N			some chert pebbles and frags.
105.0						qtz ss	lt gytn	vf-f	P	sa								N			some chert pebbles and frags.
107.5						qtz ss	lt gytn	vf-m	P	sa								N			some chert pebbles and frags.
110.0						qtz ss	lt tn	f-m	m	sa								N			sparse chert pebbles and frags
112.5						qtz ss	lt tn	f-m	m	sa								W			
115.0						qtz ss	lt or tn	f-m	m	sa								N			sparse multi colored chert frags.
117.5						qtz ss	lt tn	f-m	m	sr								N			
120.0						sndy sltst	dk gy	vf-f	P	sa								N			
122.5						slty qtz ss	ywgy	vf-m	P	sa								W			
125.0						sltst-sh	gygn-rdbr											VW			Upper Brushy Basin Contact @ 122.5

PERCENTAGE COMPOSITION IMAGE



Date 2-3-09 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-4

Property White Mesa Mill Project Nitrate Investigation Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ______

PAGE 2 OF 2
T.D. PROBE 136.0
T.D. DRILL 136.0
FLUID LEVEL 43.84

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL.	CARBON AMOUNT	CARBON TYPE	REMARKS
125.0–127.5						sndy sltst	gygn	vf-f	P	sa								N			
127.5–130.0						sndy sltst	vltgygn	vf-f	P	sa								N			
130.0–132.5						sltst-sh	gygn											N			
132.5–135.0						sndy sltst	gygn-wh	vf-f	P	sa								N			
135.0–136.0																					No cuttings were recovered from 135.0-136.0

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 8-19-09 Geologist L. CASEBOLT Drilling Co. Bayles Exploration Inc. Hole No. TWN-5

Property White Mesa Mill Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ____

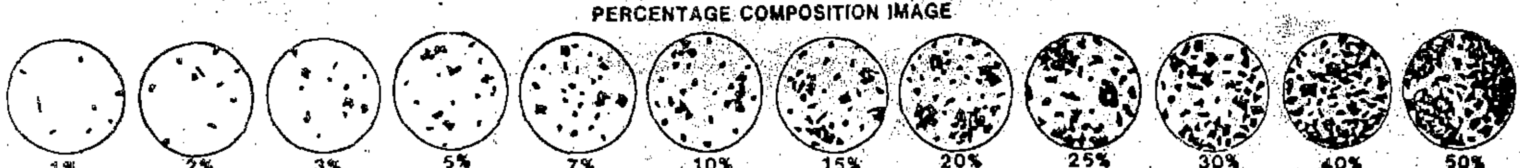
T.D. PROBE ____

T.D. DRILL 155.0

FLUID LEVEL ____

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Iron Oxide	Pyrite Amount	Pyrite Habit	React. 10% HCl	Remarks
0–2.5	sltst, mdst	rdbn							S	Surface soil
2.5–5.0	sltst-sh	rdbn-tn							VS	Surface soil
5.0–7.5	sltst, mdst	rdbn-tn							VS	Surface soil
7.5–10.0	qtz ss	rdbn	vf-f	m	a	H			VS	
10.0–12.5	sndy sh	pk ywbn	vf-m	p	a				VS	Mancos Shale ct @ 10.0'
12.5–15.0	sndy sh	ywbn	vf-m	p	a				W	
15.0–17.5	sndy sh	ywbn	f-m	p	a				N	
17.5–20.0	Sh	dkgybn							N	
20.0–22.5	Sh	dkgybn							N	
22.5–25.0	qtz ss, sh	gybn	f-m	p	a	L			N	
25.0–27.5	sh	gybn							N	
27.5–30.0	qtz ss	tn	f-m	m	a	L			N	Dakota Fm ct @ 27.5
30.0–32.5	qtz ss	vltgytn	f-m	m	a				N	
32.5–35.0	qtz ss	wh	f-m	m	a				N	
35.0–37.5	qtz ss	wh	f-m	m	a				N	
37.5–40.0	qtz ss	wh	f-m	m	a				N	
40.0–42.5	qtz ss	wh	f-cr	m	a				N	some chert frags & grains
42.5–45.0	qtz ss	wh	f-m	m	a				N	
45.0–47.5	qtz ss	wh	m	w	r				N	
47.5–50.0	qtz ss	wh	m-cr	m	a				N	
50.0–52.5	qtz ss	wh	m	w	a				N	
52.5–55.0	qtz ss	lt tn	m-cr	m	a				N	abund chert grains
55.0–57.5	chert ss cgl	orgy	vf-peb	p	a				N	very abund chert grains
57.5–60.0	chert ss, cgl	orgy	vcr-peb						N	chert grains & frag. & pebbles dominate.
60.0–62.5	sh	tn							N	
62.5–65.0	qtz ss	lt tn	m-peb	p	a				N	
65.0–67.5	qtz ss	lt tn	m-vcr	p	a				N	
67.5–70.0	qtz ss-cgl	orgy	m-peb	p	a				N	
70.0–72.5	qtz ss cgl	gytn	m-peb	p	a				N	dominant chert & qtzite pebble & fragments
72.5–75.0	sltst, sh	gy tn							N	
75.0–77.5	sndy sh	gy	f-m	p	a				N	
77.5–80.0	qtz ss, sh	gy	f-m	p	a				N	
80.0–82.5	qtz ss	wh	m	w	r				N	
82.5–85.0	qtz ss, sh	wh-ywgy	f-m	m	a				W	
85.0–87.5	sh	ppbn-gy							N	
87.5–90.0	sh-qtz ss	gyrdbn-wh	f-m	m	a				S	
90.0–92.5	qtz ss-sh	wh-gyrdbn	f-m	m	a				S	
92.5–95.0	sh	rdbn-gy							W	
95.0–97.5	qtz ss	vlttn	f-m	m	a				m	Moisture first noted
97.5–100.0	qtz ss	vlttn	f-m	m	a				S	H_2O injection
100.0–102.5	qtz ss-sh	wh-ppbngy				L	TR	C	N	shale frag may be transient
102.5–105.0	qtz ss	wh	m-cr	m	a		TR	C	N	light colored chert frags & grains
105.0–107.5	qtz ss	wh	f-cr	p	a				N	
107.5–110.0	qtz ss	wh	m-cr	m	a		TR	C	N	
110.0–112.5	qtz ss	wh	m-vcr	m	a		TR	C	N	some multicolored chert grains
112.5–115.0	sh	ltgy					TR	C	N	some vcr chert grains
115.0–117.5	qtz ss sh	vltgy	f-cr	p	a				N	some cr chert grains
117.5–120.0	sndy sh	ltgy-ltgn	f-cr	p	a				N	" " " "
120.0–122.5	sndy slt-sh	gy-rdbn	f-cr	p	a				N	
122.5–125.0	sndy sh	gy-rdbn	f-cr	p	a				N	

PERCENTAGE COMPOSITION IMAGE

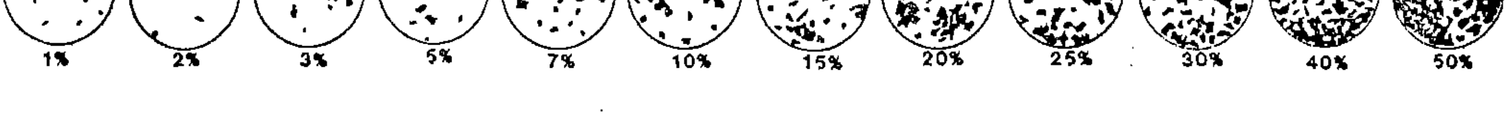


Date 8-19-09 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-5
Property White Mesa Mill Project Nitrate Study Unit No. ___ Sec. ___ Twp. ___ Rge. ___
County San Juan State Utah Location ___ Elev. ___

PAGE 2 OF 2
T.D. PROBE ___
T.D. DRILL 155.0
FLUID LEVEL ___

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
125.0																					
127.5						qtz ss, sh	wh-ppbn	vf-m	m	a								N			
130.0						qtz ss	wh	vf-m	m	a								N			
132.5						qtz ss	wh-ltgn	vf-m	m	a								N			
135.0						qtz ss	wh-ltgy	vf-m	m	a								N			
137.5						qtz ss	vltgy	vf-f	m	a								N			
140.0						qtz ss	vltgy	vf-f	m	a								N			
142.5						qtz ss	vltgy	vf-f	m	a								N			
145.0						qtz ss	vltgy	vf-f	m	a			R	C				N			
147.5						qtz ss, sh	vltgy-ltgn	vf-f	m	a								N			Upper Brushy Basin Fm contact @ 147.0
150.0						qtz ss, sltst	ltgy-dkgygn	vf-f	m	a								N			
152.5						sh	gy-ppbn											N			
155.0						sh	gy-ppbn											N			
TD.																					

PERCENTAGE COMPOSITION IMAGE

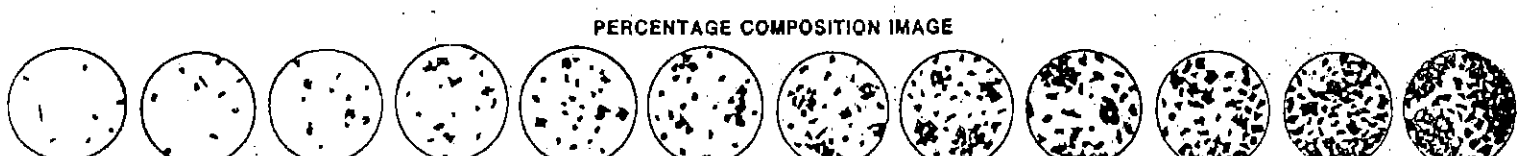


Date 8-18-09 Geologist L. Casebolt Drilling Co. Baylas Exploration, Inc Hole No. TWN-6
Property White Mesa Mill Project ~~[struck]~~ NITRATE STUDY Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 2
T.D. PROBE ____
T.D. DRILL 135.0
FLUID LEVEL ____

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
2.5						sltst, mdst	rd br											S			Surface Soil.
5.0						Sh	ywbn											VS			Upper ct w/ Mancos Sh. Fm. Some selenite xls
7.5						Sh	ywbn											S			Selenite
10.0						sh	ywbn-gy											S			"
12.5						sh	ywbn-gy											S			"
15.0						sh	ywbn-gy											S			"
17.5						Sh	ywbn-gy											S			"
20.0						sh	ywbn-gy											S			"
22.5						sndy sh	orbn	f-m	m	a								N			
25.0						sh	dk ywbn											N			
27.5						sh	dk ywbn											N			
30.0						qtz ss	dk tn	f-m	m	a		L						N			Upper Dakota ct @ 27.5'
32.5						qtz ss	tn	f-m	m	a		L						N			
35.0						qtz ss	tn bn	vf-f	p	a		L						N			
37.5						qtz ss	tn bn	f-m	m	a		L						N			
40.0						qtz ss	tn	m	m	a								N			
42.5						qtz ss	tn	m	m	a								N			
45.0						qtz ss	tn	m	m	a								N			
47.5						qtz ss	tn	m	m	a								N			
50.0						qtz ss	tn	m	m	a								N			
52.5						qtz ss	tn	f-m	m	a		L						N			
55.0						qtz ss	tn	m	m	a		L						N			
57.5						qtz ss	tn bn	m	m	a								N			
60.0						qtz ss	tn	m-cr	m	r								N			
62.5						qtz ss	tn	m-vcr	m	r								N			
65.0						qtz ss, cgl	tn bn	m-peb	p	a								N			abund. multi colored chert frags + pebbles
67.5						qtz ss	tn bn	m-vcr	m	a								N			
70.0						qtz ss	tn bn	m-vcr	m	r								N			moisture first noted @ 67.5
72.5						qtz ss	tn bn											N			H_2O injection begins @ 70.0'
75.0						qtz ss, cgl	ywtn-gy	m-peb	p	a								N			some chert pebbles + frags.
77.5						qtz ss	ywgy tn	m-vcr	p	a								N			" " frags + grains.
80.0						sh	gygn-pebn											N			
82.5						sh	ppbn											N			
85.0						sh	ppbn											N			
87.5						sh	gn ppbn											N			
90.0						sh-qtz ss	gn-wh											N			
92.5						qtz ss	wh											N			
95.0						qtz ss	wh											N			
97.5						qtz ss	wh											N			
100.0						qtz ss	wh											N			
102.5						qtz ss	wh	f-m	m	a								N			
105.0						qtz ss	ltgy	m-vcr	m	a								N			
107.5						qtz ss	ltgy	m-vcr	m	a								N			
110.0						qtz ss	ltgy	m-vcr	m	r								N			
112.5						qtz ss	wh	m	m	r								N			
115.0						qtz ss, cgl	wh-gy	m-peb	p	a								N			Some chert frag + pebbles
117.5						qtz ss, cgl	wh-gygn	m-peb	p	a								N			abund chert frags + pebbles.
120.0						qtz ss	wh	m-cr	w	R								N			
122.5						qtz ss	wh	m	w	R								N			
125.0						qtz ss	wh	m	w	R								N			

PERCENTAGE COMPOSITION IMAGE



1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 8-18-09 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-6

Property White Mesa Mill Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ____

T.D. PROBE ____

T.D. DRILL 135.0

FLUID LEVEL ____

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
125.0																					
127.5						qtz ss, sh	vlt tn, gn	f-m	m	r			TR	C				N			Upper Brushy Basin Fm contact @ 127.0
130.0						qtz ss, sh	gn-rdbn	f-m	m	r								N			
132.5						sh	rdbn-gy											N			
135.0						sh	rdbn-gy											N			
T.D.																					

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 8-20-09 Geologist G. CASEBOLT Drilling Co. Bayles Exploration Inc Hole No. TWN-7
Property White Mesa Mill Project NITRATE STUDY Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF ____
T.D. PROBE ____
T.D. DRILL 120.0
FLUID LEVEL ____

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																					
2.5						sltst, mdst	rd bn											S			Surface Soil.
5.0						sltst, mdst	rdbn											S			Surface Soil
7.5						siltst, mdst	rdbn											VS			
10.0						siltst, mdst	rdbn											VS			
12.5						sh	ywbn											VS			Mancos sh contact at 10.0 ft.
15.0						sh	dkgybn											VS			
17.5						sh	dkgybn											S			
20.0						sh	dk-ltgybn											W			
22.5						sh, qtz ss	orbn	f-m	p	a								N			Dakota Fm. ct @ 22.0'
25.0						qtz ss	ltgy	f-m	p	a								N			
27.5						qtz ss	vltgy	f-m	p	a	L							N			
30.0						qtz ss	lt tn	f-m	p	a	L							N			
32.5						qtz ss	wh	m	m	r								N			
35.0						qtz ss	wh	m-cr	m	r								N			Some chert grains as the coarser fraction.
37.5						qtz ss	wh	m	w	r								N			
40.0						qtz ss	wh	m-cr	m	a	L							N			
42.5						qtz ss	wh	m	w	r								N			
45.0						qtz ss	wh	m	w	r								N			
47.5						qtz ss	wh	m	m	a								N			
50.0						qtz ss	wh	m	m	a								N			
52.5						qtz ss	lttn	m-vcr	p	a								N			
55.0						qtz ss	ltgytn	m-vcr	p	a								N			
57.5						sh	tn-ltgy											N			
60.0						sh-qtz ss cgl	lttn-dkbn	peb	p	a								N			dk bn chert pebble frags.
62.5						qtz ss, cgl	ortn	m-peb	p	a	L							N			abund chert frag, grains and pebbles
65.0						qtz ss, cgl	ywtn	m-peb	p	a	L							N			" " " " " "
67.5						qtz ss, cgl	ywtn	m-peb	p	a	L							N			" " " " " "
70.0						qtz ss cgl	dktn	m-peb	p	a	L							N			" " " " " "
72.5						qtz ss cgl, sh	ltgntn	f-peb	p	a								N			" " " " " "
75.0						sh. qtz ss	ltgn	f-m	m	a								N			
77.5						qtz ss	lt tn	f-m	m	a	L							M			
80.0						sh	ltgygn											N			
82.5						sh	ltgygn-rdbn											N			
85.0						sh	gygn-rdbn											N			
87.5						sh	rdbn-gygn											N			
90.0						sh	rdppbn											N			
92.5						sh	rdppbn											N			
95.0						sh	gygn-ppbn											N			
97.5						sh, qtz ss	ltgn-ppbn-wh	vf-m	p	a	L							N			
100.0						qtz ss	wh	f-m	p	a								M			
102.5						qtz ss, sh	wh-gn-ppbn	f-m	p	a	L							N			
105.0						sh	ppbn-gn											N			Brushy Basin ct @ 102.5
107.5						sh	gnppbn											N			
110.0						sndy sh	ltgygn	f-m	p	a								N			
112.5						sndy sh	ltgygn	f-cr	p	a								N			
115.0						qtz ss	ltgy-ltgn	f-m	p	a								N			
117.5						qtz ss, sh	lttn	f-m	p	a								N			
120.0						sndy sh	gytn	f-m	p	a								N			T.D.
TD																					

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 8-19-09 Geologist L. CASEBOLT Drilling Co. Bayles Exploration, Inc. Hole No. TWN-8

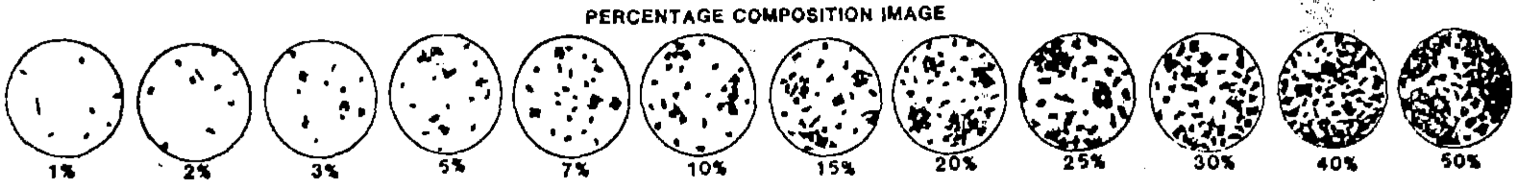
Property White Mesa Mill Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 2
T.D. PROBE 150.0
T.D. DRILL 150.0
FLUID LEVEL ____

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5	sltst mdst	rdbn											VS			Surface Soil.
5.0	qtz ss	prtn	vf-f	m	a								S			Surface Soil.
7.5	qtz ss	lttn	vf-f	m	a		L						W			Dakota Fm @ 5.0'
10.0	qtz ss	lttn	vf-f	m	a								N			
12.5	qtz ss	tn	f-m	m	a								N			
15.0	qtz ss	tn	f-m	m	a		L						N			
17.5	qtz ss	tn	f-m	m	a								N			
20.0	qtz ss, sh	tn-gy	m-cr	p	a								N			
22.5	qtz ss	tn	m	w	r								N			
25.0	qtz ss	tn	f	w	r								N			
27.5	qtz ss, sh	tn-dkgy	m	w	r								N			
30.0	qtz ss, sh	tn-dkgy	f-m	w	a								N			
32.5	qtz ss	tn gy	m-vcr	p	a								N			light colored chert frags.
35.0	qtz ss-sh	tn-dkgy	m-cr	p	a								N			
37.5	qtz ss, cgl	tngy	m-peb	p	a								N			abund. multicolored chert frags, grains and pebbles.
40.0	qtz ss, cgl	tngy	m-peb	p	a								N			" " " " " " "
42.5	qtz ss cgl	tngy	m-peb	p	a								N			" " " " " " "
45.0	qtz ss	tn	m	w	R								N			
47.5	qtz ss	tn	m	w	R								N			
50.0	qtz ss, cgl	tn	m-peb	p	a								N			
52.5	qtz ss	tn	f-m	m	a		L						N			
55.0	qtz ss	ltgy	f-m	m	a								N			
57.5	qtz ss	wh	f-m	m	a								N			
60.0	qtz ss	ltgy	f	w	r								N			
62.5	qtz ss	ltgy	f	w	r								N			
65.0	qtz ss	ltgy	f	w	r								N			
67.5	qtz ss	ltgy	f	w	r								N			
70.0	qtz ss, sh	ltgn-wh	f	w	r								W			
72.5	qtz ss	wh	f	w	r								W			
75.0	qtz ss	wh	f-m	p	a			Tr	C				W			
77.5	qtz ss	wh	m-cr	m	a								N			Moisture first noted
80.0	qtz ss	wh	m-cr	m	a								N			H_2O inject begin.
82.5	qtz ss	wh	m-peb	p	a			<1%	c				N			some chert frags & grains
85.0	qtz ss	wh	m-vcr	p	a			Tr	c				N			
87.5	qtz ss	wh	f-vcr	p	a		L	1%	C				N			
90.0	qtz ss, cgl	wh-dkgy	m-peb	p	a			1%	c				N			abund. dark chert pebs & grains
92.5	qtz ss, cgl	dkgy	f-peb	p	a								N			some " " " "
95.0	qtz ss, cgl	dk bn	m-peb	p	a								N			abund " " " "
97.5	qtz ss, cgl	ltgy	f-peb	p	a								N			some " " " "
100.0	qtz ss, sh	wh-gy	f-vcr	p	a			1%	C				N			
102.5	sh	gn											N			
105.0	sltst-sh	gn-ltpk											N			
107.5	qtz ss	wh	f-m	p	a								N			
110.0	qtz ss	wh	f-m	p	a			Tr	C				N			
112.5	qtz ss.	wh	f-cr	p	a			1%	C				N			
115.0	qtz ss, cgl	wh	f-peb	p	a			Tr	C				N			chert frags.
117.5	qtz ss	wh	f-peb	p	a								N			
120.0	qtz ss, cgl	wh	m-peb	p	a			3%	C				N			noteable pyrite occurrance, chert frags.
122.5	qtz ss	wh	f-m	m	r			Tr	C				N			
125.0	qtz ss	wh	f-m	m	r								N			

PERCENTAGE COMPOSITION IMAGE

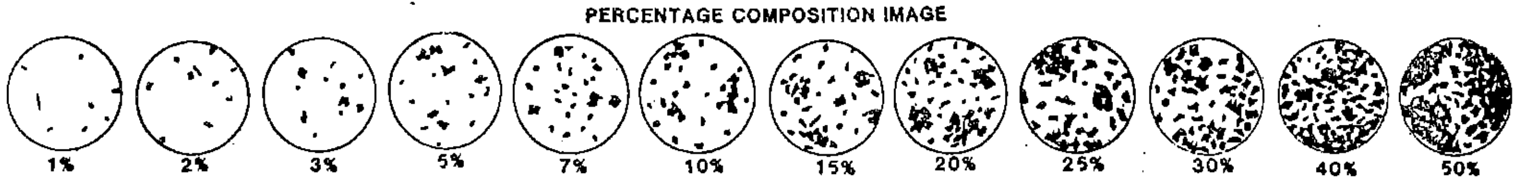


Date 8-19-09 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-8
Property White Mesa Mill Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 2 OF 2
T.D. PROBE 150.0
T.D. DRILL 150.0
FLUID LEVEL ____

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
125.0–127.5						qtz ss	wh	f-m	m	a							N				
127.5–130.0						qtz ss	wh	f	m	a							N				
130.0–132.5						qtz ss	wh	vf-f	m	a							N				
132.5–135.0						qtz ss	wh	vf-f	m	a							N				
135.0–137.5						qtz ss	vltgy	vf	m	a							N				
137.5–140.0						qtz ss	vltgy	vf f	m	a							N				
140.0–142.5						qtz ss, sh	vltgy	vf f	m	a							N				
142.5–145.0						sh	gy-rdbn										N				Upper Brushy Basin Fm contact @ 142.5'
145.0–147.5						sh	rdbn-ppbn										N				
147.5–150.0						sh	gy										N				
T.D.																					

PERCENTAGE COMPOSITION IMAGE

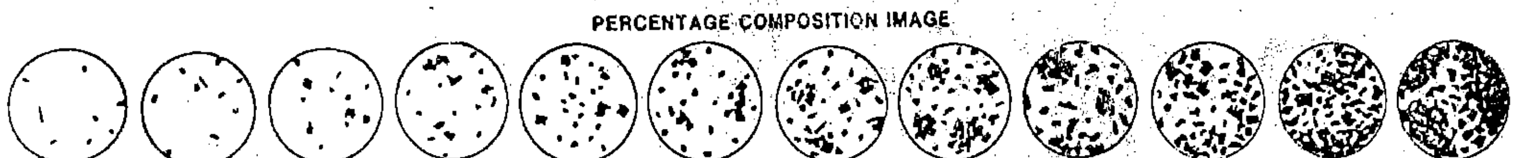


Date 8-17-09 Geologist L. Casebolt Drilling Co. Boyles Exploration Hole No. TWN-9
Property White Mesa Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 162.5
FLUID LEVEL ____

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite: Amount	Pyrite: Habit	Pyrite: Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon: Amount	Carbon: Type	Remarks
0–2.5						sh	lt pktn											VS			
2.5–5.0						sndy sh	lt pktn	f-m	P	a								VS			
5.0–7.5						qtz ss	tn	f-m	P	a		L						S			Top of Dakota Fm @ 5.0 ft.
7.5–10.0						qtz ss	tn	f-cr	P	o								N			
10.0–12.5						qtz ss	tn	m-cr	P	a								N			
12.5–15.0						qtz ss	dktn	m-cr	P	o								N			
15.0–17.5						qtz ss	dktn	m-vcr	P	a								N			
17.5–20.0						qtz ss	dktn	m-cr	P	o								N			
20.0–22.5						qtz ss, sh	tn-dkgy	m-vcr	P	a								N			
22.5–25.0						qtz ss	tn	m	W	r								N			
25.0–27.5						qtz ss	tn	f-m	M	r								N			
27.5–30.0						sh	dkgy											N			
30.0–32.5						sh, qtz ss	dkgy-gy	f-m	M	a								N			
32.5–35.0						qtz ss	tn	m-cr	M	r								N			
35.0–37.5						qtz ss, sh	gytn	f-cr	P	a								N			
37.5–40.0						qtz ss	lttn	m-cr	M	r								N			Some chert grains
40.0–42.5						qtz ss, sh, cgl	dkgy	f-peb	P	a		L						N			
42.5–45.0						qtz ss, cgl	gybn	m-peb	P	a								N			very abund. chert frags + pebbles.
45.0–47.5						qtz ss, cgl	gybn	m-peb	P	a								N			" " " " "
47.5–50.0						qtz ss, cgl	tn	m-peb	P	a								N			Some chert frags + pebbles.
50.0–52.5						qtz ss	ortn	m-cr	P	a								N			
52.5–55.0						qtz ss, cgl	gytn	m-cr	P	a								N			abund chert pebbles & fragments.
55.0–57.5						qtz ss, cgl	gytn	m-peb	P	a								N			" " " " "
57.5–60.0						qtz ss, cgl	gytn	m-peb	P	a								N			" " " " "
60.0–62.5						qtz ss	tn	f-m	M	r								N			
62.5–65.0						qtz ss	tn	m-cr	M	r								N			
65.0–67.5						qtz ss	lttn	m	W	r								N			
67.5–70.0						qtz ss, cgl	tn-dkbn	f-peb	P	a								N			
70.0–72.5						qtz ss, cgl	tn	f-peb	P	a								N			
72.5–75.0						qtz ss		m	W	R								N			
75.0–77.5						qtz ss, cgl	tn	f-peb	P	a								N			abund chert frags + pebbles.
77.5–80.0						qtz ss, cgl	tn	m-peb	P	a								N			"
80.0–82.5						qtz ss, cgl	gytn	m-peb	P	a								N			"
82.5–85.0						qtz ss, cgl	gytn	m-peb	P									N			
85.0–87.5						qtz ss, cgl	gytn	m-peb										N			
87.5–90.0						qtz ss, cgl	gytn	m-peb										N			
90.0–92.5						qtz ss, cgl	gytn	m-peb										W			
92.5–95.0						qtz ss, cgl, sh	gytn-gn	f-peb										S			Brushy Basin Ct @ 94.0'
95.0–97.5						sh	gn											S			
97.5–100.0						sh	gn											VW			
100.0–102.5						sh	gn-ppbn											VW			
T.D.																					

PERCENTAGE COMPOSITION IMAGE



1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 8-17-09 Geologist L. Casebolt Drilling Co. Bayles Exploration Inc. Hole No. TWN-10

Property White Mesa Mill Project NITRATE Study Unit No. ___ Sec. ___ Twp. ___ Rge. ___

County San Juan State Utah Location ___ Elev. ___

PAGE 1 OF 1

T.D. PROBE 107.5

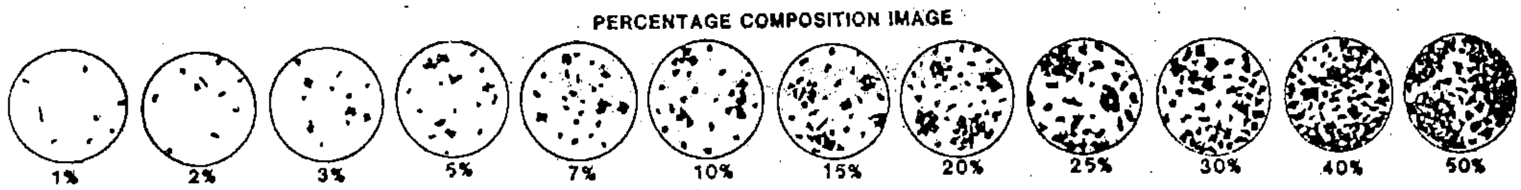
T.D. DRILL 107.5

FLUID LEVEL ___

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Iron Oxide	React.-10% HCl	Remarks
0–2.5	sltst, mdst	rdbn					S	Surface soil
2.5–5.0	sltst, mdst	rd bn					S	Surface Soil
5.0–7.5	sndy sh	tn	f-m	p	a		VS	Mancos sh contact at 5.0'
7.5–10.0	sh	ywbn					VS	
10.0–12.5	sh	ywbn					VS	
12.5–15.0	sh	ywbn					S	
15.0–17.5	sh	ywbn					M	
17.5–20.0	sh	ywbn					W	
20.0–22.5	sh	ywbn					W	
22.5–25.0	sh	ywbn-gy					W	
25.0–27.5	sh	ywbn-gy					N	
27.5–30.0	sh	ywbn-gy					N	
30.0–32.5	qtz ss	tn	f-cr	m	r		N	Upper Dakota fm contact @ 30.0'
32.5–35.0	qtz ss	tn	f-cr	m	r	L	N	
35.0–37.5	qtz ss, sh	tn-blk	m-cr	m	r		N	
37.5–40.0	sh	dkgy					N	
40.0–42.5	sh, qtz ss	dkgy-tn	f-m	m	a	L	N	
42.5–45.0	qtz ss cgl, sh	tn-dkgy	m-peb	p	a		N	Some chert pebbles + frags.
45.0–47.5	qtz ss, cgl	tn	f-peb	p	r		N	" " " "
47.5–50.0	qtz ss, cgl	tn	m-peb	p	r		N	abund " " "
50.0–52.5	qtz ss, cgl	tn-gy	m-peb	p	a		N	" " " "
52.5–55.0	qtz ss, cgl	tn	m-peb	p	r		N	" " " "
55.0–57.5	qtz ss, cgl	tn	m-peb	p	r		N	" " " "
57.5–60.0	qtz ss	tn	f-cr	m	r		N	
60.0–62.5	qtz ss	tn	f-m	m	a		N	
62.5–65.0	qtz ss, sh	tn-gn	f-vcr	p	a		N	
65.0–67.5	sh	gy					N	
67.5–70.0	sh	gy-pprdbn					N	
70.0–72.5	sh	gy-pprdbn					N	
72.5–75.0	sh, qtz ss cgl	gygn-bn	m-peb	p	a		N	
75.0–77.5	qtz ss, sh	tn	m-cr	m	a		N	
77.5–80.0	qtz ss	tn	f-cr	m	a		N	
80.0–82.5	qtz ss	tn	m-vcr	m	a		N	abund chert grains and frags.
82.5–85.0	qtz ss	tn	m-vcr	m	a		N	
85.0–87.5	qtz ss	tn	f-m	m	r		N	
87.5–90.0	qtz ss	tn	f-m	m	r		N	
90.0–92.5	qtz ss	tn	f-m	m	r		N	Moisture @ 92.5
92.5–95.0	qtz ss	tn	m-vcr	m	r		N	Begin H_2O injection
95.0–97.5	qtz ss, sh	vltgygn	f-cr	p	a		N	
97.5–100.0	qtz ss	wh-vltgy	f-m	m	a		N	
100.0–102.5	qtz ss	vltgy	vf-f	m	a		N	Brushy Basin Ct @ 102.5
102.5–105.0	sh	gn-rdbn					N	
105.0–107.5	sh	gn					N	T.D.

T.D.

PERCENTAGE COMPOSITION IMAGE

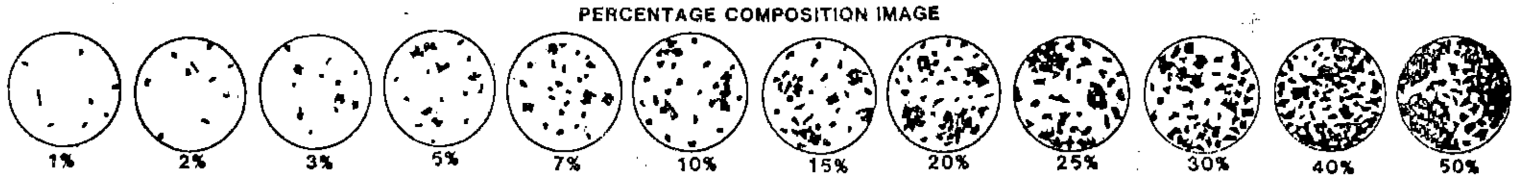


Date 9-29-2009 Geologist L. Casebolt Drilling Co. Bayles Exploration Inc. Hole No. TWN-11
Property White Mesa Mill Project Nitrate Study Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 2
T.D. PROBE ______
T.D. DRILL 147.5
FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Non-Metallic / React.-10% HCL	Carbon Amount	Carbon Type	Remarks
2.5	sltst, mdst	rd bn								W			Surface Soil
5.0	sltst, mdst	rdbn								S			Surface soil
7.5	sltst, sh	rd bn-ywbn								VS			Color change, Mancos Sh @ approx 6'
10.0	Sh/qtz ss	lt ywbn	f-m	p	a		L			VS			
12.5	qtz ss, sh	lt bn	f-m	p	a		L			S			
15.0	sh	dkgybn								S	Tr	I	trace carbonaceous frags.
17.5	sh	dkgybn								N	A	I	abund. " "
20.0	sh	dkgybn								N	Tr	I	trace " "
22.5	qtz ss, sh	gybn	f-m	p	r					N			Top Dakota Fm @ approx 21.0'
25.0	qtz ss	gytn	f-m	p	a					N			
27.5	qtz ss	tn	f-m	p	a					N			
30.0	qtz ss	tn	f-m	p	r					N			
32.5	qtz ss, sh	tn	f-m	p	a					N			
35.0	qtz ss, sh	tn/gy	f-m	p	a					N			
37.5	qtz ss	tn	f-m	m	a					N			
40.0	qtz ss	lt tn	f	m	a					N			
42.5	qtz ss	ortn	f	m	a		L			N			
45.0	qtz ss	lt bn	f	m	a		L			N	Tr	I	
47.5	qtz ss	lt bn	f	m	a					N	Tr	I	moisture first noted @ 47'
50.0	cgl/qtz ss	lt gybn	m-peb	p	a		L			N	Tr	I	Begin H2O injected at 47.5' tr. carbonaceous frags.
52.5	cgl, qtz ss	ltgybn	m-peb	p	a					N			abund. chert frags + pebbles.
55.0	qtz ss, cgl	lt tn	m-peb	p	a					N			some chert frags & pebbles.
57.5	qtz ss, sltst	lt tn	vf-m	p	a					N			
60.0	qtz ss, sh	lt tn	vf-m	p	a					N			
62.5	qtz ss, cgl	tn bn	m-peb	p	r					N			some multi colored chert frags. + grains
65.0	qtz ss	tn	m-vcr	p	r					N			" " " " grains
67.5	qtz ss	tn	m-vcr	p	r					N			" " " " "
70.0	qtz ss	tn	m-vcr	p	r					N			" " " " "
72.5	qtz ss cgl	tn	m-peb	p	r					N			" " " " "
75.0	cgl, qtz ss	lt ortn	m-peb	p	a					N			abund. " " " frags, pebbles.
77.5	qtz ss, cgl	wh-lt tn	m-vcr	p	a					N			" " " " "
80.0	qtz ss	tn	m-cr	p	r					N			" " " " grains
82.5	qtz ss	tn	m-cr	p	r					N			" " " " "
85.0	qtz ss	lt gy	vf-f	m	a					N			sparse chert grains
87.5	qtz ss	lt gy	vf-f	m	a					N			
90.0	qtz ss	lt gy	vf-f	m	a					N			
92.5	qtz ss, sh	lt gy	vf-f	m	a					N			
95.0	qtz ss	lt gy	vf-f	m	a					N			
97.5	qtz ss	wh	vf-f	m	a					N			
100.0	qtz ss	wh	vf-f	m	a					N			
102.5	qtz ss	wh	vf-f	p	a			Tr	C	N			Trace of pyrite grains
105.0	qtz ss	wh	vf-f	p	a					N			
107.5	qtz ss	wh	vf-f	p	a					N			
110.0	qtz ss	wh	f-m	p	a			Tr	C	N			some aggregates of pyrite
112.5	qtz ss	wh	f-m	m	a					N			
115.0	qtz ss	wh	f-m	m	a					N			
117.5	qtz ss	wh	f-m	m	a					N			
120.0	qtz ss	wh	f-m	m	a					N			
122.5	qtz ss	wh	f-m	m	a			Tr	C	N			Tr of pyrite aggregate
125.0	qtz ss	wh								N			

PERCENTAGE COMPOSITION IMAGE



Date 9-29-09 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-11
Property White Mesa Mill Project Nitrate Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 2 OF 2
T.D. PROBE ______
T.D. DRILL 147.5
FLUID LEVEL 68'

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
127.5						qtz ss	wh	f-m	m	a								N			
130.0						qtz ss	wh	f-m	m	a								N			
132.5						qtz ss cgl	lt gy	m-peb	P	a								VW			abund. chert fragments and pebbles
135.0						qtz ss sh	lt gy	f-cr	P	a								N			
137.5						qtz ss	lt gy	vf-f				L						N			
140.0						qtz ss	lt gy	vf-f				L						N			
142.5						sh	gy-rdbn											N			Brushy Basin Cf. @ 140.0'
145.0						sh	gy-rdbn											N			
147.5						sh	rdbn											N			T.D.

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 9-29-09 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-12
Property White Mesa Mill Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 115.0
FLUID LEVEL ____

REMARKS Well by Highway

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Amount	Habit	Alter.	Metallic	Non-Metallic	React.-10% HCl	Amount	Type	Remarks
2.5						sltst-mdst	rd bn											S			Surface Soil
5.0						sltst-mdst	rd bn											VS			Surface soil
7.5						qtz ss	ortn	f-m	m	a		L						S			Top of Dakota Fm @ 5.0'
10.0						qtz ss	tn	f-m	m	a								N			
12.5						qtz ss	tn	f-m	m	a								N			
15.0						qtz ss	tn	f	m	a								N			
17.5						qtz ss	tn	f	m	a								N			
20.0						qtz ss, sh	tn	f	m	a								N	Tr	I	
22.5						qtz ss, sh	gytn	f	m	a								N	Tr	I	
25.0						qtz ss	tn	m	m	a								N			
27.5						qtz ss	ortn	m	m	a		L						N			
30.0						qtz ss	tn	m-cr	p	a		L						N			some chert frag, and grains
32.5						qtz ss	ywtn	f-m	p	a								N			
35.0						qtz ss	ywtn	f-m	p	a								N			
37.5						qtz ss	ywtn	f-m	p	a								N			
40.0						qtz ss	ywtn	m-vcr	p	a								N			abund chert frag, & grains
42.5						qtz ss	ywtn	vf-f	p	a								N			
45.0						qtz ss	tn	m-peb	p	a								N			Begin H_2O injection @ 42.5 abund chert frags
47.5						cgl, qtz ss	ywtn	m-peb	p	a								N			abund multicolored chert frags
50.0						cgl, qtz ss	tn	m-peb	p	a								N			" " " " "
52.5						qtz ss, cgl	vlttn	vf f	p	a								N			some chert frags
55.0						qtz ss, cgl	vlttngy	vf f	p	a								N			
57.5						qtz ss	wh	vf f	p	a								N			
60.0						qtz ss	wh	vf f	p	a			Tr	C				N			
62.5						qtz ss	wh-tn	vf-cr	p	a								N			some chert frags.
65.0						qtz ss	wh	m-vcr	p	a			Tr	C				N			
67.5						qtz ss	wh	m-vcr	p	a			1%	C				N			
70.0						qtz ss	wh	m-vcr	p	a			Tr	C				N			
72.5						qtz ss	wh	m	m	a								N			
75.0						qtz ss	wh	m	m	a								N			
77.5						qtz ss	ltgy	m-cr	m	a								N			
80.0						qtz ss	ltgy	f-m	p	a			Tr	C				W			
82.5						qtz ss	tn	f-m	p	a								W			
85.0						qtz ss	wh	f-m	p	a								N			
87.5						qtz ss	wh	m	p	a								N			
90.0						qtz ss	ltgn	f-m	p	a								N			
92.5						qtz ss	wh	f-cr	p	a			Tr	C				N			
95.0						qtz ss	wh	f-m	p	a			Tr	C				W			
97.5						qtz ss	wh	f-m	p	a			Tr	C				N			
100.0						qtz ss	wh	f-m	p	a								N			
102.5						cgl, qtz ss	tn	f-peb	p	a								N			abund. chert frags & pebbles
105.0						cgl, qtz ss	gy	f-peb	p	a								N			" " " "
107.5						cgl, qtz ss	gytn	f-peb	p	a								N			" " " "
110.0						sh	gy rdbn											N			Upper Brushy Basin Mbr @ 107.5'
112.5						Sh	gy rd bn											N			
115.0						sh	gy rd bn											N			
TD.																					

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 9-30-09 Geologist L. Cosebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-13
Property White Mesa Mill Project Nitrate Study Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 120.0
FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React. 10% HCL	Carbon Amount	Carbon Type	Remarks
0																
2.5	sltst mdst	lt rd bn											S			Surface soil
5.0	sltst mdst	rd bn											VS			Surface Soil
7.5	qtz ss	rd bn	f	m	a								VS			Top of Dakota @ 5.0'
10.0	qtz ss	lt tn	f	m	a								N			
12.5	qtz ss, sh	dk yw gy	f-m	m	a								N			
15.0	sh, qtz ss	dk yw gy	f-m	m	a								N			
17.5	qtz ss	tn	vf-m	p	a								N			
20.0	qtz ss	tn	f	m	a		L						N			
22.5	qtz ss	tn	f	m	r								N			
25.0	qtz ss	lt tn-tn	f-vcr	p	a								N			some chert grains
27.5	qtz ss	tn	f-vcr	p	a								N			" " "
30.0	qtz ss, cgl	v lt tn-tn gy	m-peb	p	a								N			abund. chert frags & pebbles.
32.5	qtz ss	v lt tn	m-cr	m	r								N			
35.0	qtz ss, cgl	tn-gy	m-peb	p	a								N			Some chert frags & pebbles.
37.5	qtz ss	tn	f-m	m	a								N			abund dk gray chert frags & grains
40.0	qtz ss	tn	m	m	r								N			
42.5	qtz ss	tn	f-m	m	r								N			
45.0	qtz ss	tn	f-m	m	r								N			
47.5	qtz ss	tn	f-vcr	p	a								N			abund. chert frags & grains
50.0	qtz ss	tn	f-vcr	p	a								N			" " " "
52.5	qtz ss	tn	m-vcr	p	a								N			
55.0	qtz ss	tn	f-m	m	r								N			
57.5	qtz ss, cgl	tn	f-peb	p	a								N			some chert frags.
60.0	qtz ss, cgl	tn	f-peb	p	a								N			" " "
62.5	qtz ss, cgl	dk tn	m-peb	p	a								N			abund. chert frags & pebbles.
65.0	qtz ss, cgl	wh	f-peb	p	a								N			
67.5	qtz ss	wh	m-cr	p	a								N			
70.0	qtz ss	v lt tn	m-vcr	p	a								N			
72.5	qtz ss, cgl	or tn	m-peb	p	a								N			abund chert frags & pebbles.
75.0	sndy sh, cgl	lt gy gn	f-peb	p	a								N			
77.5	qtz ss, sltst	lt gy gn	f-cr	p	a								N			
80.0	qtz ss-sltst	wh-gy	vf-cr	p	a								N			
82.5	qtz ss, sltst	wh-lt gn	m-peb	p	a								W			
85.0	qtz ss, sltst	wh-lt gy	f-m	p	a								N			
87.5	sltst, qtz ss	gy-rd bn	vf-m	p	a								N			
90.0	sndy sltst	gy-rd bn	vf-m	p	a								N			
92.5	sndy sh	wh, gy-rd bn	vf-peb	p	a								N			Some chert frags & pebbles.
95.0	sh, qtz ss	wh, rd bn	m-cr	p	a								N			
97.5	sh, qtz ss	rd bn-gy	m-vcr	p	a								N			
100.0	qtz ss-sh	rd bn-wh	f-peb	p	a								N			
102.5	qtz ss, cgl	wh	f-peb	p	a			Tr	c				N			very abund. chert frags & pebbles
105.0	cgl	wh-lt tn	m-peb	p	a			Tr	c				N			" " " " "
107.5	cgl	tn	f-peb	p	a			Tr	c				N			" " " " "
110.0	cgl	tn-gn	m-peb	p	a			Tr	c				N			" " " " "
112.5	qtz ss, cgl	wh-gy rd	f-peb	p	a			Tr	c				N			" " " " "
115.0	qtz ss, sltst	wh-lt gy	vf-f	p	a								N			
117.5	sh	gy-rd bn											N			Upper Brushy Basin contact @ 115.0 ft.
120.0	sh	gy-rd bn											N			
T.D.																

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date *Sept. 28, 2009* Geologist *L. Casebolt* Drilling Co. *Bayles Exploration, Inc.* Hole No. *TWN-14*

Property *White Mesa Mill* Project *Nitrate Study* Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County *San Juan* State *Utah* Location ______ Elev. ______

PAGE *1* OF *2*

T.D. PROBE ______

T.D. DRILL *135.0*

FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Iron Oxide	Pyrite Amount	Pyrite Habit	React. 10% HCL	Remarks
2.5	sndy sltst	rdbn							N	Surface soil
5.0	Sndy sltst	rdbn							S	Surface soil
7.5	qtz ss	tnbn	cr	P	a	L			S	Color Change at 5.0' qtz ss, tnbn Top of Dakota Fm.
10.0	sh	vdk gy	-	-	-				N	
12.5	sh-qtz ss	vdkgy-tn	f-cr	P	a	L			N	
15.0	qtz ss	lt tn	f-m	M	r	L			N	
17.5	qtz ss	lt tn	f-m	M	R	L			N	
20.0	qtz ss	ltgytn	f-m	M	R				N	
22.5	qtz ss-sh	tn-ltgy	f-m	M	r	L			N	
25.0	qtz ss-sh	tn-gy	f-m	M	r	L			N	carbonaceous fragments
27.5	qtz ss-sh	tn-gy	f-m	M	r	L			N	sparce carbonaceous fragments
30.0	qtz ss-sh	tn-gy	vf-m	M	r	L			N	
32.5	qtz ss	vltgytn	m-cr	M	r	L			N	sparce gy chert frags.
35.0	qtz ss	ywtn	m-vcr	M	r	L			N	abund. chert frags.
37.5	qtz ss	ywtn	m-vcr	W	R	L			N	" " "
40.0	qtz ss	tn	f-vcr	M	R				N	" " "
42.5	qtz ss	tn	f-m	M	r				N	" " "
45.0	qtz ss-sltst	wh-lttn	vf-f	M	R	L			N	some gray chert frags
47.5	qtz ss	vlttn	m	W	R				N	some multi colored chert frags. & grains
50.0	qtz ss	vlttn	m	W	R				N	abunt " " " " "
52.5	qtz ss	vlttn	f-m	M	r				N	some " " " grains
55.0	qtz ss	vlttn	f-m	M	r				N	" " " " "
57.5	qtz ss	vlttn	f-m	M	r				N	some angular chert frags.
60.0	sh	ltgy-gy							N	
62.5	sh-sltst	gy-dkgy							N	
65.0	sh-sltst, ss	gy	f-m	P	r				N	
67.5	qtz ss	wh-vltgy	vf-m	P	r				N	abund multicolored chert grains
70.0	qtz ss	lt tn	vf-m	P	r				N	
72.5	qtz ss	ltgytn	f-m	P					N	abund dkgy chert grains
75.0	qtz ss	tn	f-vcr	P	a				N	" multi colored chert grains
77.5	qtz ss-cgl	tn-ltgy	f-vcr	P	a				N	" " " " " and frags
80.0	qtz ss-cgl	lt tngy	f-vcr	P	a				N	" " " " " " "
82.5	cgl-qtz ss	gytn	f-peb	P	a				N	abund dkgy chert pebbles & frag.
85.0	cgl-ss-sh	tngygn	f-peb	P	a				N	" " " " "
87.5	qtz ss-sh	wh-ltgn	f-m	M	r				N	Some chert grains,
90.0	qtz ss	wh-ltgn	vf-f	M	a		sp	c	N	some chert grains, sparse disseminated pyrite
92.5	qtz ss	wh	vf-f	M	a		s	c	N	some disseminated pyrite
95.0	sltst-sh-ss	gnrdbn-wh	vf-f	M	a				N	
97.5	sltst-sh	gnrdbn							N	
100.0	sltst-ss	wh-ltgn	vf-f	M	a				N	
102.5	qtz ss-sh	wh-ltgn	vf-f	M	a				N	
105.0	qtz ss-sh	wh-vltgn	vf-f	M	a				N	
107.5	qtz ss-sltst	wh-gn-rdbn	vf	M	a				N	
110.0	sltst-sh	gygn-rdbn							N	some apparent slickenside surfaces
112.5	sltst-sh	tn-rdbn	peb		P				N	chert pebble
115.0	sh	rdbn							N	
117.5	sh cgl ss	ltgn	peb		P				N	chert pebbles.
120.0	Cgl, ss	dktn	f-peb				s	c	N	abund chert pebbles & frag. some dissem. pyrite
122.5	sltst ss	ltgn-rdbn	vf-f	M	P				N	Upper Brushy Basin Ct @ 120.0
135.0	sltst	ltgn-rdbn							N	

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date Sept 28, 2009 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-14
Property White Mesa Mill Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 2 OF 2
T.D. PROBE ____
T.D. DRILL 135.0
FLUID LEVEL ____

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE: AMOUNT	PYRITE: HABIT	PYRITE: ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON: AMOUNT	CARBON: TYPE	REMARKS
125.0																					
127.5						sltst	ltgy-rdbn											N			
130.0						sltst	gy gn-rdbn											N			
132.5						Sh	rdbn-gygn											N			
135.0						Sh, qtzss	rdbn-wh											N			T.D.

PERCENTAGE COMPOSITION IMAGE

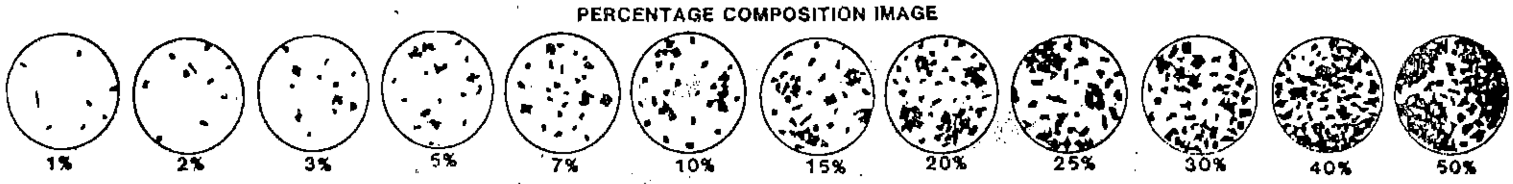
1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 12-7-09 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-15
Property White Mesa Mill Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 2
T.D. PROBE ____
T.D. DRILL 155
FLUID LEVEL 89

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																					
2.5						sltst, mdst	rdbn											W			Surface soil.
5.0						sltst, mdst	rdbn											VS			Surface soil
7.5						sltst, mdst	rdbn											VS			Surface soil
10.0						sltst, mdst	rdbn											VS			Surface soil
12.5						sltst, sh	rd bn ywbn											VS			color change ywgn Mancos Sh. @ 12.0'
15.0						sh	ywbn											S			
17.5						sh	ywbn											S			
20.0						sh	ywbn											S			
22.5						sh	ywbn											S			
25.0						sh	ywbn											W			
27.5						sh	ywbn-gy											N			
30.0						sh	ywbn-gy											N			
32.5						sh	vdkgy											N			
35.0						sh	ywbn-gy											N			
37.5						sh	vdkgybn											N			
40.0						qtz ss, sh	tn-dkgy	m	m	a		L						N			Upper Dakota Ct. @ 38.0'
42.5						qtz ss	tn	m	m	a		L						N			
45.0						qtz ss, sh	tn-gy	m	m	a		L						N			
47.5						sh	vdkgy											N			
50.0						sh, qtz ss	bn-vdkgy	m	m	a		L						N	Tr	F	
52.5						qtz ss	gybn	m-cr	P	a								N	Tr	F	
55.0						qtz ss	ywtn	m-cr	P	a								N			
57.5						qtz ss	ywtn	m-cr	P	a								N			
60.0						qtz ss	ywtn	m-cr	P	a								N			
62.5						qtz ss/cgl	ywgy	m-peb	P	a								N			
65.0						qtz ss/cgl	ywortn	m-peb	P	a								N			H2O injection beg. @ 62.5
67.5						sndy sh	lt blgy	vf-f	P	a								N			
70.0						sh	lt blgy	vf-f	P	a								N			
72.5						qtz ss	wh-gy	vf-f	P	a								N			
75.0						qtz ss	wh-rd	vf-f	P	a		H						N			
77.5						qtz ss	ortn	f	m	a		L						N			
80.0						qtz ss	tn	f-peb	P	a								N			
82.5						qtz ss	tn	f-peb	P	a								N			
85.0						qtz ss	tn	f-peb	P	a		L						N			
87.5						qtz ss	tn	m	m	a								N			
90.0						qtz ss	tn	m	m	a								N			
92.5						qtz ss	tn	f-m	m	a								N			
95.0						qtz ss, cgl	tn-orbn	f-peb	P	a		L						N			some chert frag. & grains
97.5						qtz ss, cgl	tn	m-peb	P	a								N			abund chert frags & pebbles.
100.0						qtz ss, cgl	wh-ltgy	m-peb	P	a								N			" " " "
102.5						qtz ss	lttn	m-vcr	P	a								S			
105.0						qtz ss, sh	lttn-gy	m-cr	P	a								S			
107.5						sndy sh	ltgygn	f-m	P	a								N			
110.0						qtz ss	vltgygn	vf-f	P	a								N			
112.5						qtz ss, sh	wh-ltgn	vf-f	P	a								N			
115.0						sndy sh	ltgn	f-m	P	a								N			
117.5						sh, qtz ss	ltgn	f-m	P	a								N			
120.0						qtz ss	ltgn	f-m	P	a								N			
122.5						qtz ss	ltgy	f-m	P	a								N			
125.0						qtz ss	ltgy-tn	m-peb	P	a								N			abund chert pebbles & frags

PERCENTAGE COMPOSITION IMAGE

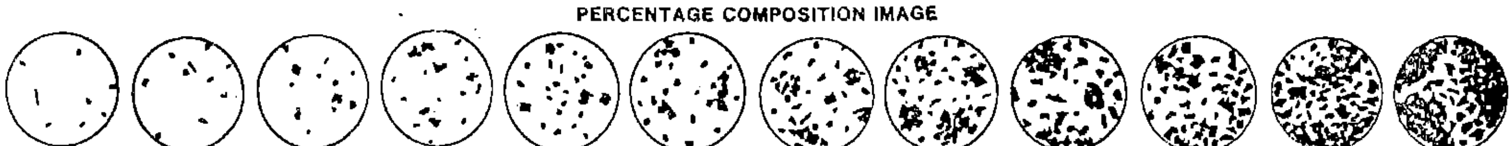


Date 10-1-09 Geologist L. Casebolt Drilling Co. Boyles Exploration, Inc. Hole No. TWN-15
Property White Mesa Mill Project Nitrate Study Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 2 OF 2
T.D. PROBE ______
T.D. DRILL 155.0
FLUID LEVEL 89'

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite: Amount	Pyrite: Habit	Pyrite: Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon: Amount	Carbon: Type	Remarks
0																					
127.5						Chert Cgl.	orgytn	cr-peb	p	a								N			very abund chert pebbles + frags
130.0						Chert Cgl	orgytn	cr-peb	p	a			Tr	C				N			" " " " "
132.5						Cgl, sh	gyrdbn	m-peb	p	a								N			" " "
135.0						Sh, cgl	gy rdbn	peb	p	a								N			
137.5						Sh	gyrdbn											N			
140.0						sltst	ltgy											N			
142.5						sltst	ltgyrdbn											N			
145.0						sltst, sh	gn-rdbn											N			
147.5						qtz ss, sltst	wh-rdbn-gy	f	m	a								N			
150.0						qtz ss	wh-ltgy	vf-f	p	a								N			
152.5						sh	gy-ppbn											N			Upper Brushy Basin Ct @ 150.0'
155.0 T.D.						sh	ppbn-gy											N			

PERCENTAGE COMPOSITION IMAGE



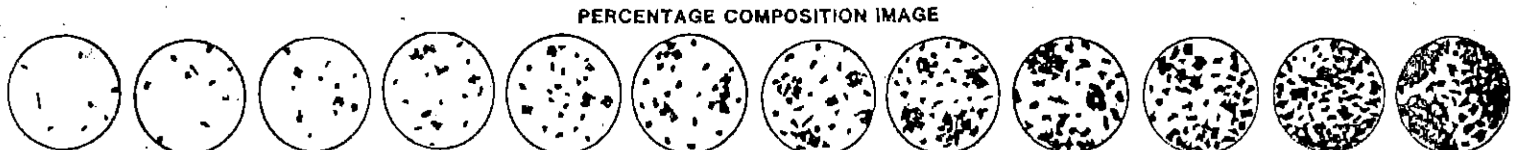
1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 9-30-09 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-16
Property White Mesa Mill Project Nitrate Study Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF ______
T.D. PROBE ______
T.D. DRILL 100.0
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCl	Carbon Amount	Carbon Type	Remarks
2.5						sltst, mdst	rdbn											VS			Surface soil
5.0						qtz ss	tn	m	m	a								N			Top of Dakota @ 2.5'
7.5						qtz ss	tn	f-m	p	a								N			
10.0						qtz ss	tnbn	m-cr	p	a								N			
12.5						qtz ss	tn	f-m	m	a								N			
15.0						qtz ss	tn	f-m	m	a								N			
17.5						qtz ss	tn	m	m	a								N			Moisture 12.5'
20.0						qtz ss	tn	f-m										N			
22.5						sndy sh	tn	f-m	p	a								N			H2O injected 20'
25.0						qtz ss	wh-tn	f-m	p	a		L						N			
27.5						qtz ss	wh	f-m	p	a								N			
30.0						qtz ss	lttn	f	m	a								N			
32.5						qtz ss	rd-ltgy	vf-f	m	a		H						N			
35.0						qtz ss	rd-lttn	f-m	m	a		L/H						N			
37.5						qtz ss	ywtn	vf-f	m	a								N			
40.0						qtz ss	lttn	f cr	p	a								N			some chert frags.
42.5						qtz ss	tn	f-cr	p	r		L						N			
45.0						qtz ss, cgl	lttn	m-peb	p									N			some chert fragments + pebbles.
47.5						qtz ss	vlttn	m	m	R								N			
50.0						qtz ss	vlttn	m	m	R								N			
52.5						qtz ss	vlttn	m	m	r								N			
55.0						qtz ss, cgl	ortn	m-peb	p	a								N			chert frags + pebbles.
57.5						sh, cgl	or-gygn	peb	p	a								N			" " "
60.0						qtz ss, sh, cgl		m-peb	p	a								N			
62.5						qtz ss, sh	vlttn-gy	m-cr	p	a		L						N			
65.0						qtz ss, sh	tn-ltgy	m	m	a		L						N			
67.5						qtz ss, cgl	ltgytn	peb	p	a								N			
70.0						qtz ss, cgl	tn	m-peb	p	a								N			
72.5						qtz ss	tn	f-m	p	a								N			
75.0						qtz ss	tn	f-m	p	a								N			
77.5						qtz ss	tn	f-m	m	a								N			
80.0						qtz ss	tn	m-vcr	p	a								N			
82.5						qtz ss	tn	f-m	m	a								N			
85.0						qtz ss, cgl	ortn-gy	m-peb	p	a								N			
87.5						qtz ss	Tn	m-cr	p	a								N			
90.0						qtz ss	gy	m-cr	p	a			Tr	C				N			
92.5						sh,	gy ppbn											N			Upper Brushy Basin Mb. @ 90.0'
95.0						sh, cgl.	pprdbn	peb										N			
97.5						sh	lt gy											N			
100.0						sh	ppbn-gy											N			

PERCENTAGE COMPOSITION IMAGE



1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

Date 10-2-09 Geologist L. Casebolt Drilling Co. Bayles Exploration Inc. Hole No. TWN-17

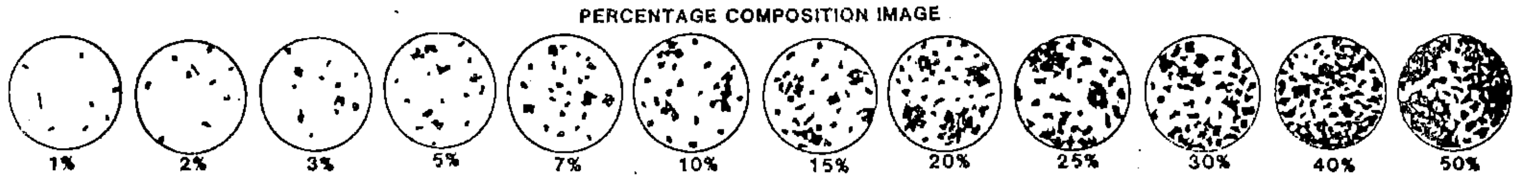
Property White Mesa Mill Project Nitrate Study Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 110.0
FLUID LEVEL ______

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	React.-10% HCL	Remarks
2.5	sltst, mdst	rdbn					S	Surface soil
5.0	sltst, mdst	rdbn					S	Surface soil
7.5	qtz ss	tn	f-m	P	a	L	N	Color change top of Dakota @ 5.0'
10.0	qtz ss, sh	tn bn	f-cr	P	a		N	white chert frags + grains.
12.5	qtz ss	tn	f-vcr	P	a		N	
15.0	qtz ss	tn	m	m	a		N	
17.5	qtz ss	tn	m-cr	m	r		N	
20.0	qtz ss	tn	m	m	r		N	
22.5	qtz ss	tn	m-cr	P	r		N	
25.0	qtz ss-qtzite	wh	m-vcr	P	a		N	fragments of orthoquartzite
27.5	qtz ss	wh-tn	m-cr	P	a		N	
30.0	qtz ss	tn	m-cr	P	a		N	
32.5	qtz ss	tn	f-m	P	a		N	
35.0	qtz ss, sh	ltgytn	f-m	P	a	L	N	
37.5	qtz ss	tn	m-cr	m	a		N	
40.0	qtz ss	tn	f-m	m	a		N	
42.5	qtz ss	lt tn	f-m	m	a		N	
45.0	qtz ss	wh	m-vcr	P	a		N	
47.5	qtz ss	lt ortn	m-vcr	P	a		N	
50.0	qtz ss, cgl	ortn	m-peb	P	a		N	some small chert pebbles.
52.5	qtz ss	wh	m-cr	P	a		N	
55.0	qtz ss, cgl	tngy	f-peb	P	a		N	some small chert pebbles + frags.
57.5	qtz ss	tn	f-vcr	P	a		N	
60.0	qtz ss	tn	f-cr	P	a		N	
62.5	qtz ss, cgl	tn	f-peb	P	a		N	some small chert frags.
65.0	qtz ss, cgl	tn	f-vcr	P	a		N	some chert frags.
67.5	qtz ss	vlttn	f-vcr	P	a		N	
70.0	qtz ss	tn	f-cr	P	a		N	
72.5	sh	ltgygn					N	
75.0	sh	ltgygn					N	
77.5	qtz ss, sh	wh-ltgn	vf-f	P	a		N	
80.0	qtz ss	wh-ltgn	vf-f	P	a	L	N	
82.5	qtz ss	wh-tn	f-cr	P	a		N	
85.0	qtz ss	wh-tn	f-m	P	a		N	
87.5	qtz ss	tn	f-m	P	a		N	
90.0	qtz ss	tn-gy	f-m	P	a		N	
92.5	sh	dkgybn					N	
95.0	qtz ss, cgl	gy	f-peb	P	a		N	
97.5	qtz ss, cgl	gy-rdbn	m-peb	P	a		N	
100.0	cgl	bn-rdbn	peb	P	a		N	abund. multicolored chert pebbles + frags.
102.5	cgl	gybn	peb	P	a		W	" " " " "
105.0	qtz ss, cgl, sh	tn-rdbn	f-peb	P	a		S	Upper DD at @ 104 ft'
107.5	sh, sltst	ltgy-rdbn	vf-f	P	a		N	
110.0	sh	pprdbn					N	T.D.

PERCENTAGE COMPOSITION IMAGE

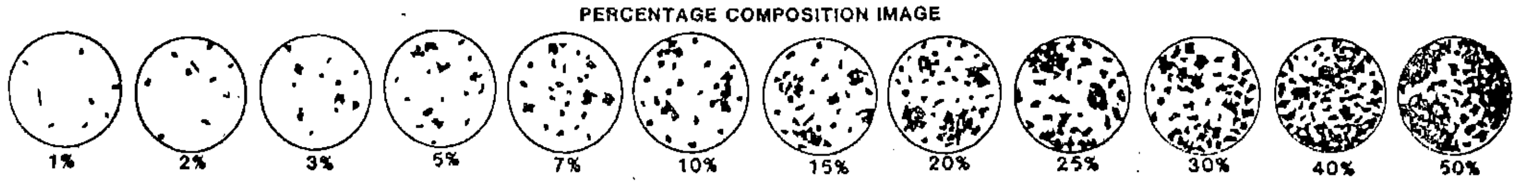


Date 10-9-09 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-18
Property White Mesa Mill Project Nitrate Study Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ______

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 145.0
FLUID LEVEL ______

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																					
2.5						sndy sltst	rdbn	vf-cr	P	a								S			surface soil
5.0						sndy sltst	rdbn	vf-m	P	a								W			surface soil
7.5						sltst-sndy	rdbn	vf-cr	P	a								W			surface soil
10.0						sltst-sndy	rdbn	vf-m	P	a								S			
12.5						qtz ss	tn	m	m	a	L							N			Upper contact Dakota fm @ 10.0'
15.0						qtz ss	tn	f-m	m	a								N			
17.5						qtz ss	tn	m	m	a								N			
20.0						qtz ss	tn	m	m	a								N			
22.5						qtz ss	tn	m	m	a	L							N			
25.0						qtz ss	tn	f-m	m	a								N			
27.5						qtz ss, sh	tn	m-cr	m	a								N			
30.0						qtz ss	tn	m-cr	m	r								N			
32.5						qtz ss	tn	m-peb	P	a								N			some light colored chert pebbles & frags.
35.0						qtz ss	tn	m-cr	P	a								N			" " " " " "
37.5						sh, qtz ss	gy	m-peb	P	a								N			" " " " " "
40.0						sh	gy											N			
42.5						sh, qtz ss	gy	m-cr	P	a								N			
45.0						sh, qtz ss	tn	m-peb	P	a								N			" " " " " "
47.5						sh	gytn											N			
50.0						sh	gytn											N			
52.5						sltst	gy											N			
55.0						sndy sh	gy	f-m	P	a								N			
57.5						sltst, sh	gy											N			
60.0						sndy sltst	gy	f-m	P	a								N			
62.5						qtz ss	gy	vf-f	P	a								N			
65.0						qtz ss, sh	gy	vf-f	P	a								N			
67.5						qtz ss, sh	tn-gy	vf-f	P	a								N			
70.0						sh	gy											N			
72.5						sh, qtz ss	gy-ortn	f-m	P	a	L							N			
75.0						qtz ss	lt tn	m	m	a	L							N			
77.5						qtz ss	lt tn	m-cr	m	a								N			
80.0						qtz ss	lt tn	m-peb	m	a	L							N			
82.5						qtz ss	wh	m	m	a								N			
85.0						qtz ss	wh	m-cr	m	a								N			
87.5						qtz ss	wh	m-cr	m	a								S			
90.0						qtz ss, sh	lt tn	m-cr	m	r								W			
92.5						qtz ss, sh	ltgn-tn	m-cr	m	r								N			
95.0						sh	gn-ppbn											N			
97.5						sh	gn-ppbn											N			
100.0						sh, qtz ss	gn-ppbn											N			
102.5						qtz ss, sh	gn-tn	m	m	r	L							N			
105.0						qtz ss	gy gn	f-m	m	r			<1%	C				N			
107.5						qtz ss	gy gn	f-m	m	r								N			
110.0						qtz ss	gy gn	f-m	m	r								N			
112.5						qtz ss	ltgy	f-m	P	r			1%	c				N			pyrite noted.
115.0						qtz ss	ltgy	f-m	P	a								N			
117.5						qtz ss	vltgy	f-m	m	a								N			
120.0						qtz ss, sh	ltgy	f-m	m	a								N			
122.5						qtz ss	ltgy	f-vcr	P	a	L							N			chert frags.
125.0						qtz ss	ltgy	f-m	m	a								N			

PERCENTAGE COMPOSITION IMAGE

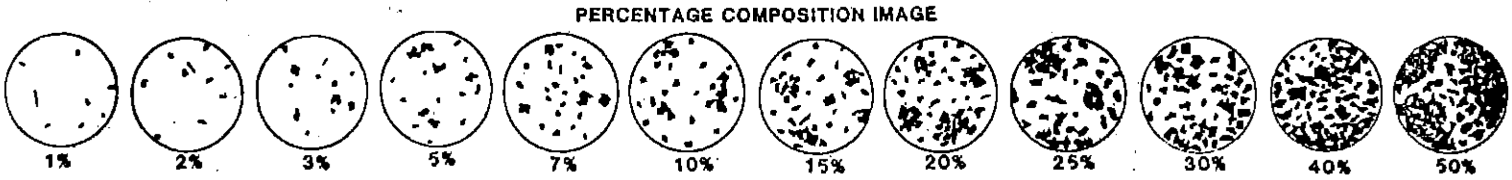


Date 10-9-09 Geologist L. Casebolt Drilling Co. Byles Exploration, Inc. Hole No. TWN-18
Property White Mesa Mill Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____
County San Juan State Utah Location ____ Elev. ____

PAGE 2 OF 2
T.D. PROBE ____
T.D. DRILL 145.0
FLUID LEVEL 57

DEPTH	SAMPLE TAKEN	GRAPHIC LOG	ALTERATION	GAMMA ANOMALY	BRECCIA PIPE	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	CEMENT MATRIX	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	PYRITE ALTER.	METALLIC	NON-METALLIC	REACT.-10% HCL	CARBON AMOUNT	CARBON TYPE	REMARKS
0																					
127.5						qtz ss	ltgy	f-cr	p	a								N			
130.0						qtz ss	ltgy	f-cr	p	a		L						N			chert frags.
132.5						qtz ss, sh	ltgy	f-m	m	a		L						N			
135.0						qtz ss	ltgy	f-m	m	a								N			
137.5						qtz ss	gy	f-m	m	a								N			
140.0						sltst	gy											N			
142.5						sltst: sh	gy-rdbn											W			
145.0						sh	rdbn											N			Upper Brushy Brushy Basin fm ct@ 142.0
TD																					

PERCENTAGE COMPOSITION IMAGE



Date 10-12-09 Geologist L. Casebolt Drilling Co. Bayles Exploration, Inc. Hole No. TWN-19

Property White Mesa Mill Project Nitrate Study Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. ____

PAGE 1 OF 1
T.D. PROBE ____
T.D. DRILL 110.0 TD
FLUID LEVEL ____

DEPTH	LITHOLOGY	COLOR OF WET SAMPLE	GRAIN SIZE	SORTING	ANGULARITY	IRON OXIDE	PYRITE AMOUNT	PYRITE HABIT	REACT.-10% HCL	REMARKS
0–2.5	mdst sltst	rdbn							W	Surface soil
5.0	mdst, sltst	rdbn							S	
7.5	qtz ss	dk tn	m	M	r	L			N	Upper Dakota Ct @ 5.0'
10.0	qtz ss	tn	m-cr	P	a				N	some wh chert grains
12.5	qtz ss	dktn	m-cr	P	a				N	" " " "
15.0	qtz ss	tn	m cr	P	a				N	abund multi colored chert frags.
17.5	qtz ss	tn	m-cr	P	a	L			N	" " " " "
20.0	qtz ss	tn	m-cr	P	a				N	
22.5	qtz ss, cgl	tn	m-peb	P	a				N	moisture first noted from 20.0
25.0	cgl, qtz ss	bn	m peb	P	a				N	abund. multi colored chert pebbles
27.5	cgl, qtz ss	bn	m peb	P	a				N	" " " " "
30.0	qtz ss	tn	m vcr	P	a				N	
32.5	qtz ss	tn	f-m	P	a				N	
35.0	qtz ss	tn	m-cr	P	a				N	begin H2O from inject @ 35'
37.5	qtz ss	tn	m	m	r				N	
40.0	qtz ss, cgl	lt gy	m-peb	m	a				N	
42.5	qtz ss	lt gy tn	f-m	P	a				N	
45.0	qtz ss	lt gy tn	f-m	P	a				N	
47.5	qtz ss	lt tn	f-m	P	a				N	
50.0	cgl, qtz ss	lt gy tn	f-peb	P	a				N	
52.5	qtz ss, cgl	lt gy tn	f-peb	P	a				N	
55.0	qtz ss	tn	f-vcr	P	a				N	
57.5	qtz ss cgl	or tn	f-peb	P	a				N	
60.0	sh, qtz ss	gy tn							N	
62.5	sltst	lt gy							N	
65.0	sltst, sh	lt gy							N	
67.5	qtz ss sltst	lt gy	vf-f	P	a				N	
70.0	qtz ss	lt gy	vf-f	P	a				N	
72.5	qtz ss	lt gy-lt bn	vf-m	P	a	L			N	
75.0	qtz ss	lt gy-tn	vf-m	P	a	L			N	
77.5	qtz ss-sltst	lt gy-tn	vf-m	P	a				N	
80.0	qtz ss	lt gy-tn	f-vcr	P	r				N	
82.5	qtz ss, sltst	lt gy-tn	vf-m	P	a	L	<1%	C	N	
85.0	qtz ss	wh	f-m	P	a		<1%	C	N	
87.5	qtz ss	wh	f-m	P	a				N	
90.0	qtz ss	wh	f-m	P	a				N	
92.5	qtz ss, cgl	wh-gy	m-peb	P	a		Tr	C	N	some chert pebbles and frags.
95.0	qtz ss, cgl	gy-wh	m-peb	P	a				N	
97.5	sh, cgl, qtz ss	gy-bn	m-peb	P	a				N	
100.0	sh	gy							N	
102.5	qtz ss cgl	gy-rdbn	m-peb	P	a				N	
105.0	sh, qtz ss	gy	f-m	P	a				N	Brushy Basin Ct @ 105.0'
107.5	sh	rdbn							N	
110.0	sh	pp bn-gn							N	
TD.										

(Other form columns — Sample Taken, Graphic Log, Alteration, Gamma Anomaly, Breccia Pipe, Cement Matrix, Pyrite Alter., Metallic, Non-Metallic, Carbon Amount, Carbon Type — have no entries.)

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

SAMPLE DESCRIPTION KEY

DEPTH SCALE
Scale is 1"-50' for drill samples and 1"-5' for core.

SAMPLE TAKEN

Mark through interval which special chip sample is saved, with an "X" mark through core interval with shading.

GRAPHIC LOG
Standard rock symbol for interval.

ALTERATION
- | Reduction
- ‡ Dissolution
- ° Oxidation

GAMMA ANOMALY (Probe)

T	3xBG - .009	Trace
1	.010 - .049	Low Mineral
2	.050 - .199	High Mineral
3	.200 >	Ore

BRECCIA PIPE
- | Definate
- | Unsure

LITHOLOGY
Standard abbreviation for rock type.

COLOR
GSA Rock-Color Chart of wet samples.

GRAIN SIZE

Sandstone		Carbonates
Peb	Pebble	
vc	Very Coarse	vc
c	Coarse	c
m	Medium	m
f	Fine	f
vf	Very Fine	vf

SORTING
- W Well-sorted
- M Moderately-sorted
- P Poorly-sorted
- U Un-sorted

ANGULARITY
- VA Very Angular
- A Angular
- a subangular
- r Subrounded
- R Rounded
- WR Well Rounded

CEMENT-MATRIX
- A Argillaceous
- C Carbonate
- D Dolomite
- S Silica
- F Ferruginous

IRON OXIDE

H	Hematite	A	Abundant
L	Limonite	M	Moderate
G	Geothite	T	Trace

PYRITE-MARCASITE
Amount - In percent.

Habit
- A Aggregate
- C Interangular cement
- G Globules
- I Individual
- M Massive
- MT Marcasitic texture
- O Organic replacement

Alteration
- F Fresh
- T Tarnished
- P Pseudomorphs after pyrite

METALLIC MINERALS
Mark with an "X" and clarify in remarks and metallic minerals observed. (MoS_2,NiS,PbS,UO_2,CU_2O,etc.)

NON-METALLIC MINERALS
Mark with an "X" and clarify in remarks any non-metallic minerals observed. (Barite, Anhydrite, Gypsum, Calcite, etc.)

REACTION -10% HCL
- VS Very Strong
- S Strong
- M Moderate
- W Weak
- VW Very Weak
- N None

CARBON MATERIAL
Amount - In percent

Type
- C Coal
- F Distinct woody fragments
- H Humic
- HY Hydrocarbon
- I Interbedded trash
- L Lignitic

BRECCIA NOMENCLATURE
See sample manual - use grain size, sorting and angularity columns for classification and description.

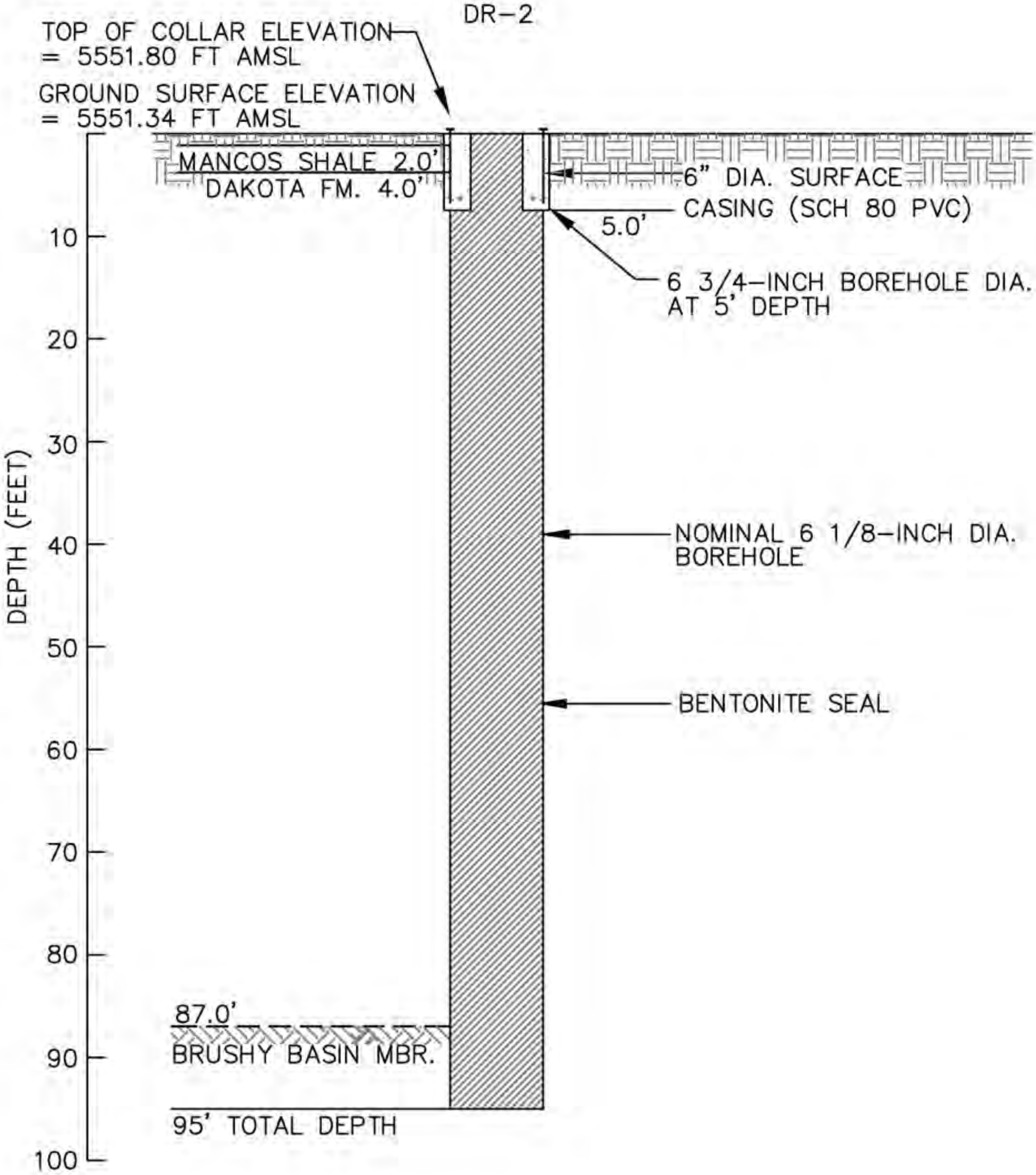
REMARKS
Use to clarify and expand on the columnar data. Explain anything not evident or any special characteristics such as: heavy minerals, tuffaceouness, cyclic sedimentation, fossils, sedimentary structures, formation picks, etc.

APPENDIX B

WELL CONSTRUCTION SCHEMATICS

APPENDIX B.1

DR - SERIES

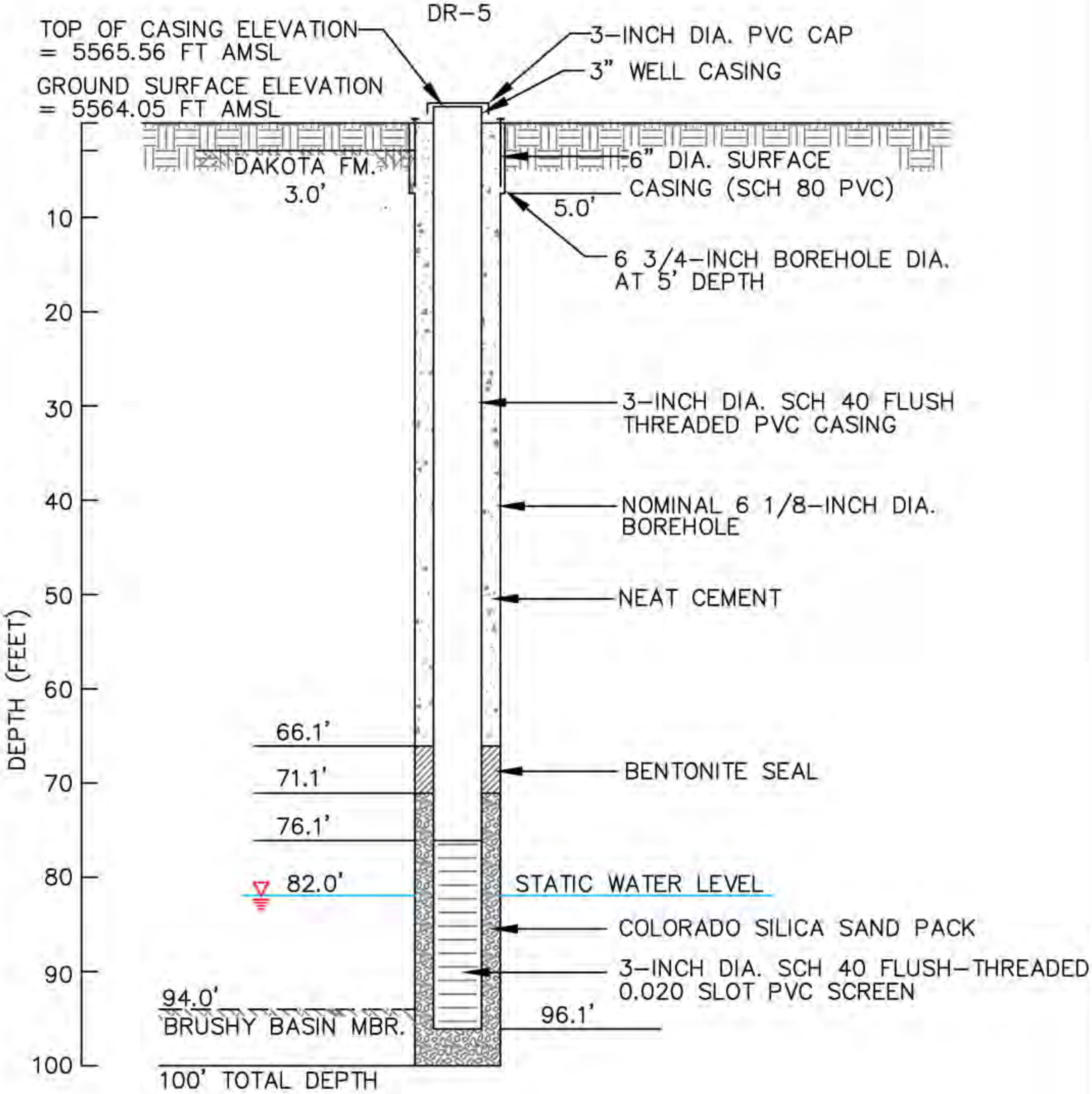


NOT TO SCALE

HYDRO GEO CHEM, INC.

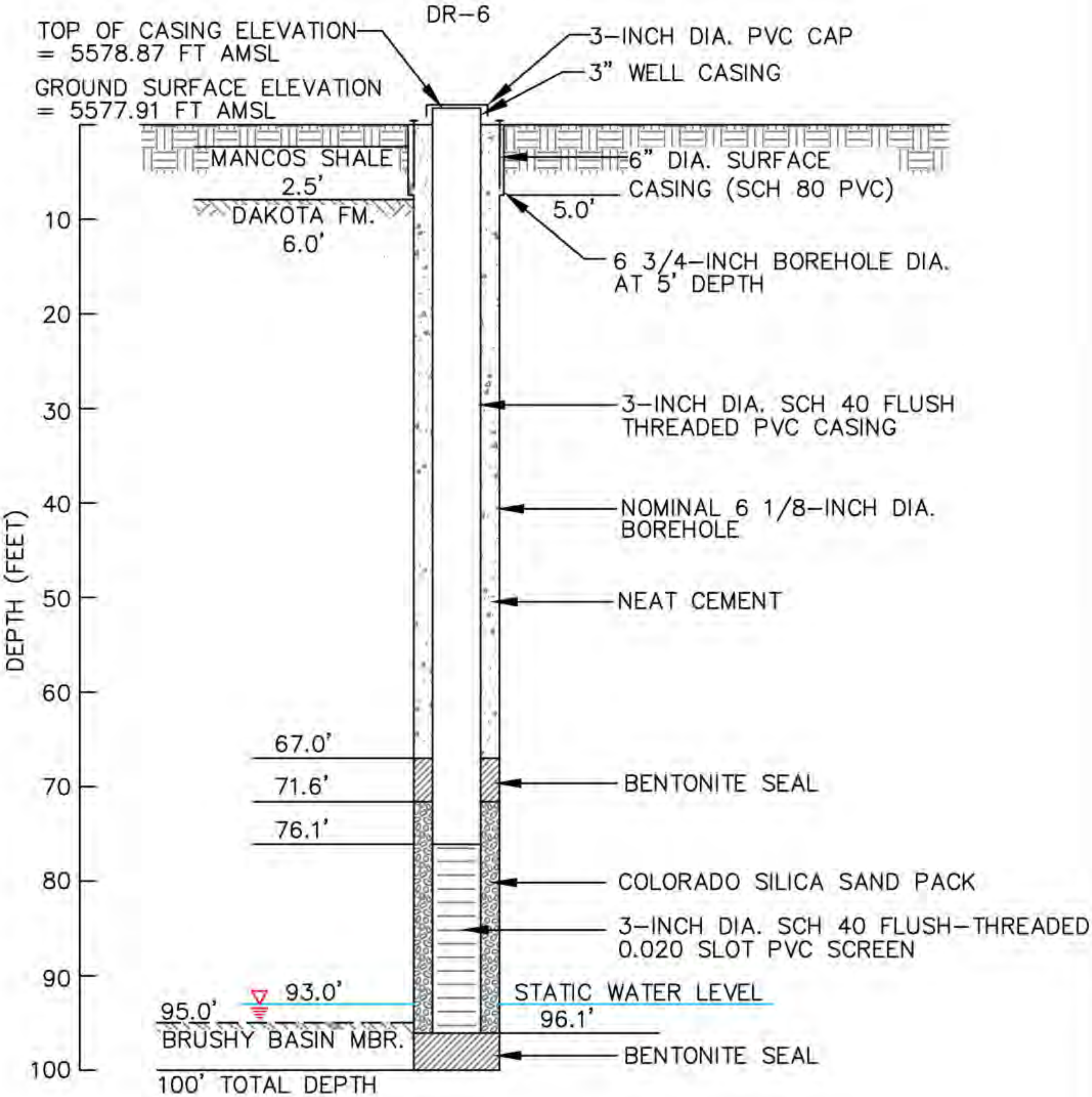
DR-2
WELL ABANDONMENT SCHEMATIC

Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180271A Well Construction Diagram	



NOT TO SCALE

HYDRO GEO CHEM, INC.	DR-5 AS-BUILT WELL CONSTRUCTION SCHEMATIC		
Approved SJS	Date 1/9/12	Reference K:\7180250A Well Construction Diagram	Figure

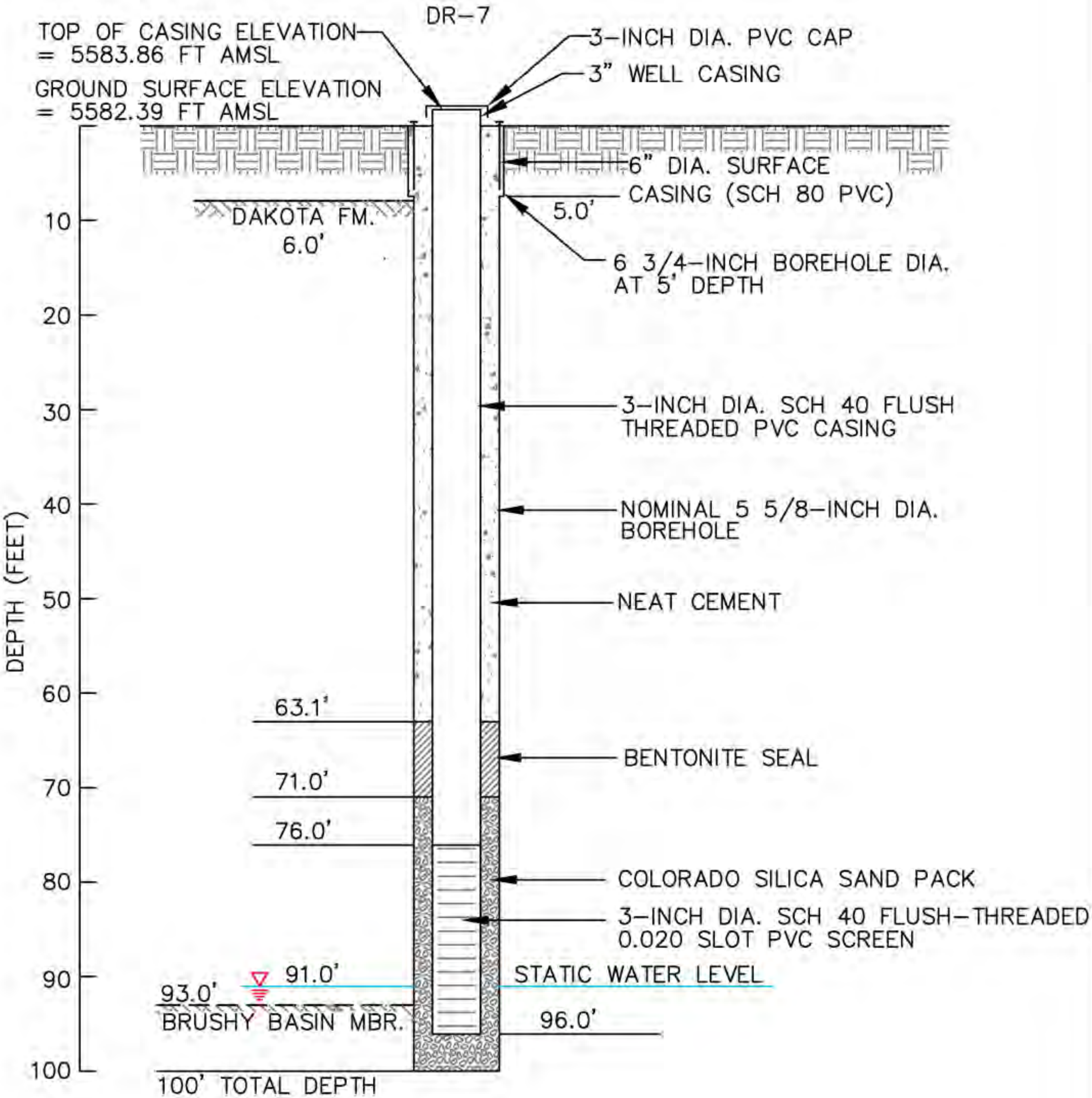


NOT TO SCALE

HYDRO GEO CHEM, INC.

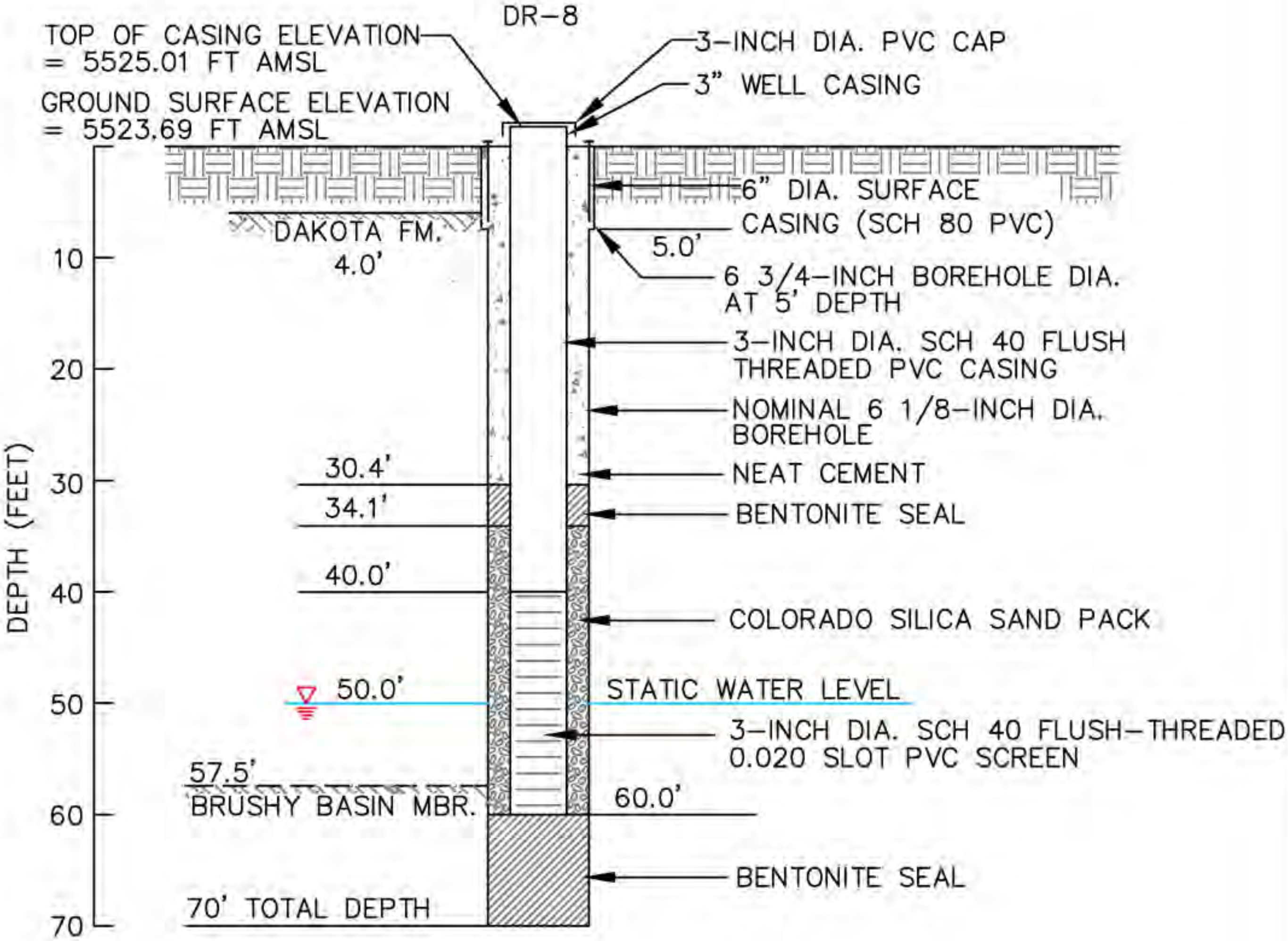
DR-6
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180251A Well Construction Diagram	



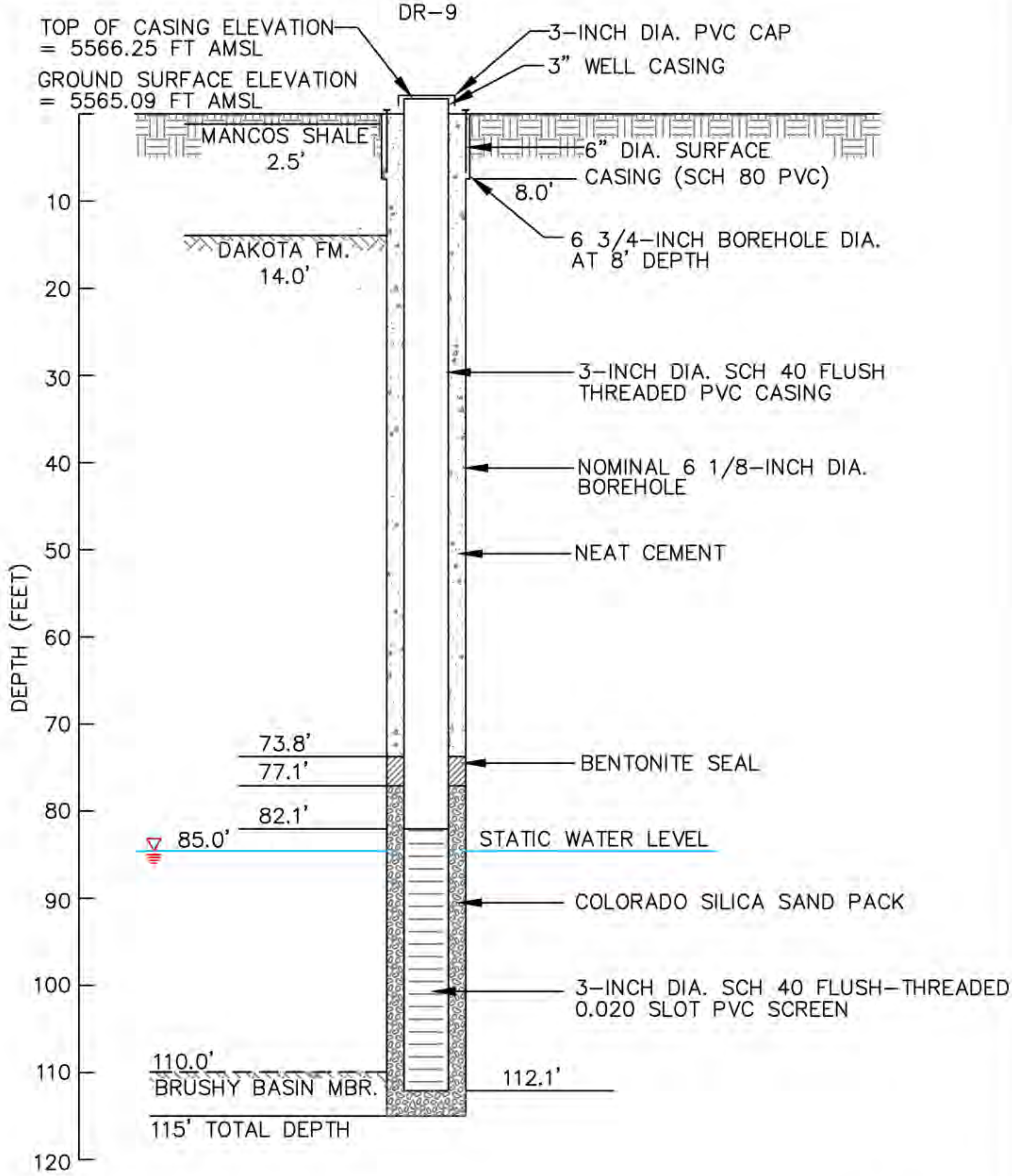
NOT TO SCALE

HYDRO GEO CHEM, INC.	DR-7 AS-BUILT WELL CONSTRUCTION SCHEMATIC		
Approved SJS	Date 1/9/12	Reference K:\7180252A Well Construction Diagram	Figure



NOT TO SCALE

HYDRO GEO CHEM, INC.	DR-8 AS-BUILT WELL CONSTRUCTION SCHEMATIC		
Approved: SJS	Date: 1/9/12	Reference: K:\7180253A Well Construction Diagram	Figure

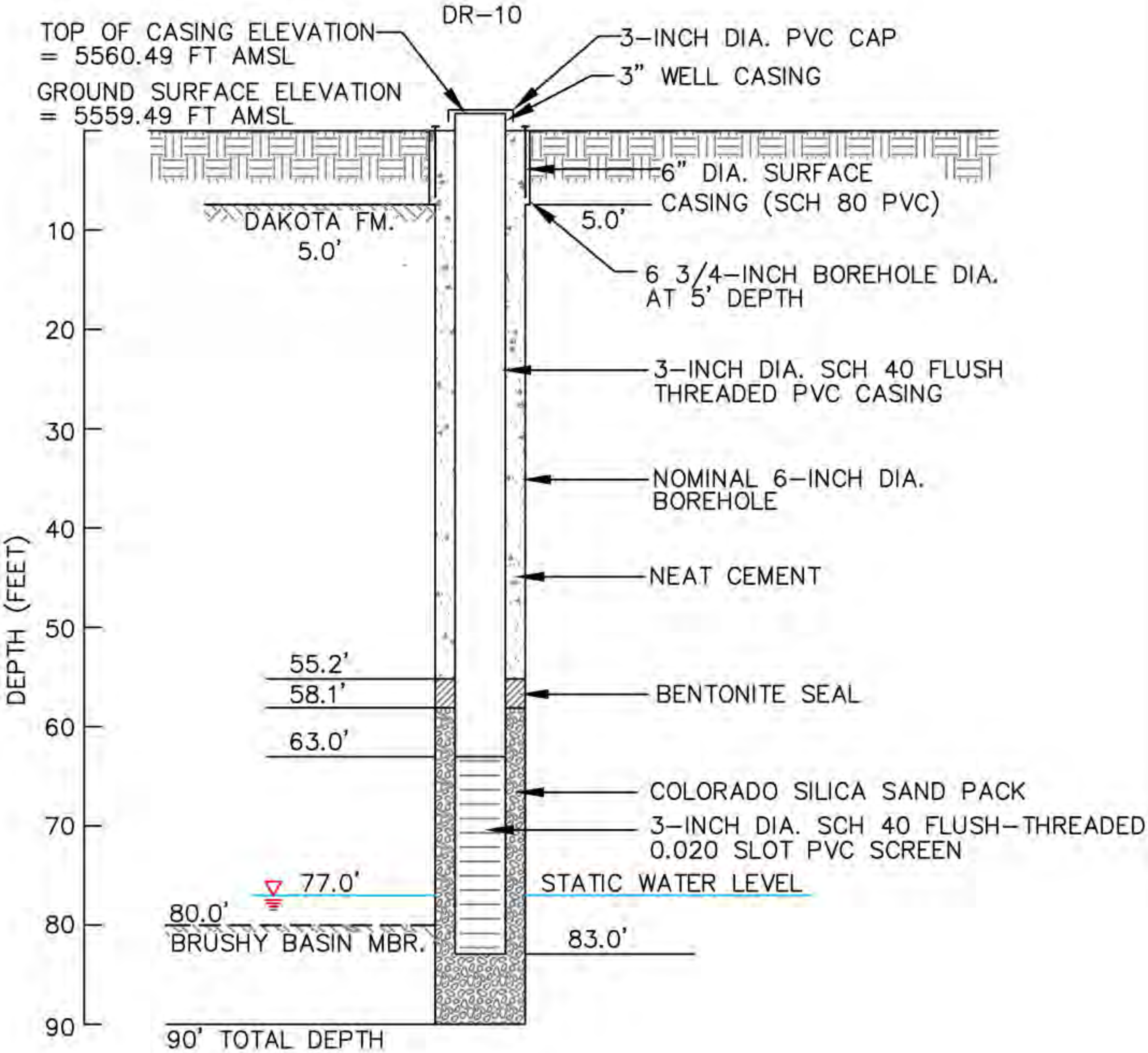


NOT TO SCALE

HYDRO GEO CHEM, INC.

DR-9
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180254A Well Construction Diagram	

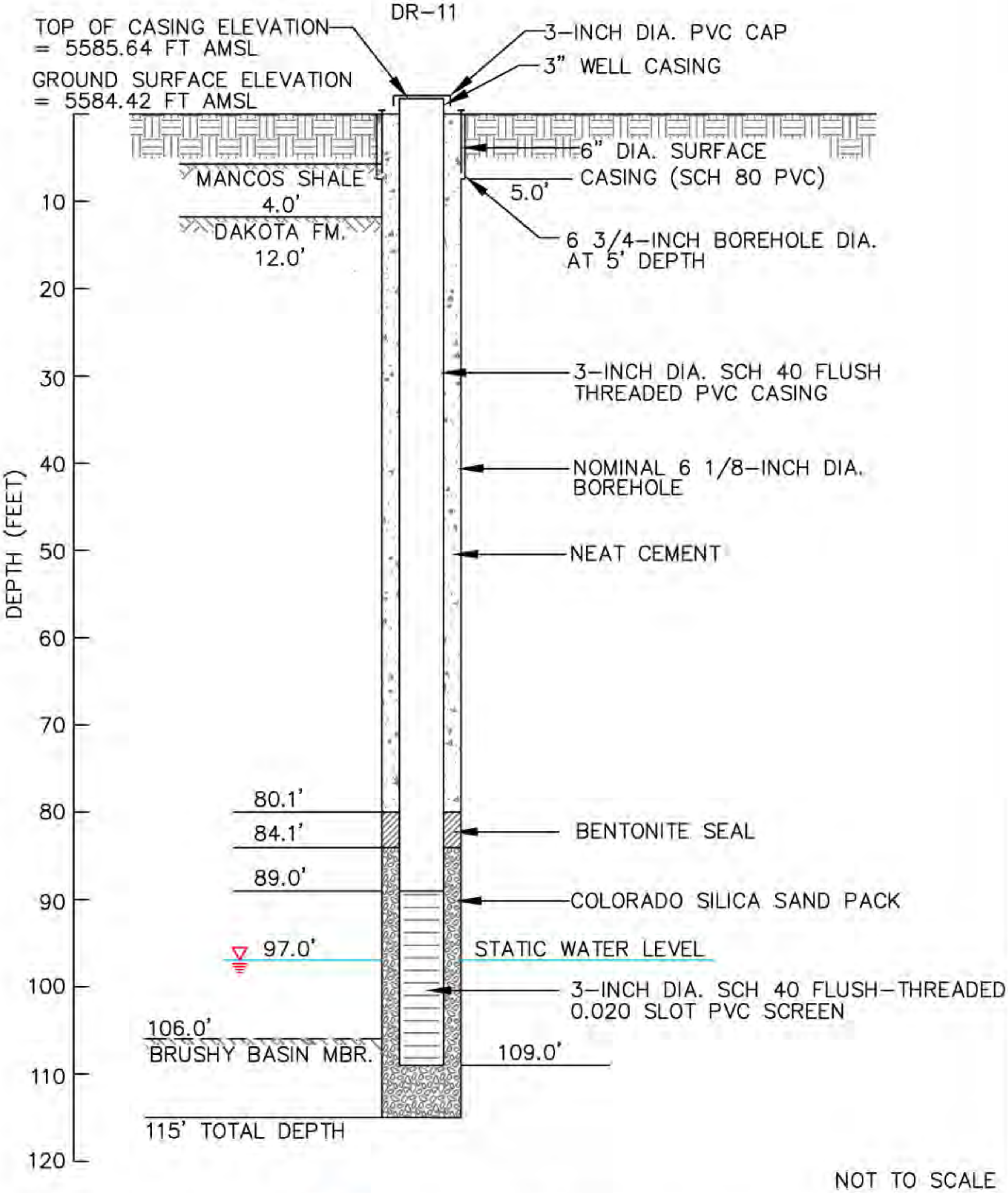


NOT TO SCALE

HYDRO GEO CHEM, INC.

DR-10
AS-BUILT WELL CONSTRUCTION SCHEMATIC

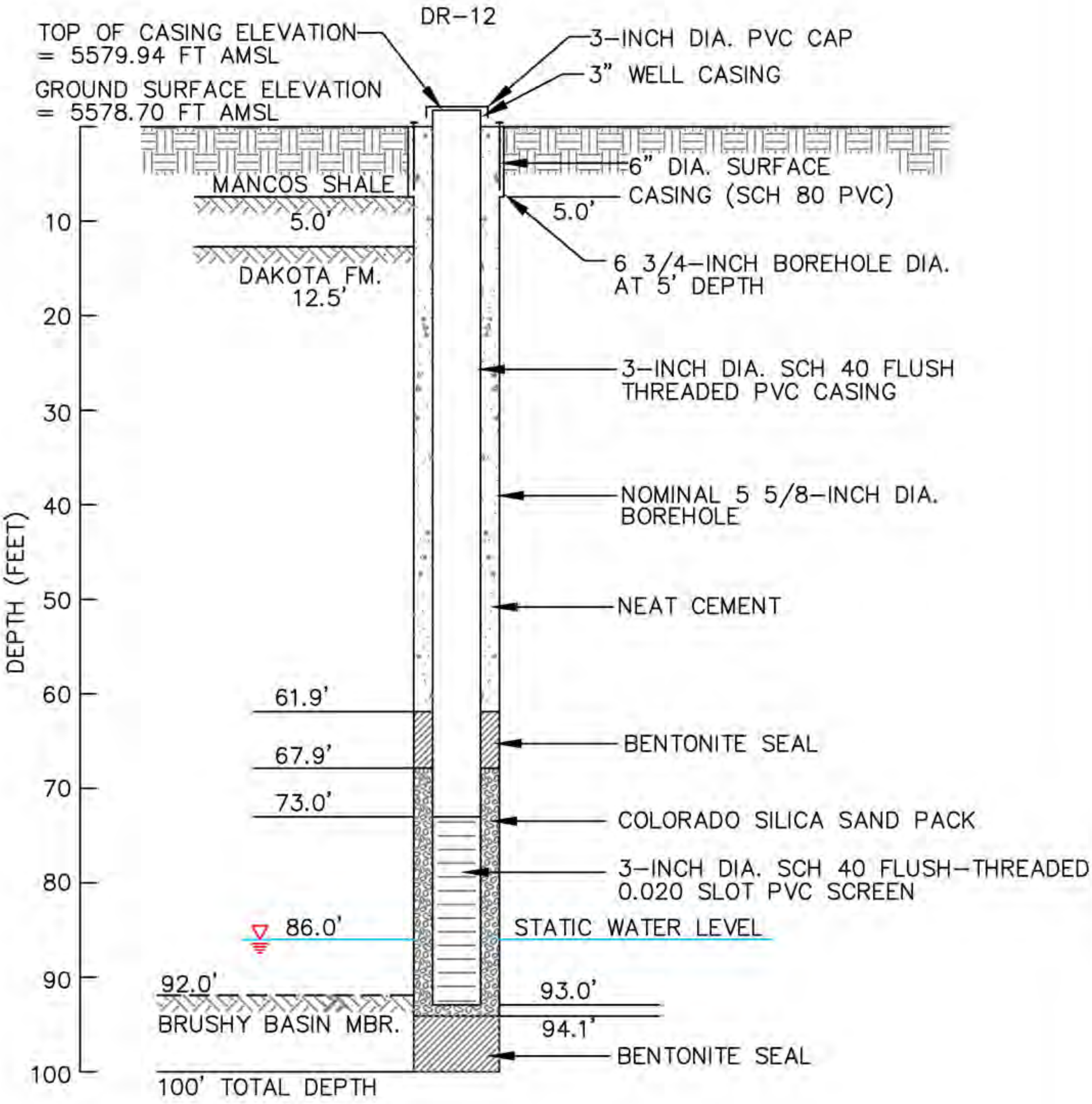
Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180255A Well Construction Diagram	7



HYDRO GEO CHEM, INC.

DR-11
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180256A Well Construction Diagram	8

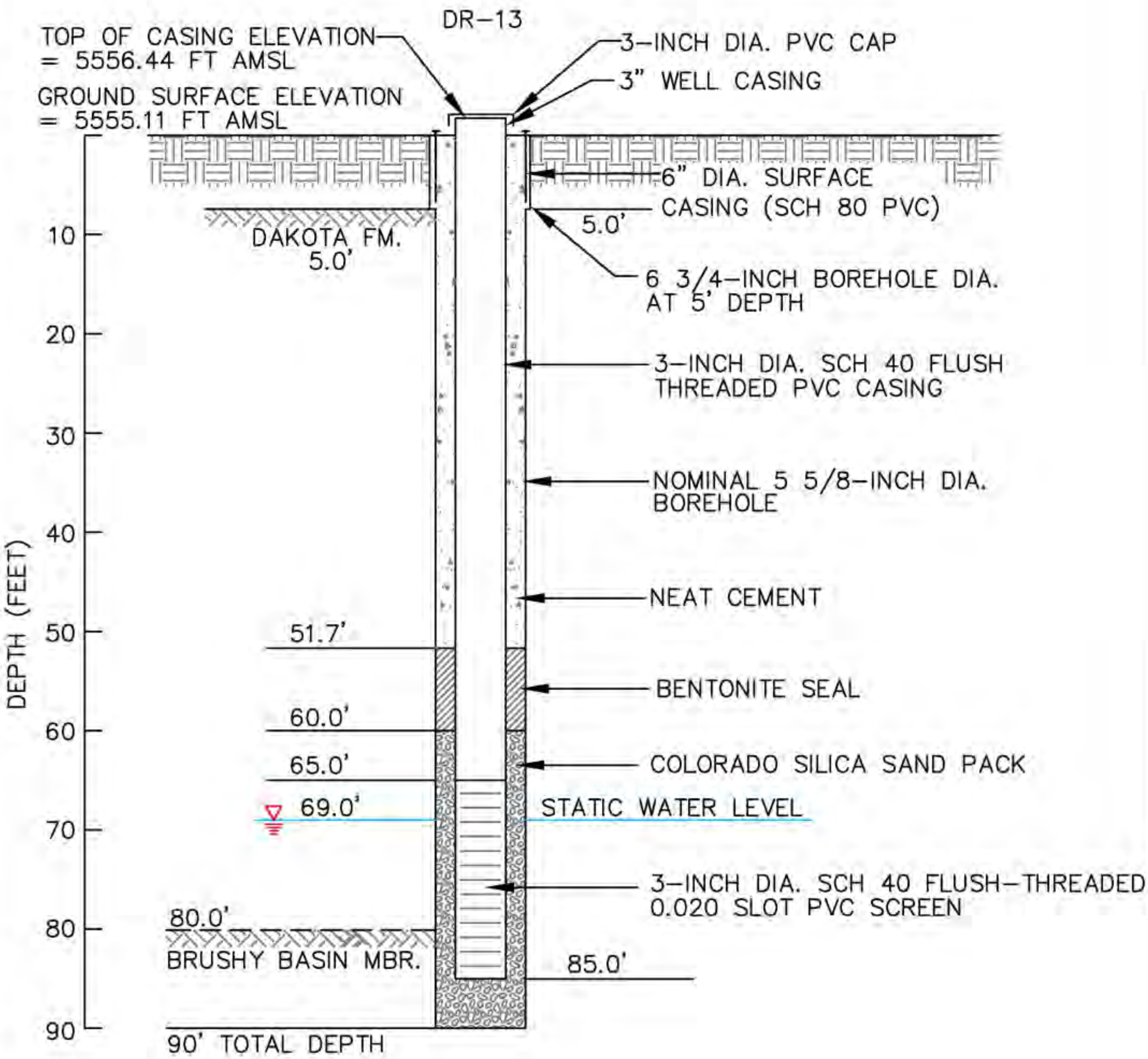


NOT TO SCALE

HYDRO GEO CHEM, INC.

DR-12
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180257A Well Construction Diagram	

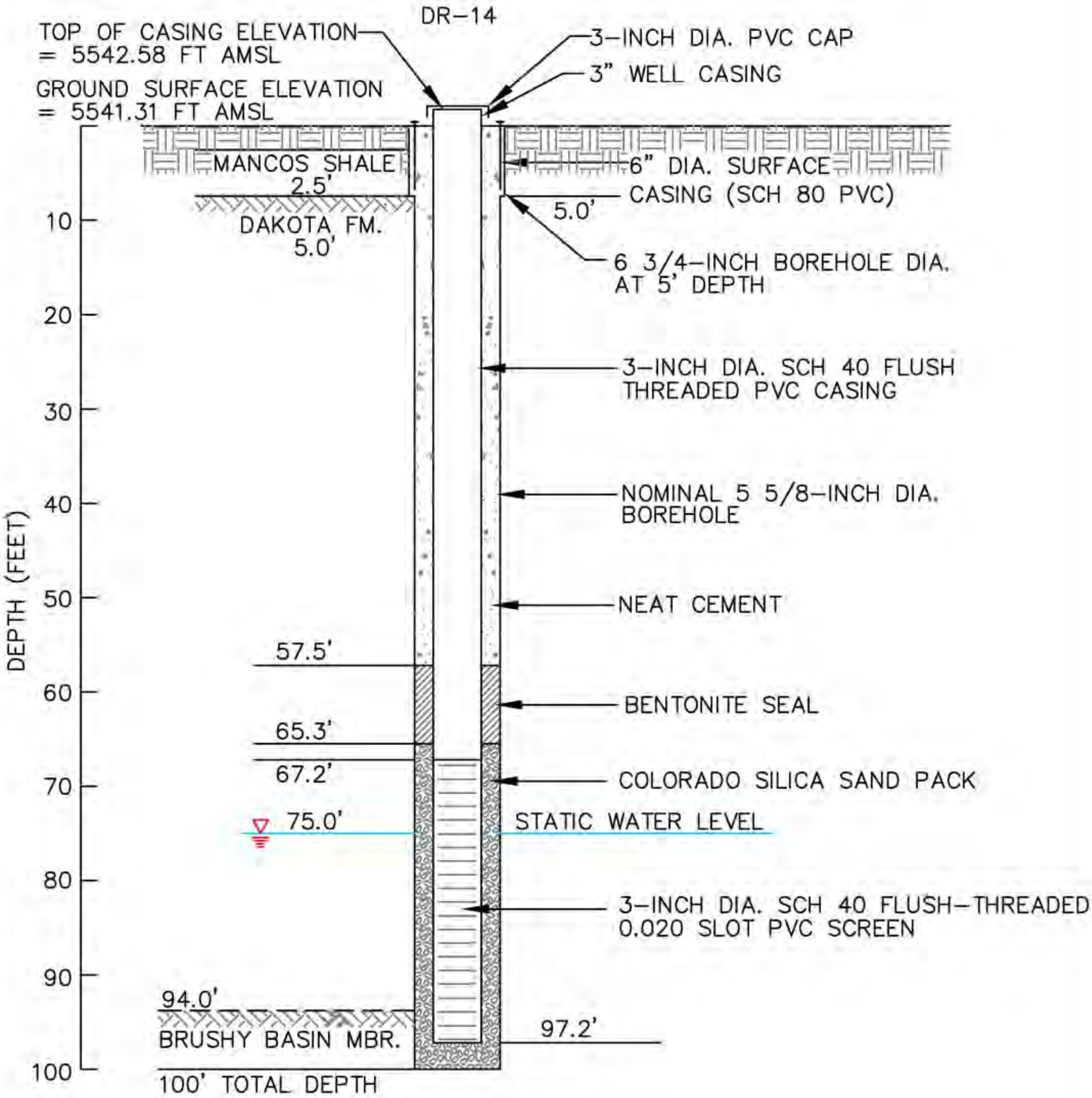


NOT TO SCALE

HYDRO GEO CHEM, INC.

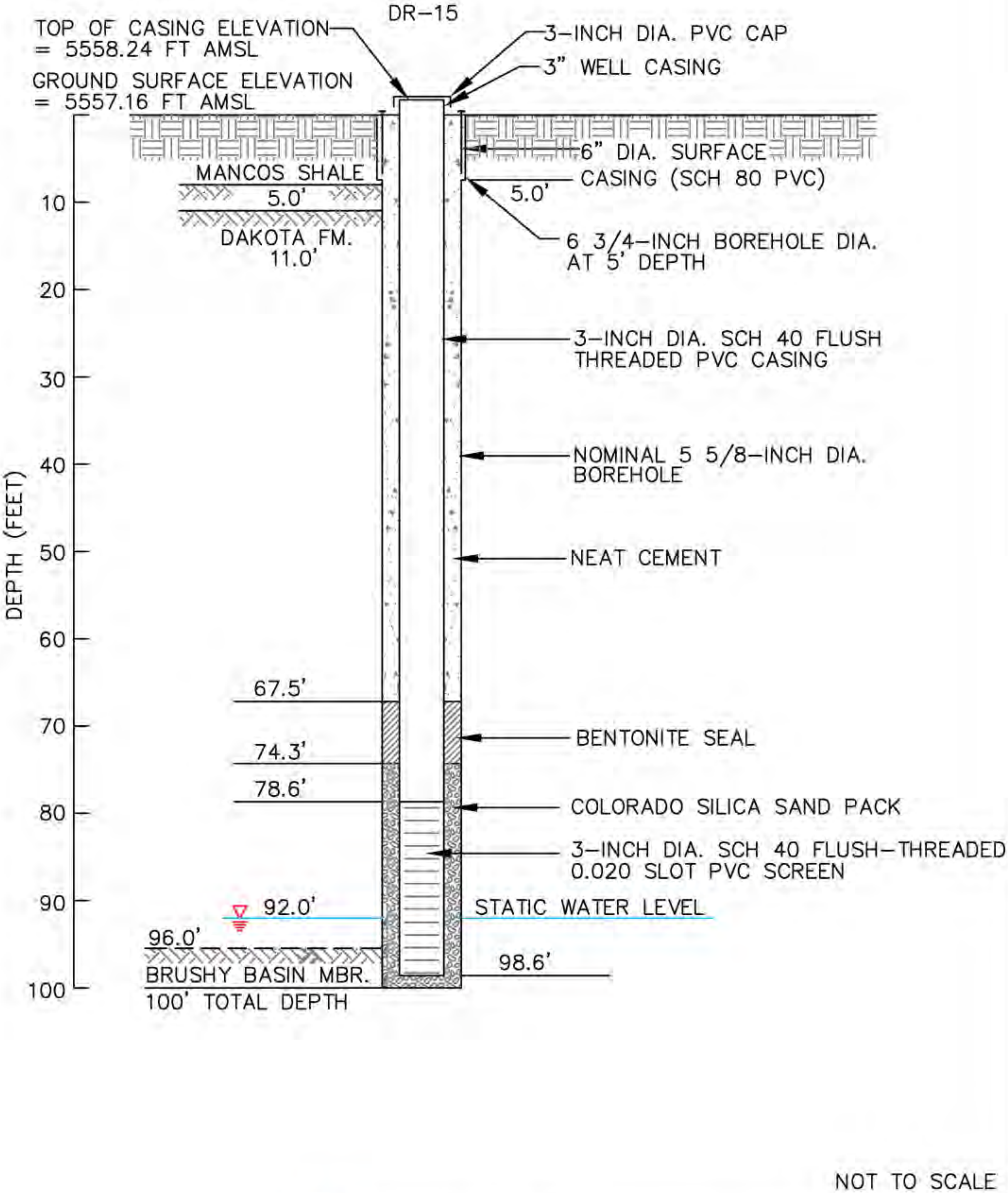
DR-13
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180258A Well Construction Diagram	



NOT TO SCALE

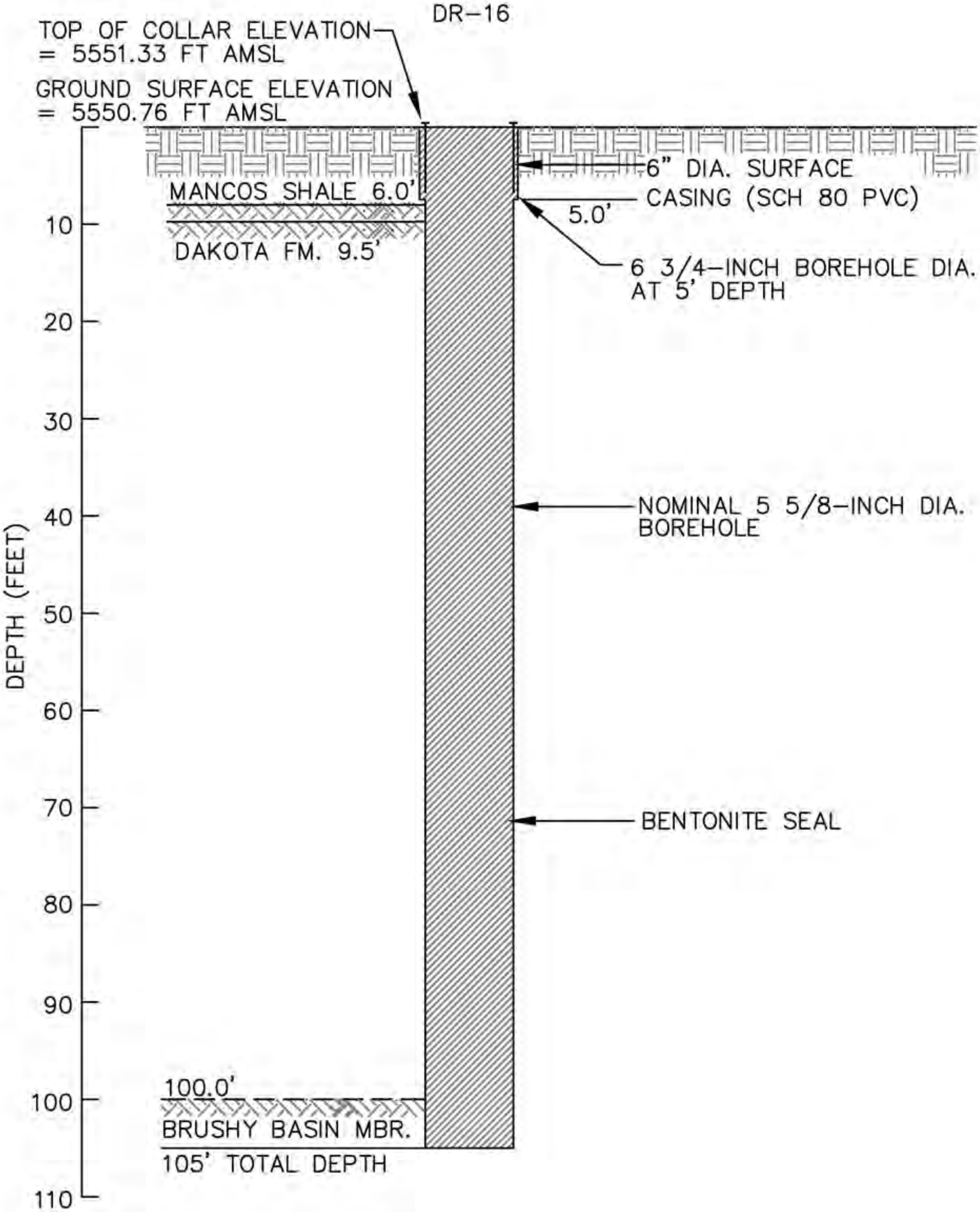
HYDRO GEO CHEM, INC.	DR-14 AS-BUILT WELL CONSTRUCTION SCHEMATIC		
Approved: SJS	Date: 1/9/12	Reference: K:\7180259A Well Construction Diagram	Figure



HYDRO GEO CHEM, INC.

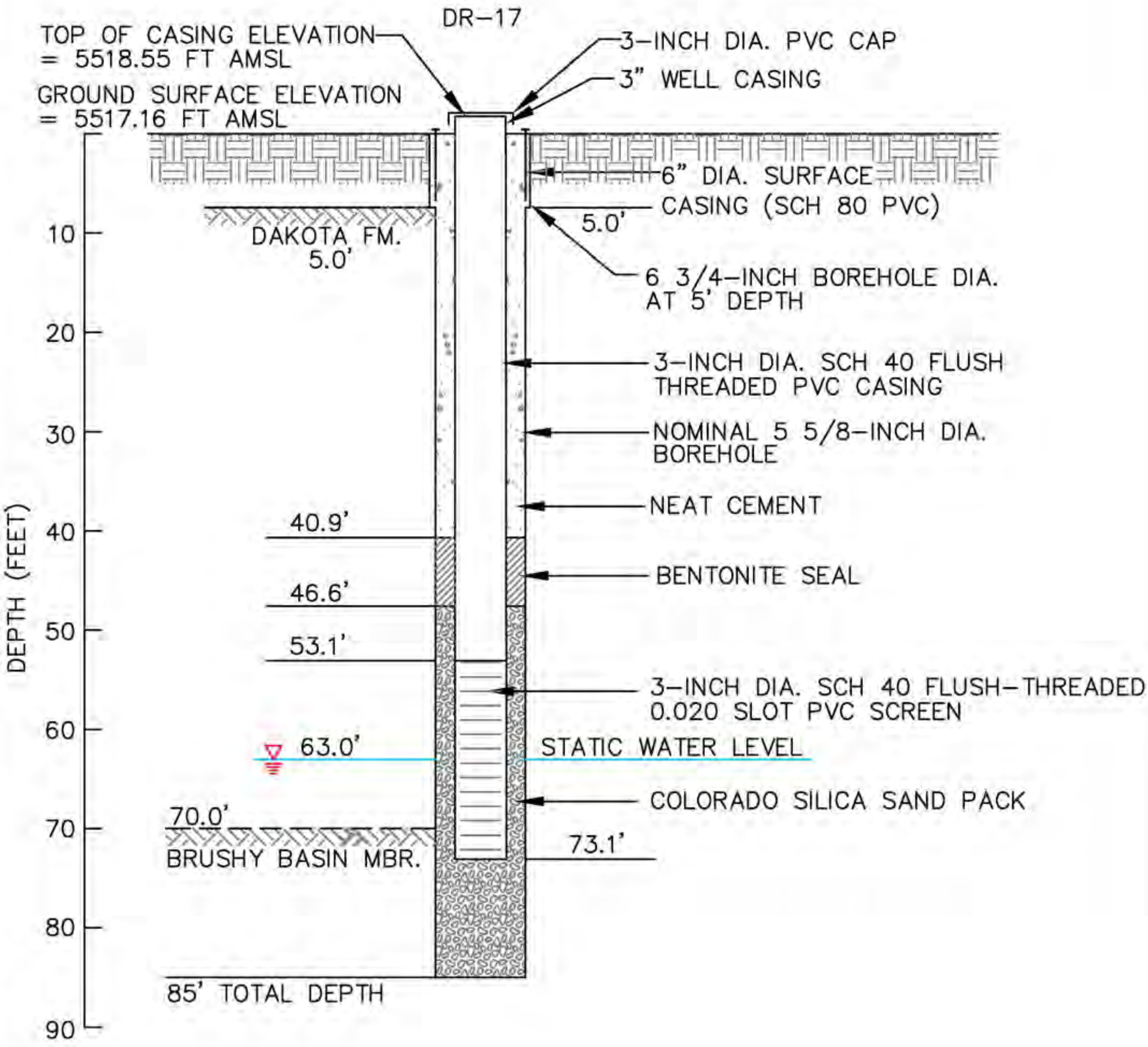
DR-15
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180260A Well Construction Diagram	



NOT TO SCALE

HYDRO GEO CHEM, INC.	DR-16 WELL ABANDONMENT SCHEMATIC		
Approved SJS	Date 1/9/12	Reference K:\7180261A Well Construction Diagram	Figure

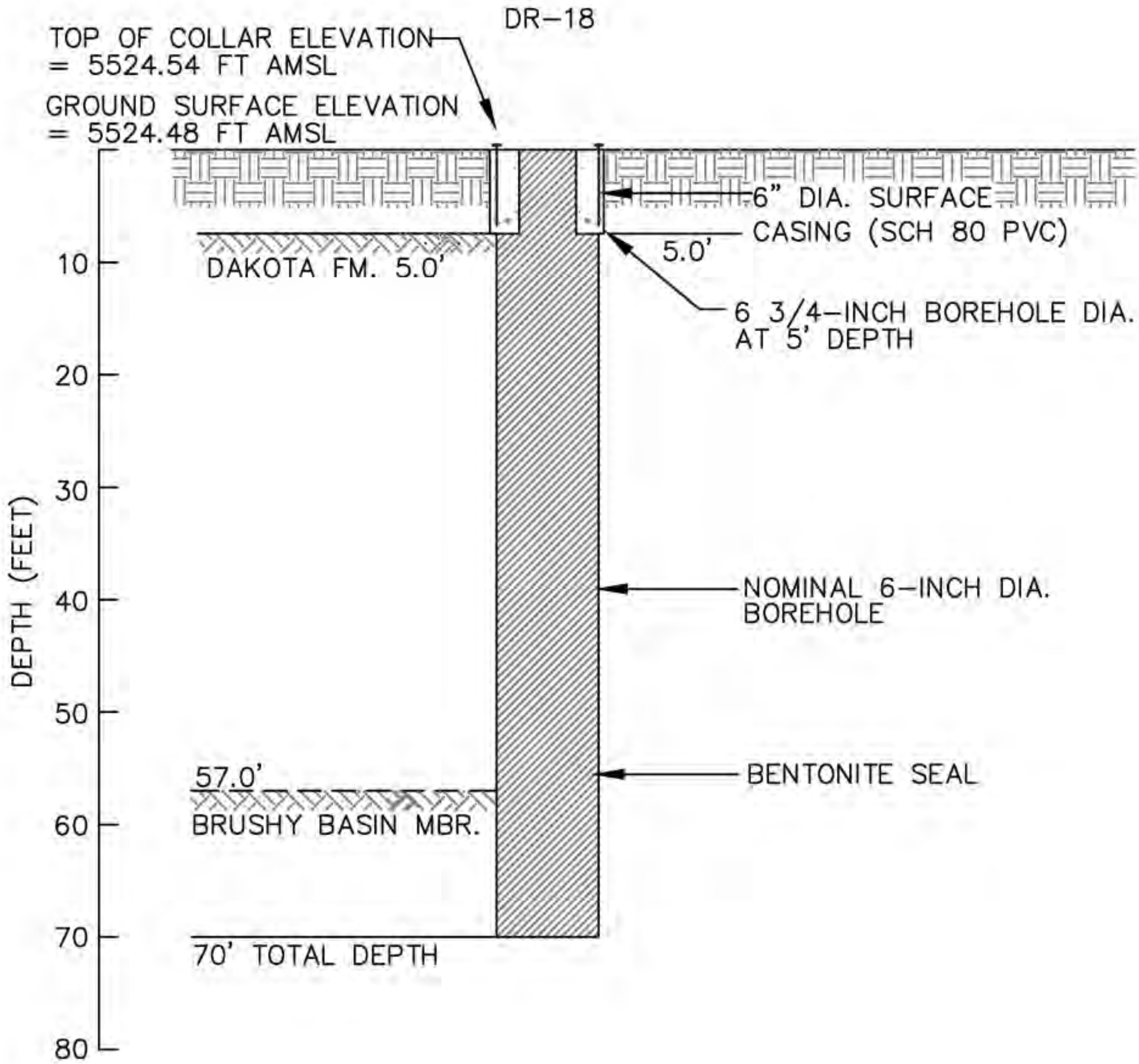


NOT TO SCALE

HYDRO GEO CHEM, INC.

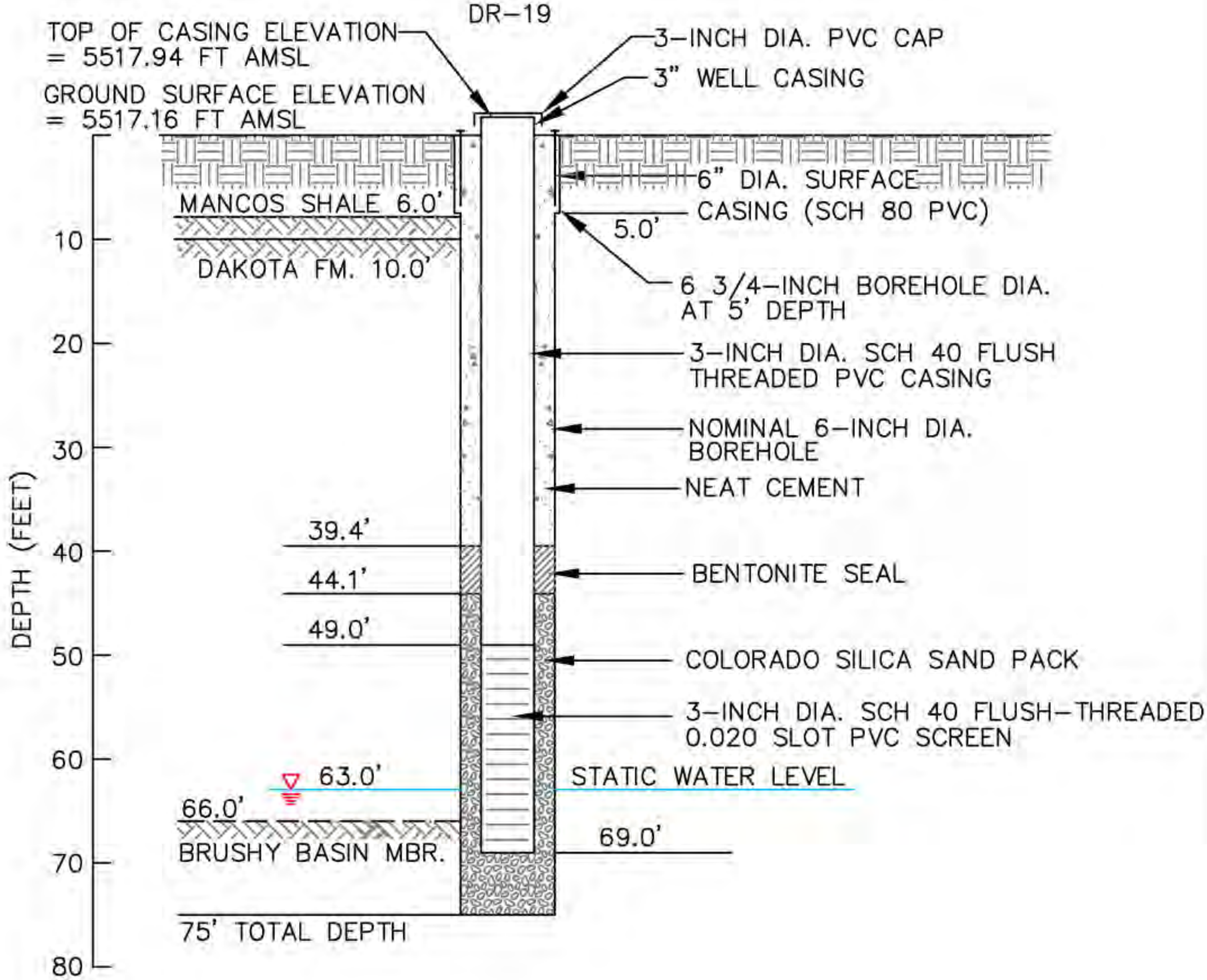
DR-17
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180262A Well Construction Diagram	



NOT TO SCALE

HYDRO GEO CHEM, INC.	DR-18 WELL ABANDONMENT SCHEMATIC		
Approved: SJS	Date: 1/9/12	Reference: K:\7180263A Well Construction Diagram	Figure

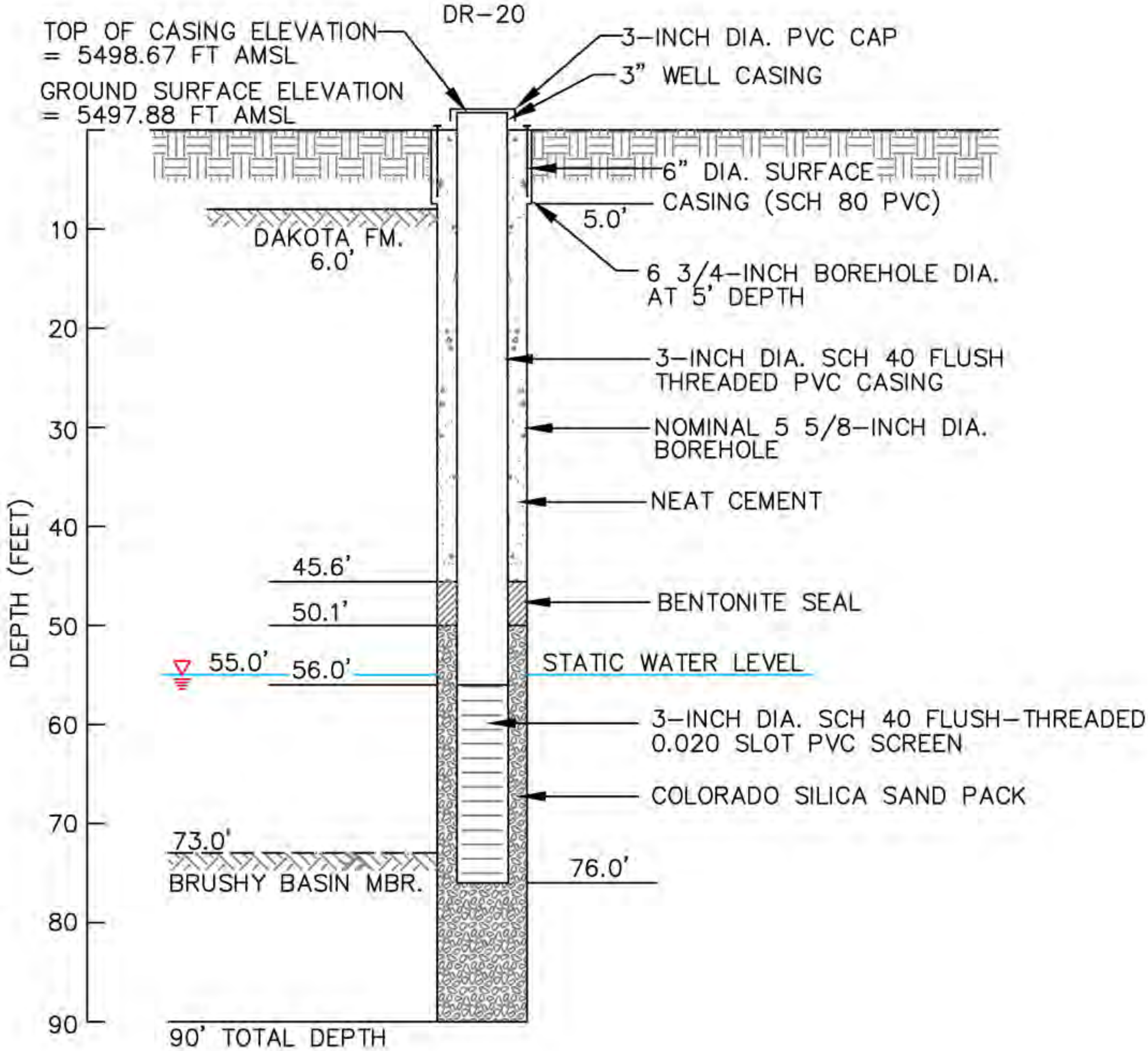


NOT TO SCALE

HYDRO GEO CHEM, INC.

DR-19
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180264A Well Construction Diagram	

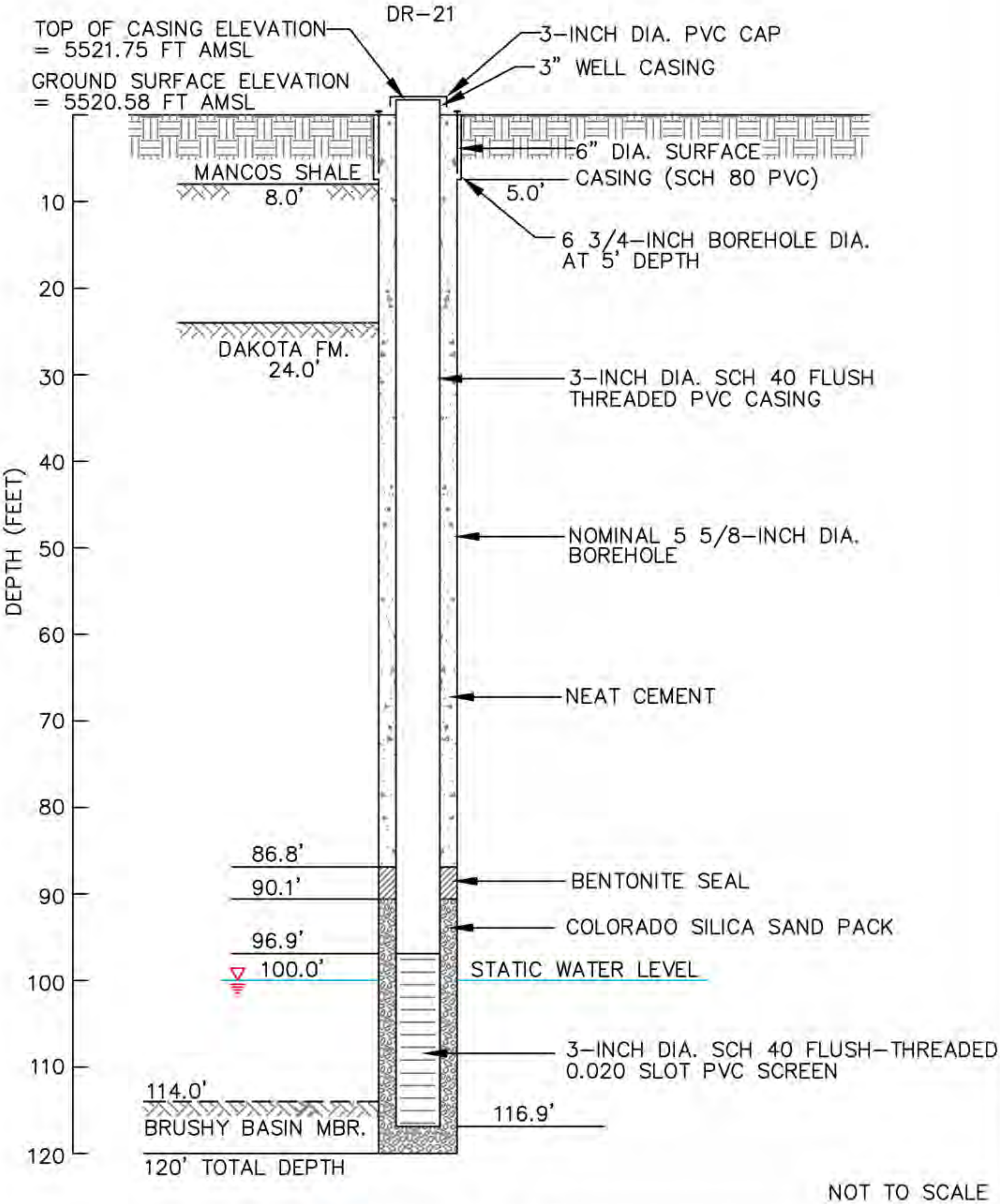


NOT TO SCALE

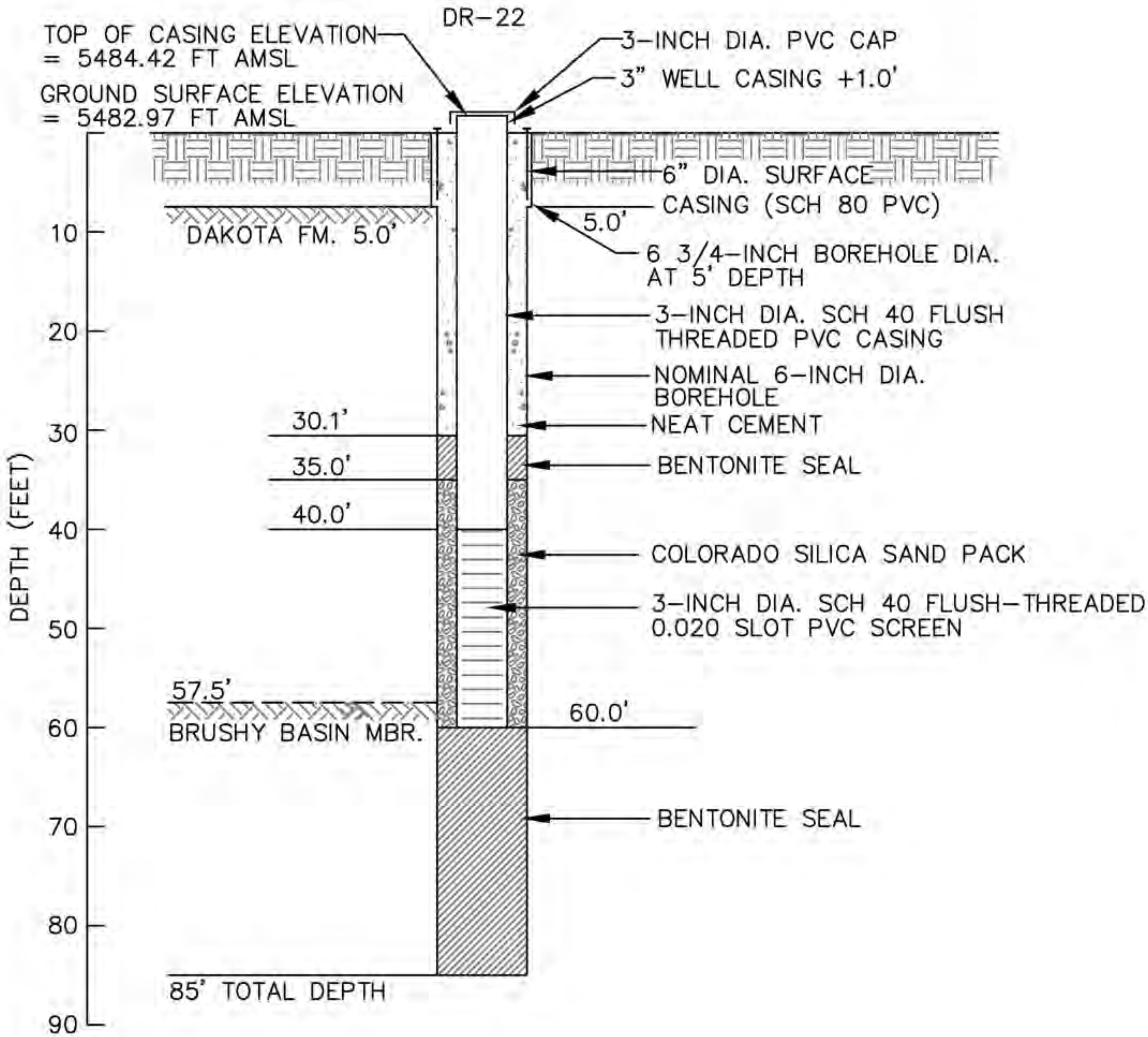
HYDRO GEO CHEM, INC.

DR-20
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180265A Well Construction Diagram	

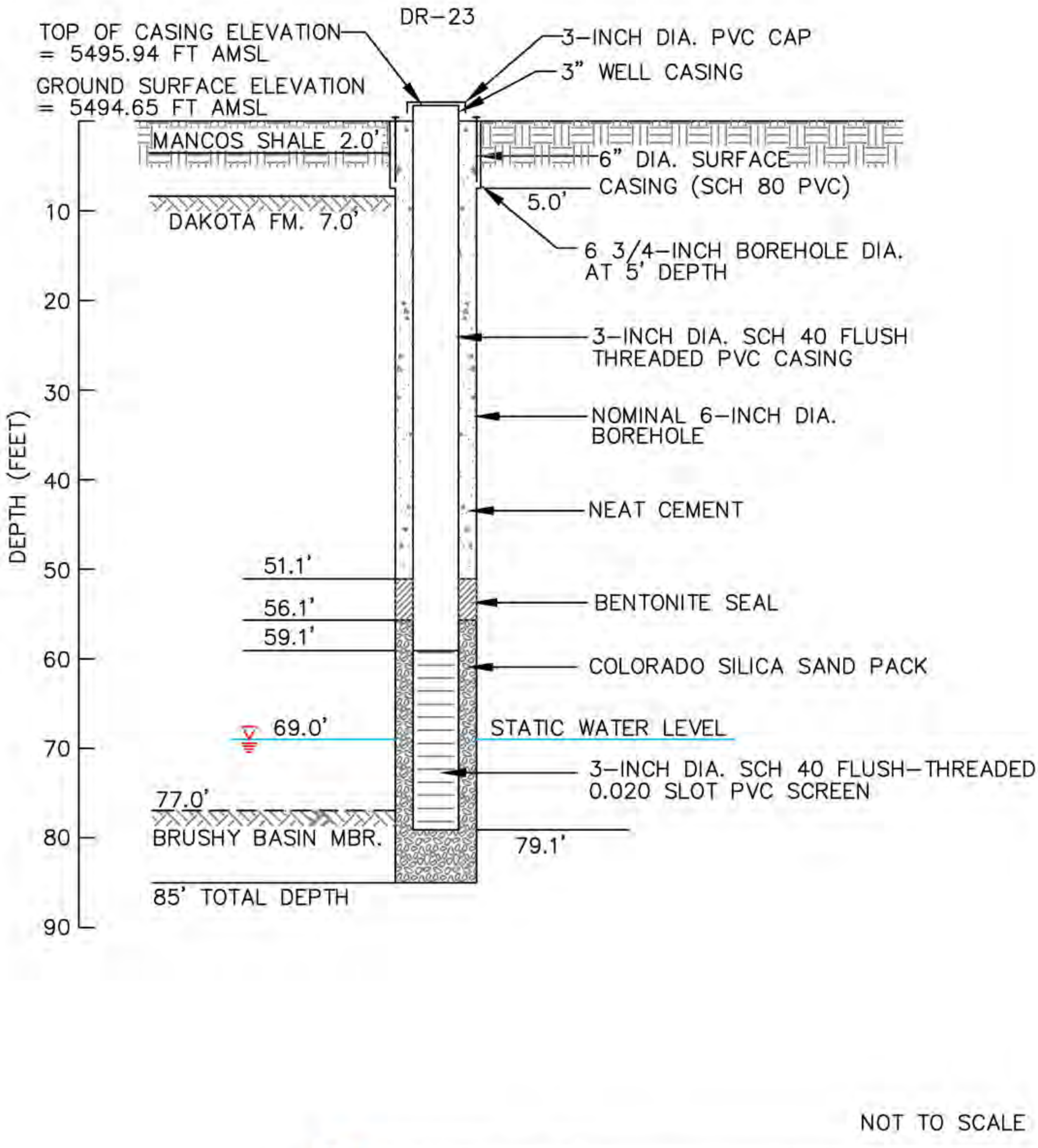


HYDRO GEO CHEM, INC.	DR-21 AS-BUILT WELL CONSTRUCTION SCHEMATIC			
	Approved SJS	Date 1/9/12	Reference K:\7180266A Well Construction Diagram	Figure



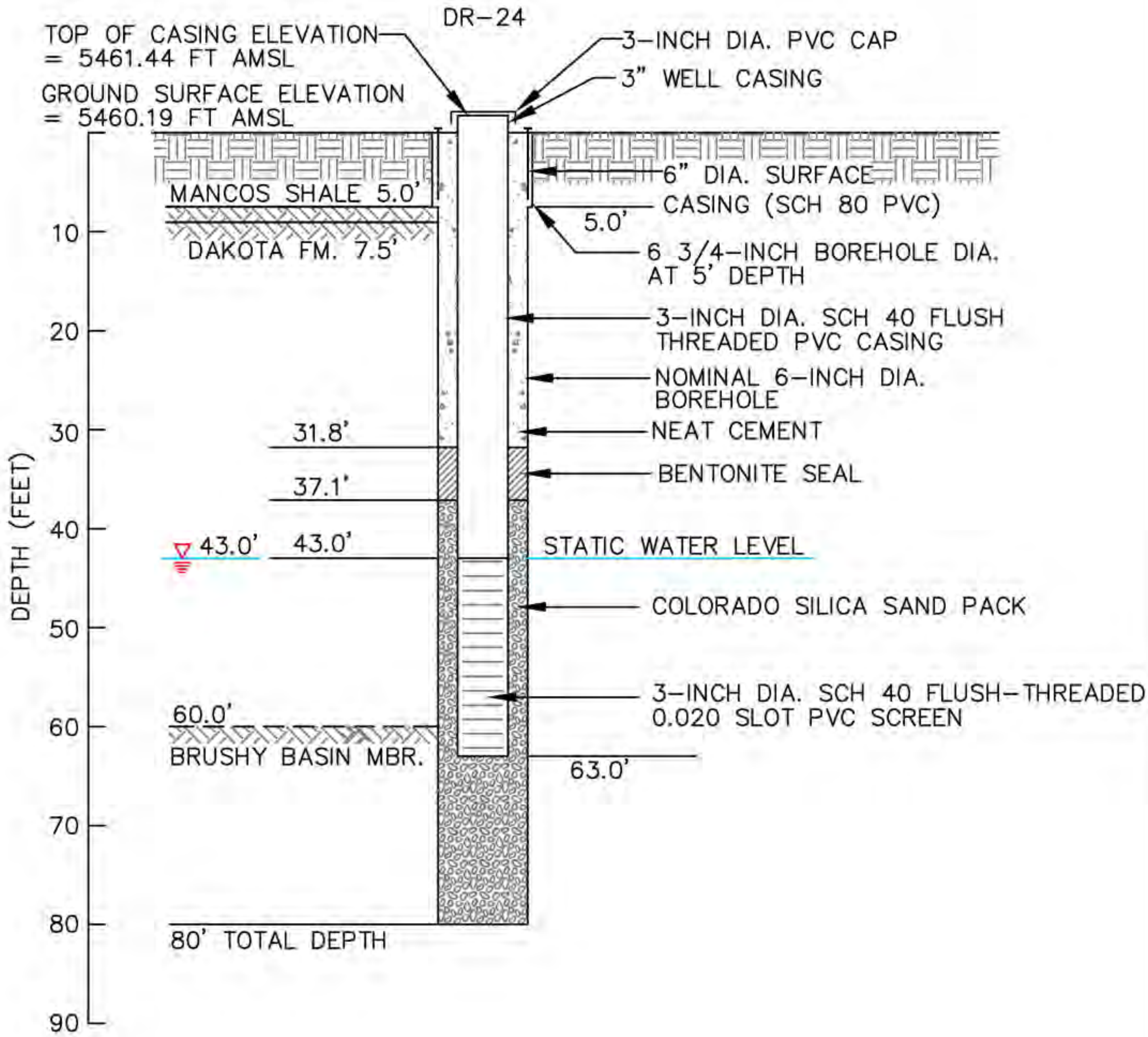
NOT TO SCALE

HYDRO GEO CHEM, INC.	DR-22 AS-BUILT WELL CONSTRUCTION SCHEMATIC			
	Approved	Date	Reference	Figure
	SJS	1/9/12	K:\7180267A Well Construction Diagram	



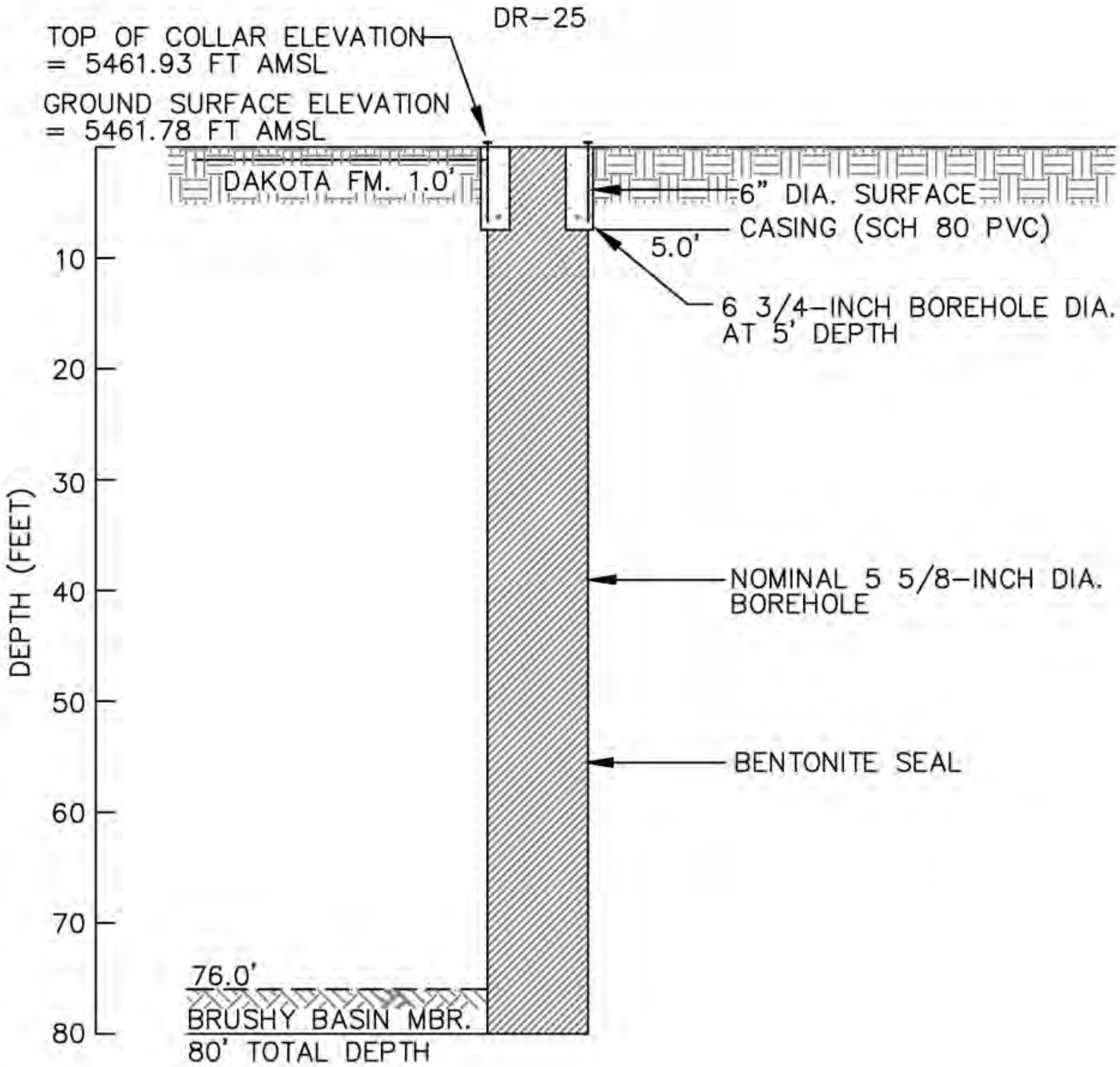
NOT TO SCALE

HYDRO GEO CHEM, INC.	DR-23 AS-BUILT WELL CONSTRUCTION SCHEMATIC		
Approved SJS	Date 1/9/12	Reference K:\7180268A Well Construction Diagram	Figure



NOT TO SCALE

HYDRO GEO CHEM, INC.	DR-24 AS-BUILT WELL CONSTRUCTION SCHEMATIC		
Approved SJS	Date 1/9/12	Reference K:\7180269A Well Construction Diagram	Figure



NOT TO SCALE

HYDRO GEO CHEM, INC.	DR-25 WELL ABANDONMENT SCHEMATIC			
Approved	Date	Reference	Figure	
SJS	1/9/12	K:\7180270A Well Construction Diagram		

APPENDIX B.2

MW - SERIES

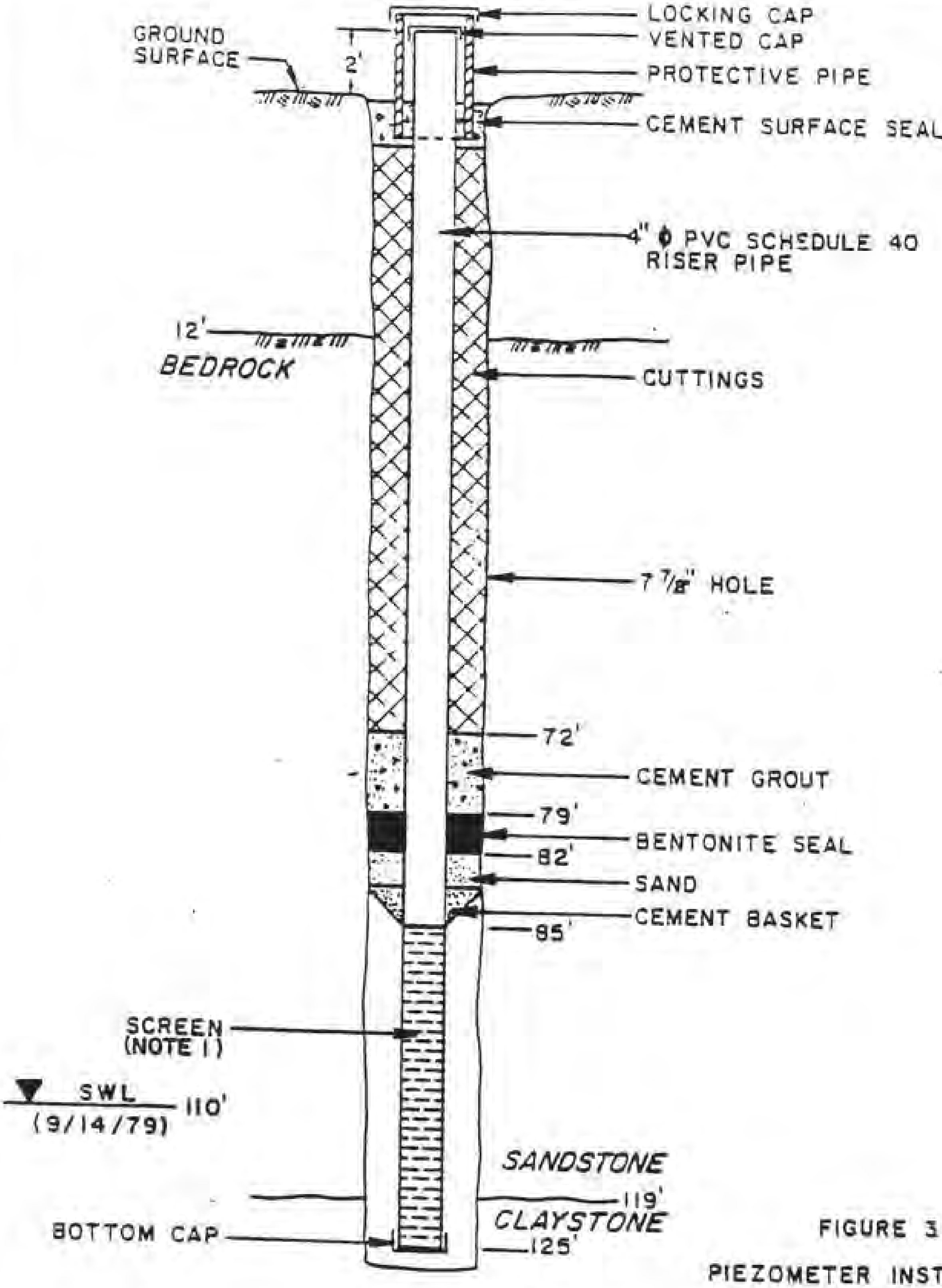


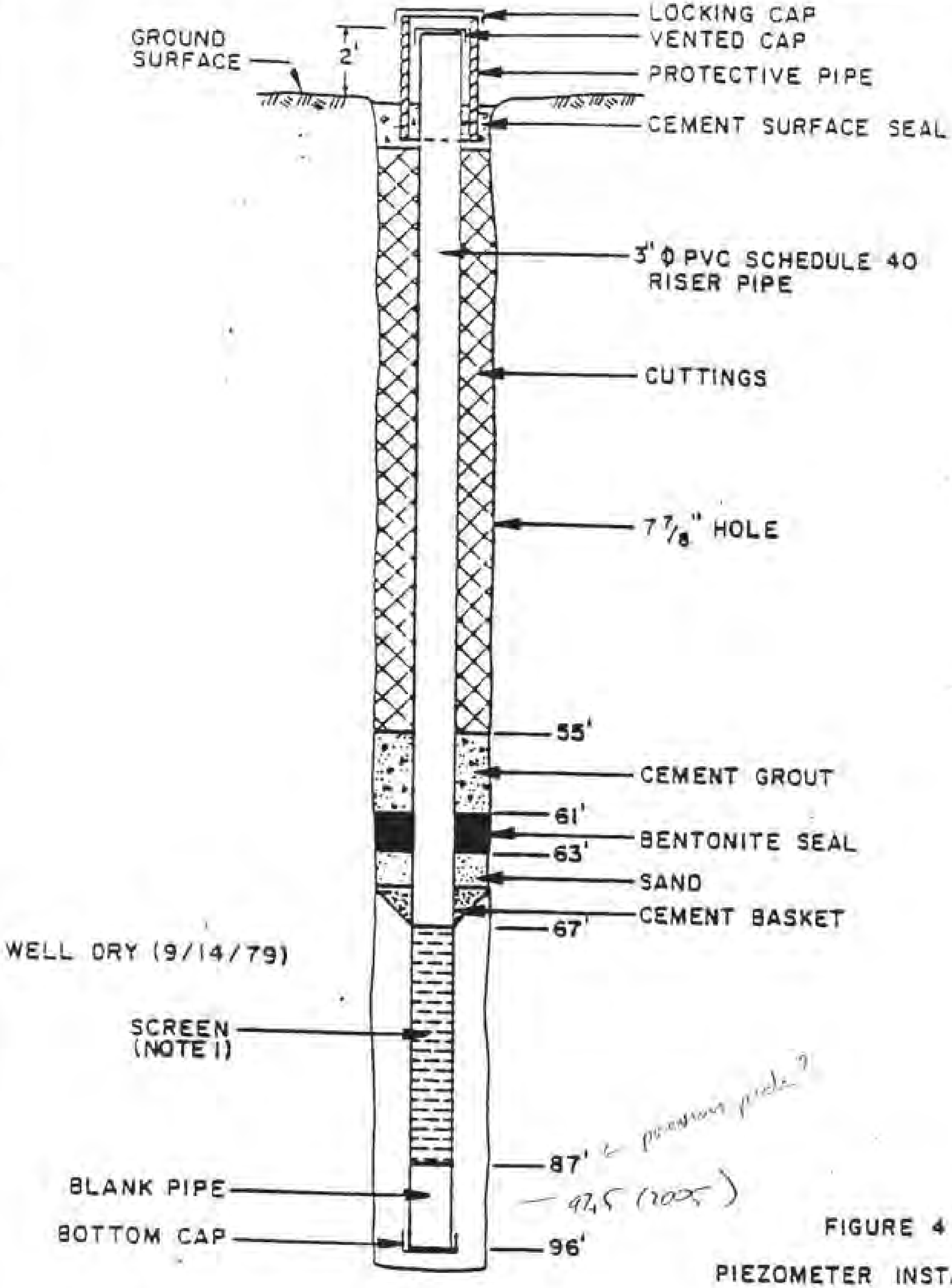
FIGURE 3

PIEZOMETER INSTALLATION
WELL NO. 2
CONSTRUCTION DETAILS

PREPARED FOR

ENERGY FUELS NUCLEAR, INC.
DENVER, COLORADO

NOTE 1: SCREEN CONSISTS OF COMMERCIALLY SLOTTED PIPE WITH 0.045 IN. WIDE SLOTS, 3 ROWS AND 40-42/SLOTS/ROW/FT. PIPE.



NOT TO SCALE

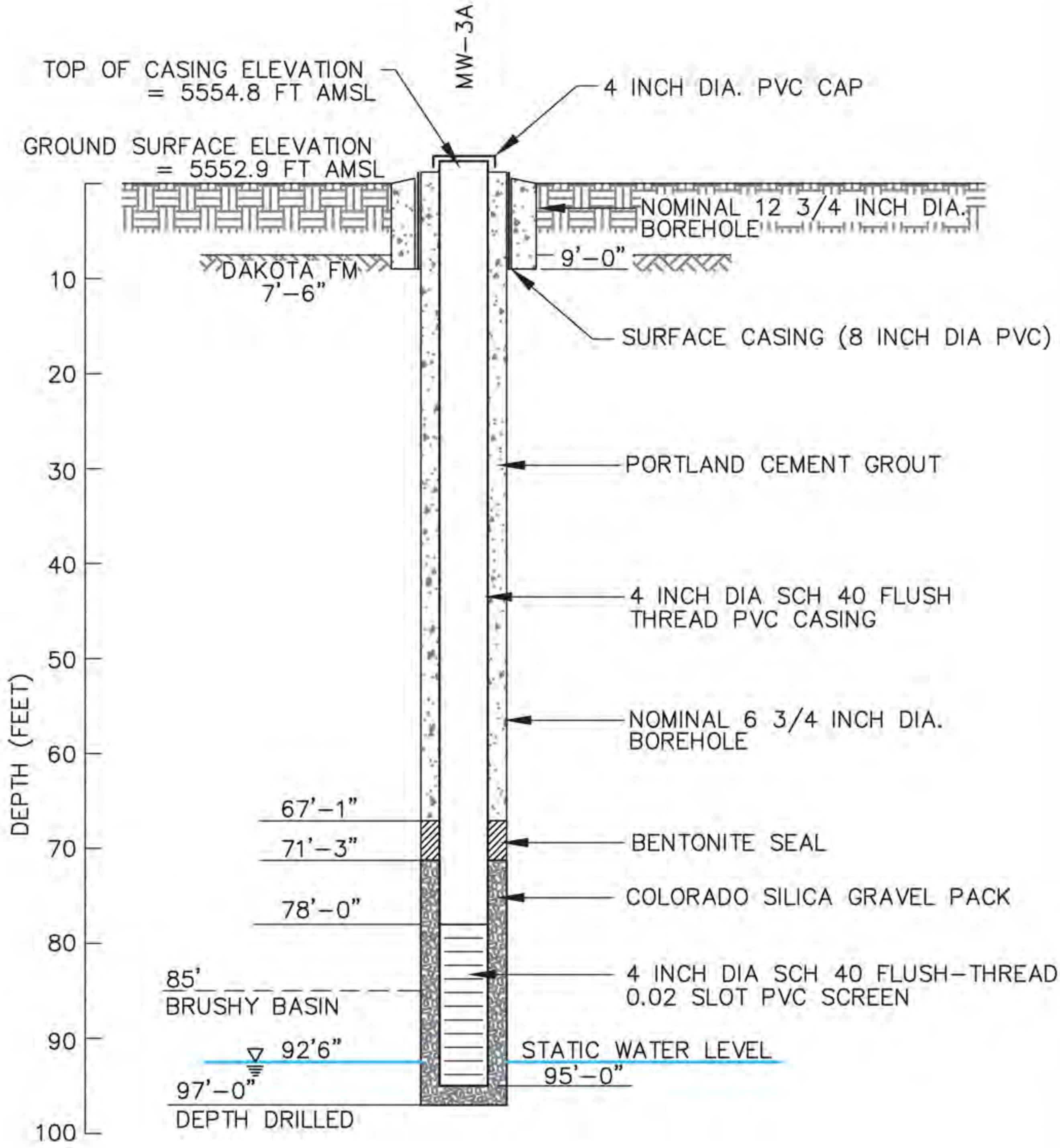
FIGURE 4

PIEZOMETER INSTALLATION
WELL NO. 3
CONSTRUCTION DETAILS

PREPARED FOR

ENERGY FUELS NUCLEAR, INC.
DENVER, COLORADO

NOTE 1: SCREEN CONSISTS OF COMMERCIALLY SLOTTED PIPE WITH 0.045 IN. WIDE SLOTS, 3 ROWS AND 40-42/SLOTS/ROW/FT. PIPE.

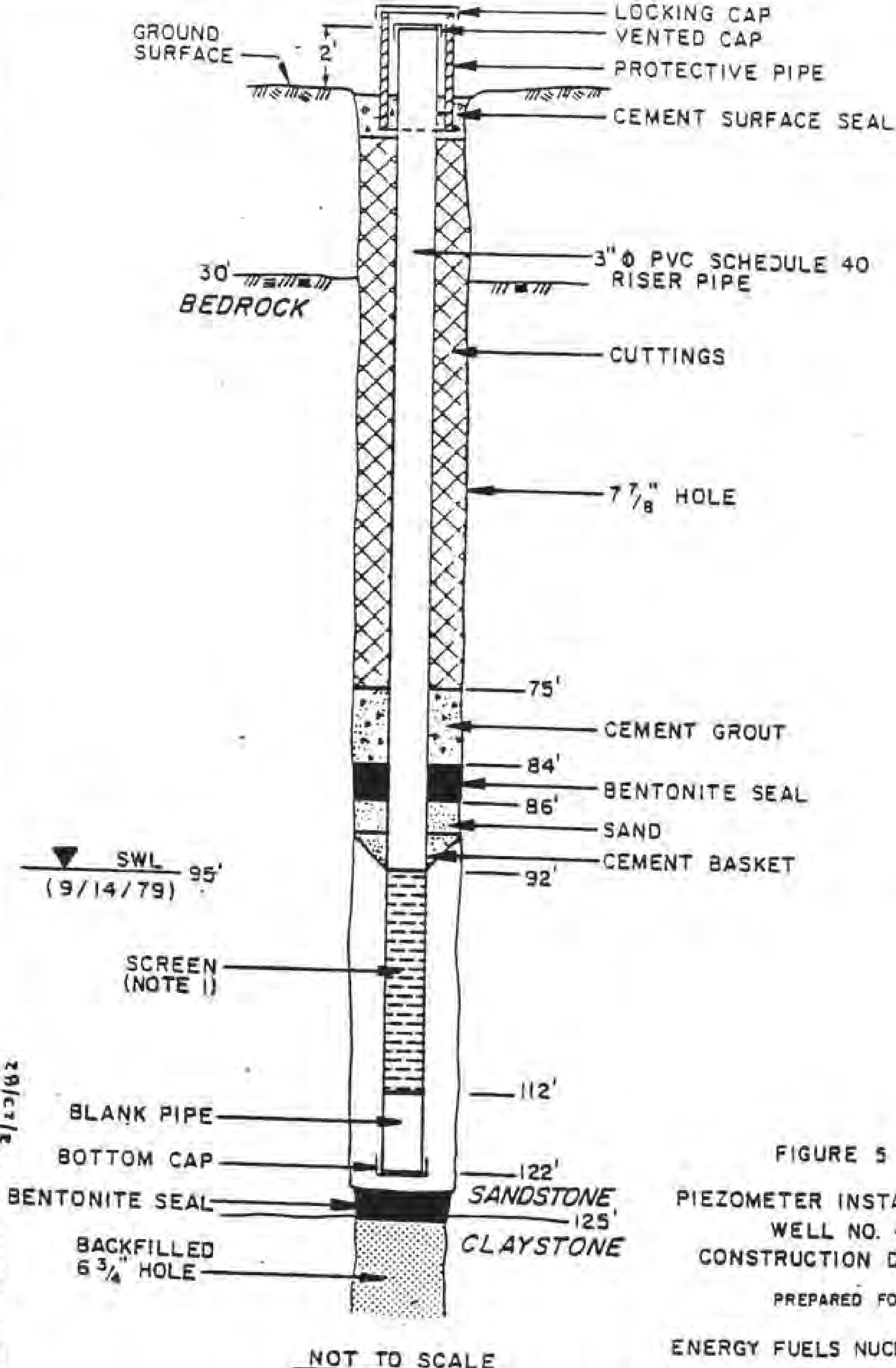


NOT TO SCALE

HYDRO GEO CHEM, INC.

MW-3A
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	8/01/05			7180210A	2



REVISION: REVISED 2-20-82

FIGURE 5

PIEZOMETER INSTALLATION
WELL NO. 4
CONSTRUCTION DETAILS

PREPARED FOR

ENERGY FUELS NUCLEAR, INC.
DENVER, COLORADO

NOTE 1: SCREEN CONSISTS OF COMMERCIALLY SLOTTED PIPE WITH 0.045 IN. WIDE SLOTS, 3 ROWS AND 40-42/SLOTS/ROW/FT. PIPE

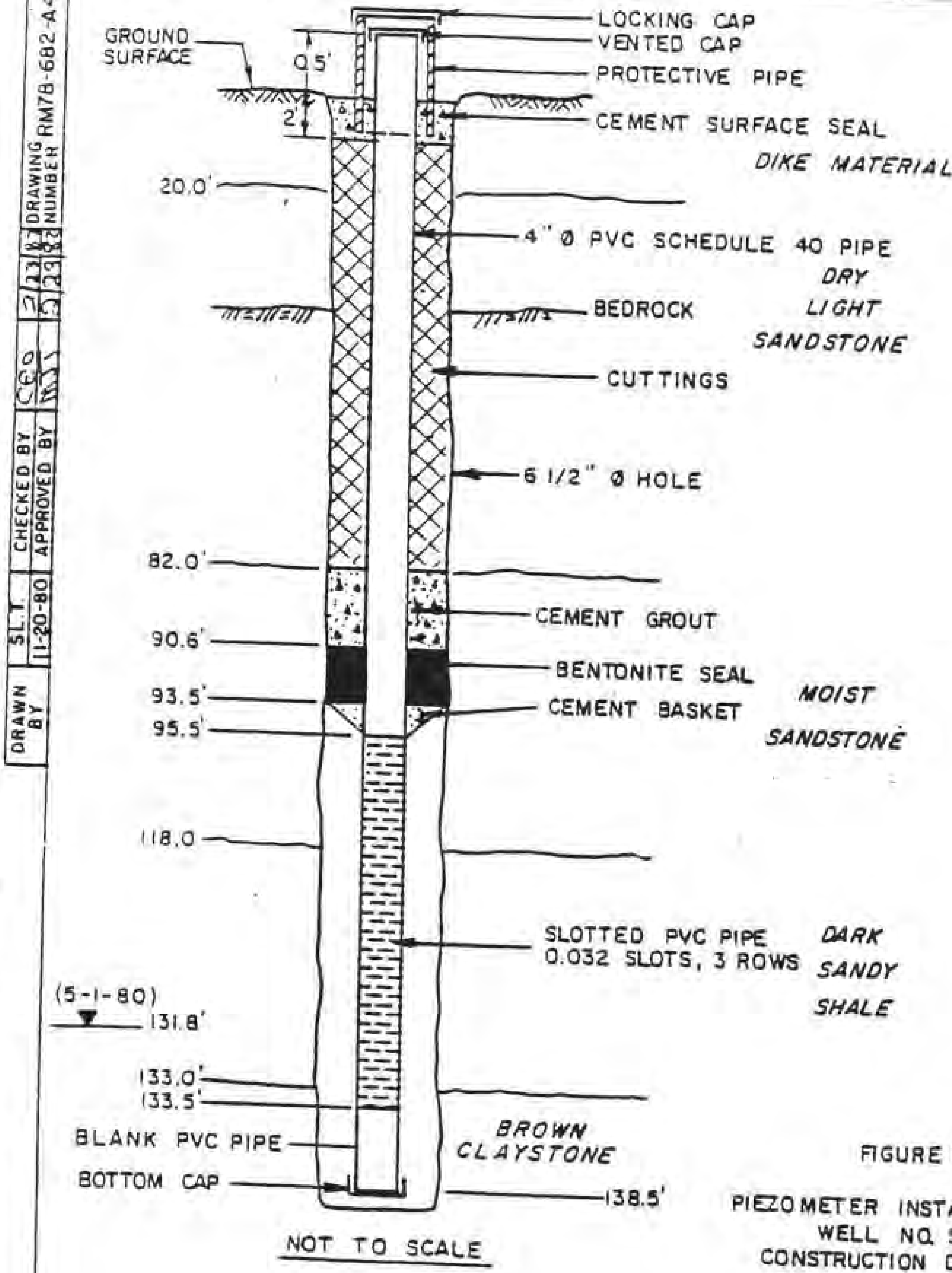


FIGURE 11

PIEZOMETER INSTALLATION
WELL NO. 5
CONSTRUCTION DETAILS

PREPARED FOR

ENERGY FUELS NUCLEAR, INC.
DENVER, COLORADO

D'APPOLONIA

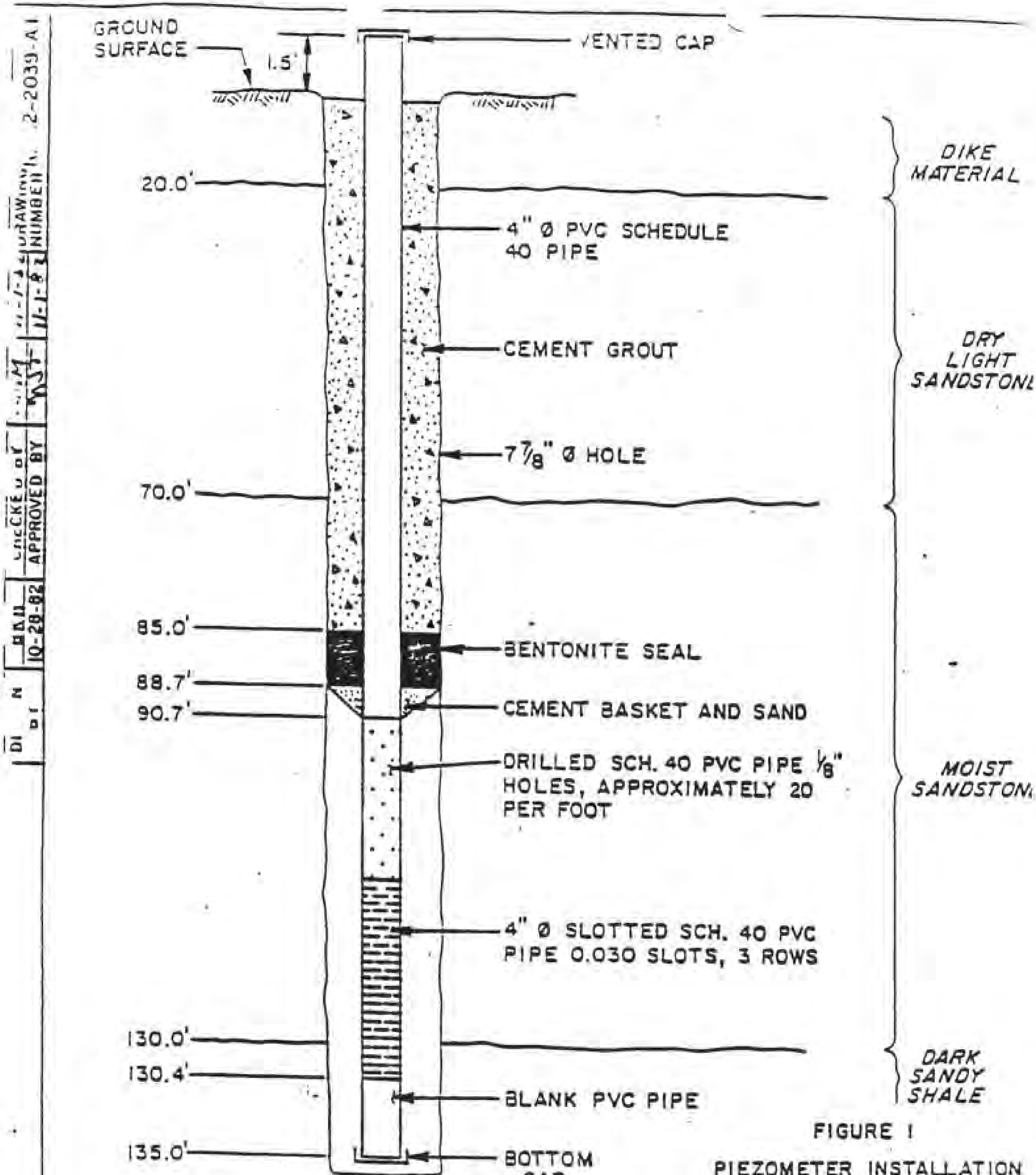


FIGURE 1

PIEZOMETER INSTALLATION
WELL NO. 11
CONSTRUCTION DETAILS

PREPARED FOR

ENERGY FUELS NUCLEAR, I
DENVER, COLORADO

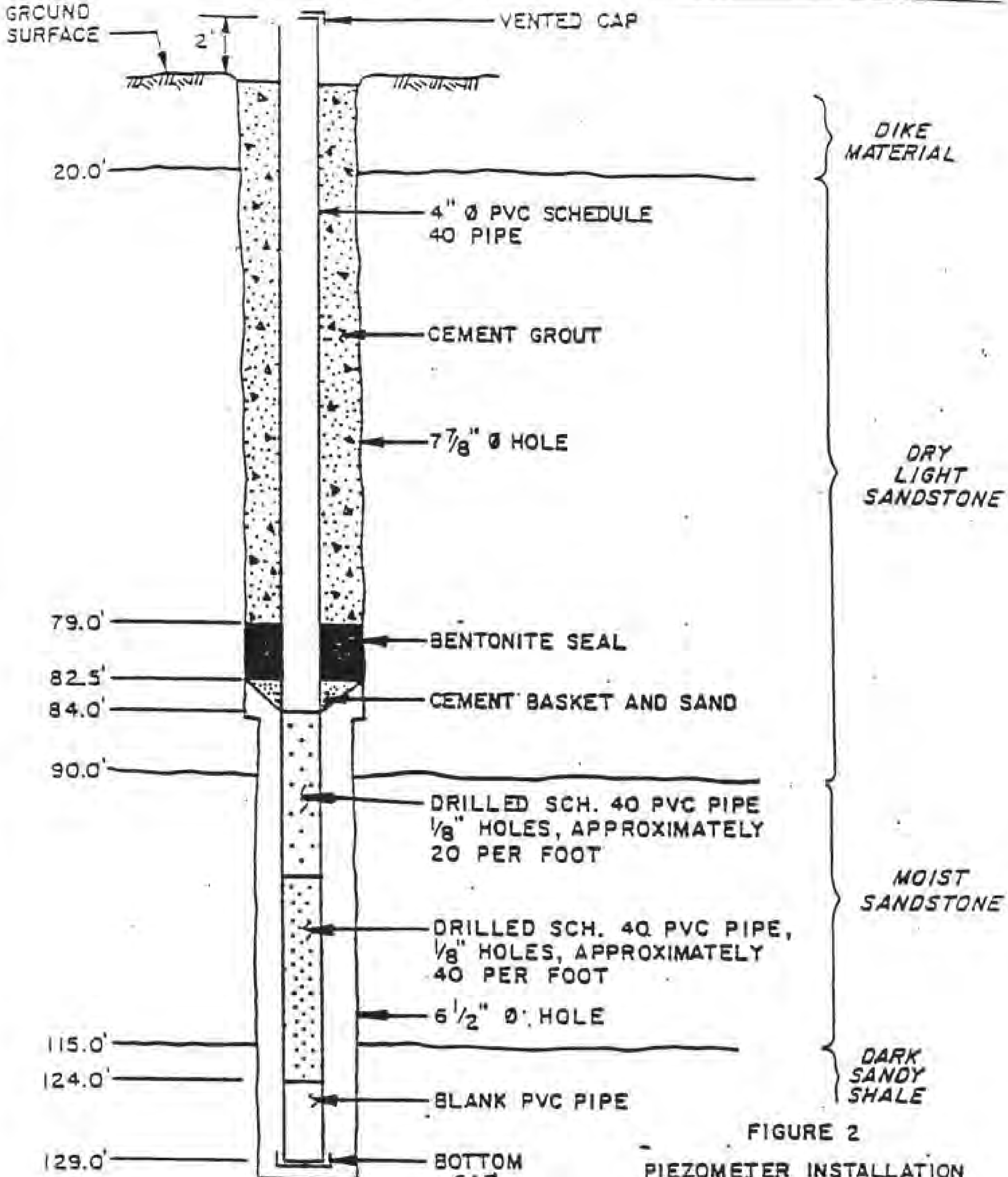


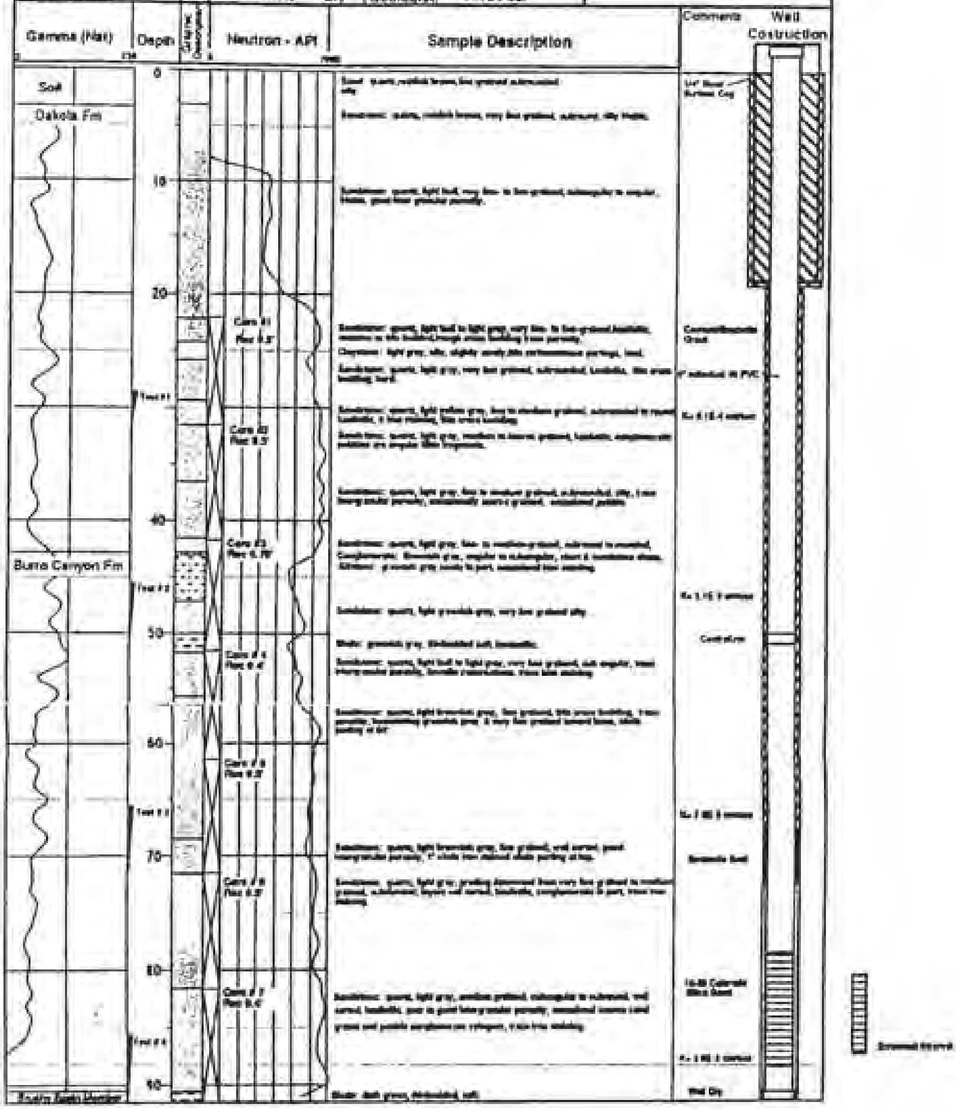
FIGURE 2

PIEZOMETER INSTALLATION
WELL NO. 12
CONSTRUCTION DETAILS

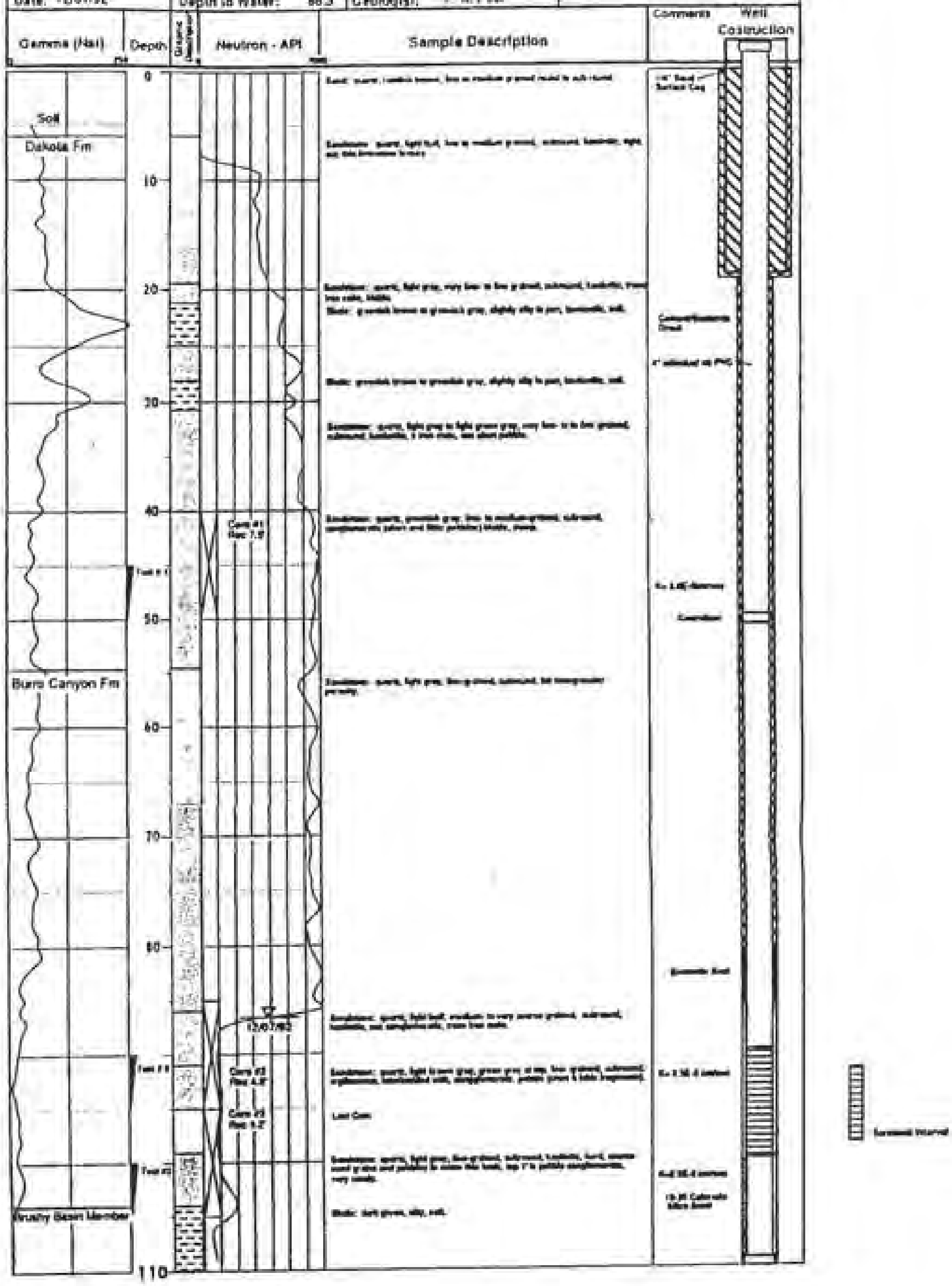
PREPARED FOR

ENERGY FUELS NUCLEAR, INC.
DENVER, COLORADO

PEEL Environmental Services			Bore Hole No. : WMMW-16
Project: White Mesa	Surface Elev. 5588.18	T. D. = 91.5	UMETCO Minerals Corporation
Date: 12/07/92	Depth to Water: Dry	Geologist: F. A. Peel	



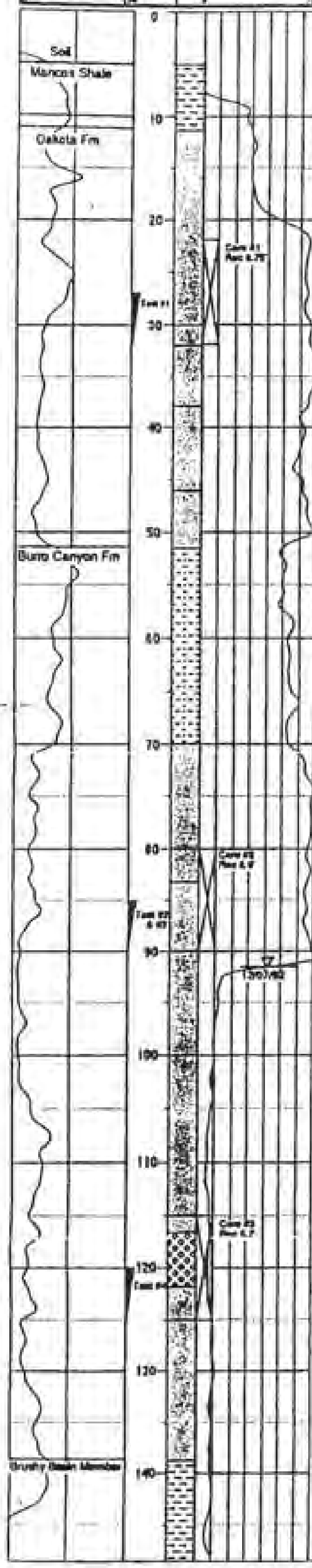
PEEL Environmental Services			Bore Hole No.: WMMW-17
Project: White Mesa	Surface Elev. 5575.06	T.D. = 110'	UMETCO Minerals Corporation
Date: 12/07/92	Depth to Water: 86.5'	Geologist: F. A. Peel	



PEEL Environmental Services

Bore Hole No. WMMW-18			
Project: White Mesa	Surface Elev. 5657.58	T.D. = 148.5'	UMETCO Minerals Corporation
Date: 12/07/92	Depth to Water: 92'	Geologist: F. A. Peel	

Gamma (Nat) | Neutron - API | Sample Description | Comments | Well Construction



Sand: quartz, red brown, silty.

Shale: black, platy, hard.

Sandstone: quartz, light buff to light gray, subround, kaolinitic, trace iron staining >>> less toward base, Occ lithic pebble, occ thin shale parting.

Sandstone: as above >>> very conglomeratic in part, pebble size chert on lithic fragments.
Sandstone: quartz, buff, fine-grained, subrounded, slightly argillaceous, kaolinitic, trace iron staining.

Sandstone: quartz, light yellow gray, fine-grained, subangular, iron staining.

Sandstone: as above >>> very fine-grained.

Siltstone: light greenish gray, argillaceous, platy.

Sandstone: quartz, light gray, very fine-grained, subangular, trace kaolinite.

Sandstone: quartz, light gray, very fine- to medium-grained, subangular, occ pebble.

Sandstone: as above interbedded with Conglomerate: pebble (lithic), light gray, sandy in part.

Sandstone: as above.

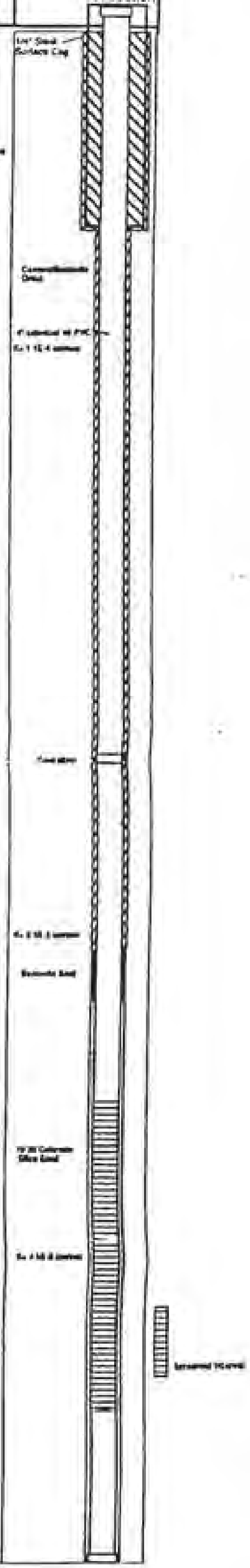
Sandstone: quartz, greenish gray, fine-grained, subangular, to subround, kaolinitic, friable, interbedded with occasional thin shale layer reddish brown, soft.

Sandstone: quartz, light green to greenish gray, very fine- to fine-grained, subround, argillaceous.
Conglomerate: pebble, lithic fragments, very friable, sandy to very sandy in part.

Sandstone: quartz, light green, very fine-grained, argillaceous with thin red and green shale stringers.

Sandstone: as above.

Shale: reddish brown platy, soft.

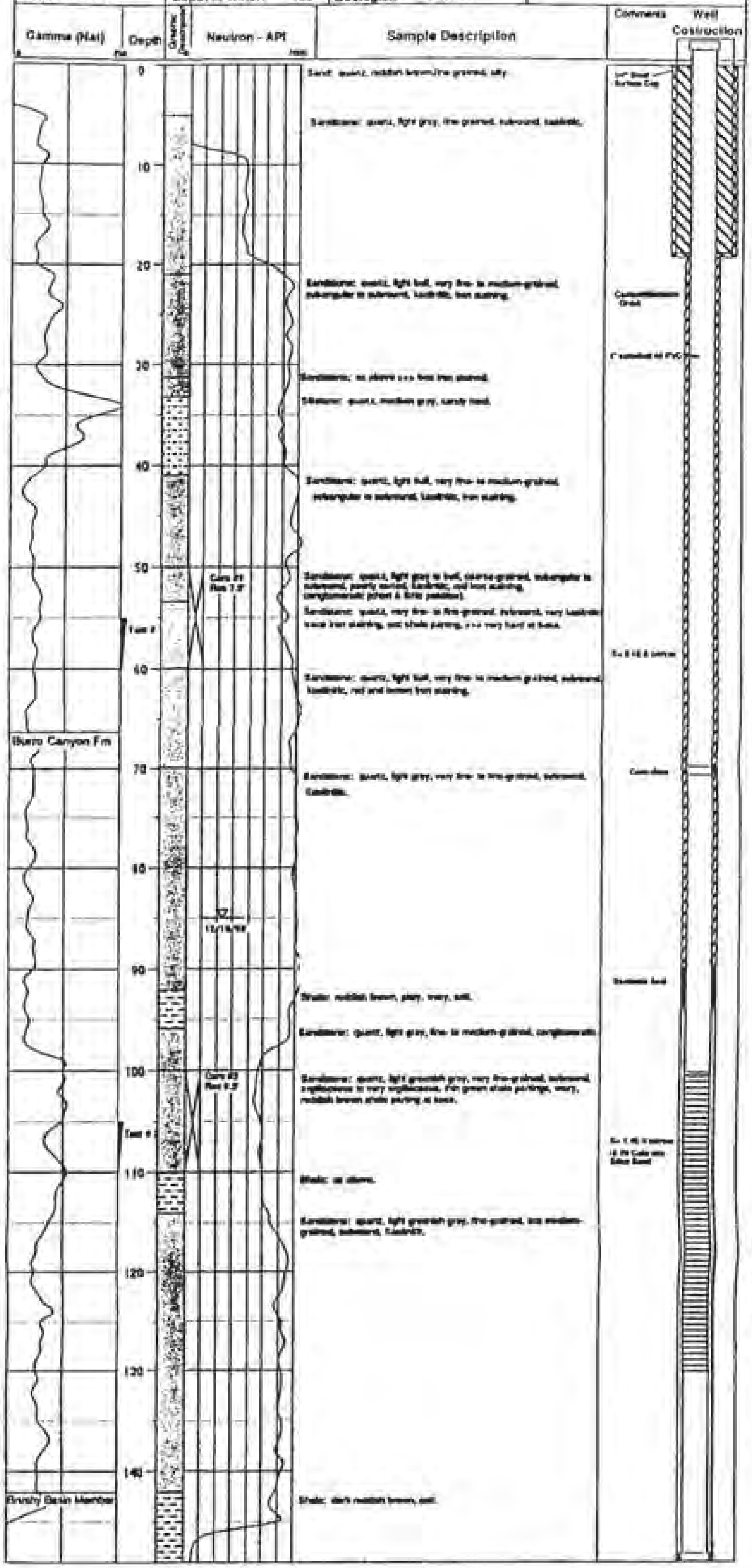


PEEL Environmental Services

Bore Hole No.: WMMW-19

Project: White Mesa | Surface Elev. 5655.05 | T. D. = 149 | UMETCO Minerals Corporation

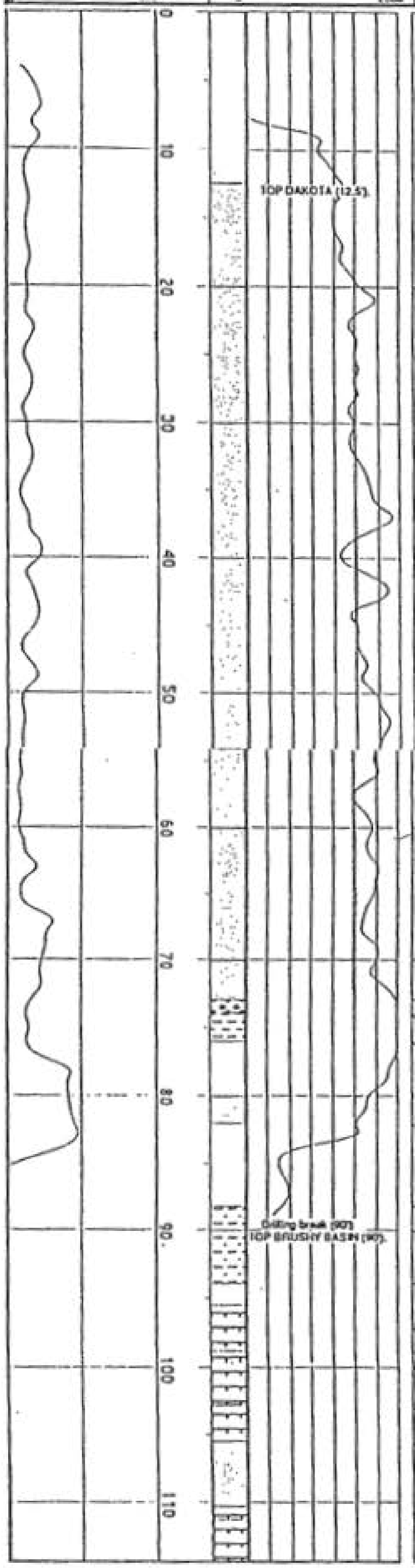
Date: 12/07/92 | Depth to Water: 150 | Geologist: F. A. Peel



PEEL Environmental Services
Arvada, CO (303)422-5116

Project: White Mesa	Surface Elev. 5538 Est	T. D. = 114.5	Bore Hole No. : WMMW-20
Date: 8/4/94	Depth to Water: 86.4	Geologist: C. Bitgood	PBTD = 90'

Gamma (Nat) 0 – 250 | Neutron - API 0 – 2000 | Sample Description



Sand: quartz, reddish brown, silty, argillaceous, eolian.

Sandstone: quartz, light gray to buff, very fine- to fine grained, argillaceous, subangular, soft.

Sandstone: quartz, light gray, fine- to medium grained, argillaceous, soft, trace iron staining, trace pinpoint porosity.

Sandstone: as above, conglomeratic in part with dark gray chert clasts.

Sandstone: quartz, light gray, argillaceous, fine- to medium grained, firm.

Sandstone: as above, conglomeratic in part, dark gray and white chert clasts.

Sandstone: as above, becoming less argillaceous, light brown gray, medium grained, well sorted, fair intergranular porosity.

Sandstone: quartz, light gray, medium grained, occasionally coarse-grained, subangular to subrounded becoming very argillaceous, shale clasts from 72.0 to 72.9'.

Conglomerate: lithic, pebble, shale and chert clasts, very sandy, poorly sorted, subrounded.

Shale: olive green, waxy, soft, top 0.2' blocky, sandy.

Missing Core

Sandstone: quartz, dark reddish green to gray, fine grained, very argillaceous, subrounded, scattered iron staining, massive, hard, tight, becoming dark reddish gray, thin bedded and platy at base.

Missing Core

Siltstone: dark reddish brown, sandy in part, argillaceous, thin stringers of dark red brown silty shale at top.

Siltstone: green, waxy, brittle, occasional vertical tension joints, silty in part, iron staining along 2" near vertical fractures.

Missing Core

Claystone: dark greenish gray with reddish cast, poorly developed horizontal plating, waxy, filled vertical joints, becoming lighter in color at base.

Claystone: light green gray, silty to sandy, hard to very hard.

Claystone: red, silty to sandy, hard, mottled green top and bottom, poorly developed horizontal plating.

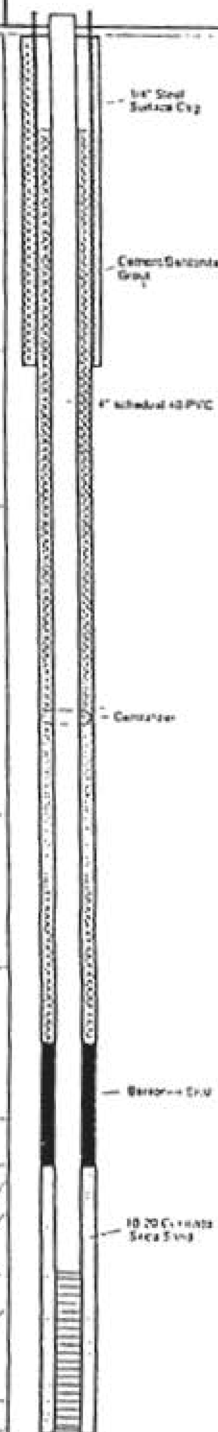
Claystone: dark reddish purple with occasional green fingers, blocky, 2" vertical fracture at base filled with white clay.

Claystone: earthy red, poorly developed horizontal plating, some thin vertical 2" to 4" hairline fractures filled and altered to light green in color.

Sandstone: quartz, light gray green, very fine- to medium grained, very argillaceous, subangular, silty, poorly sorted in part grading downward into light green gray siltstone and light green gray shale, very hard and tight, very argillaceous and sandy.

Claystone: dark red brown, massive, hard.

Claystone: light gray green, poorly developed horizontal plating, hard, sharp contact with overlying red shale.

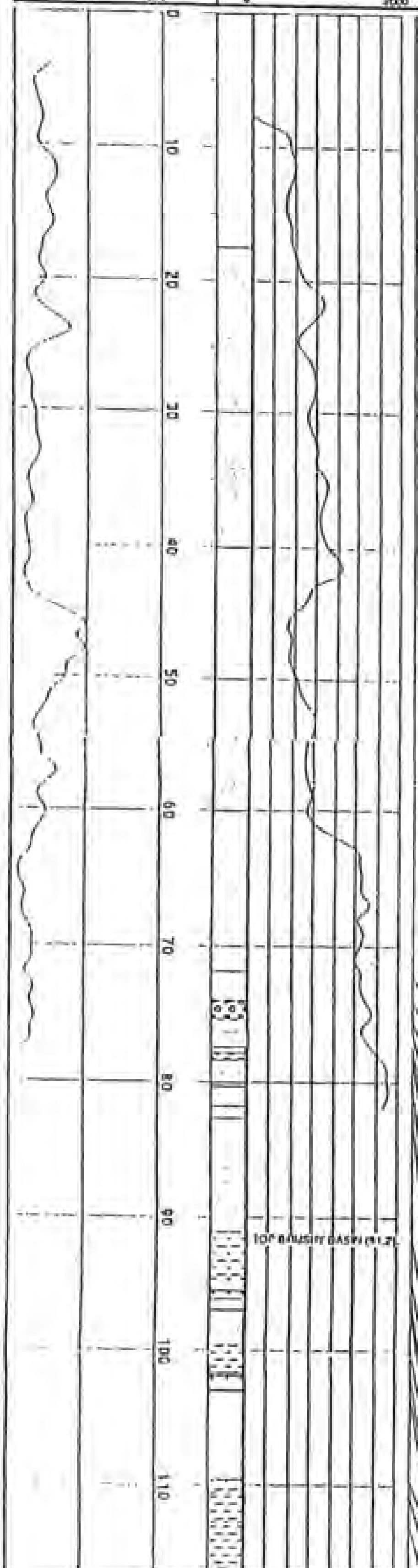


PEEL Environmental Services
Arvada, CO (303)422-5118

Bore Hole No. : WMMW-21

Project: White Mesa	Surface Elev. 5558 Est.	T. D. = 117.0'	PBTD = 90.0'
Date: 8/12/94	Depth to Water: Dry	Geologist: C. Bilgood	

Gamma (Nat) 0 – 250 | Neutron - API 0 – 2000



Sample Description

Sand: eolian sand, quartz, reddish brown.

Sandstone: quartz, light gray, fine- grained, angular to subangular to rounded, well sorted, argillaceous, some light tan to gray poorly sorted fine- to medium grained sandstone.

Sandstone: quartz, light tan, fine- to medium grained, argillaceous, ferrolitic staining, abundant chert fragments (probable conglomerate).

Sandstone: quartz, light tan, fine- to medium grained, friable, well sorted, olive green soft claystone clasts.

Sandstone: quartz, light gray to greenish gray, fine- to medium grained, sub angular to subrounded, poorly sorted, argillaceous, abundant varicolored chert fragments, conglomeratic in part, pyritic.

Sandstone: quartz, gray to light gray, fine- to medium grained, subrounded, argillaceous, well sorted, abundant pyrite and pyrite crystals probably developed along fractures.

Missing Core

Sandstone: quartz, light gray, medium-grained, subrounded, very argillaceous, conglomeratic chert fragments, angular to subangular, occasional subrounded pebble, black chert fragments.

Missing Core

Conglomerate: black pebble, chert, very sandy, quartz, medium-grained, subrounded, very argillaceous.

Sandstone: quartz, conglomeratic grading downward to sandy conglomerate.

Missing core

Conglomerate: chert pebble, argillaceous, sandy, hard, tight.

Sandstone: quartz, light gray, fine- to medium grained, subangular to subrounded, conglomeratic, argillaceous, hard, tight.

Sandstone: quartz, light gray, fine- to medium grained, rounded to subrounded, slightly conglomeratic, very hard and tight, well sorted, siliceous cement, no visible porosity.

Sandstone: as above with large vertical fractures filled with pyrite.

Sandstone: quartz, light gray, fine- to medium-grained, subrounded to rounded, very hard and tight, siliceous cement, no visible porosity.

Sandstone: quartz, light gray, very fine- to medium-grained, poorly sorted, conglomeratic, siliceous cement, parting along bedding planes, numerous vertical or near vertical fractures filled with pyrite, very hard and tight, no visible porosity.

Siltstone: very light gray green, pyritic, near vertical fractures, some horizontal bedding parting, hard, becoming more Shaley at base.

Claystone: light gray green, sandy, near vertical fractures, pyritic, blocky in part.

Missing Core

Sandstone: quartz, light gray green, very fine-grained, vertical fractures, occasional small chert pebbles, some horizontal parting.

Shale: gray green, slightly sandy, bedding plane and vertical tension fractures

Claystone: gray green, waxy, soft.

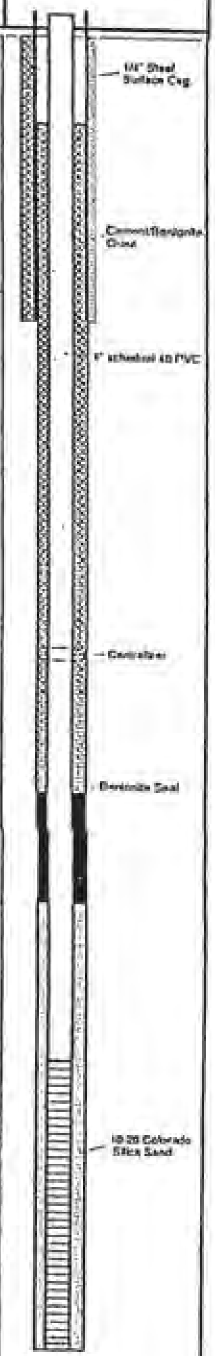
Missing Core

Siltstone: Light gray green with very fine-grained sandstone stringers, chert fragments, argillaceous, very sandy.

Shale: brownish grey, becoming grey green, soft very platy, random tension fracturing.

Shale: light greenish gray to green gray, very sandy, very silty, tension fracturing, trace soft, red shale at base.

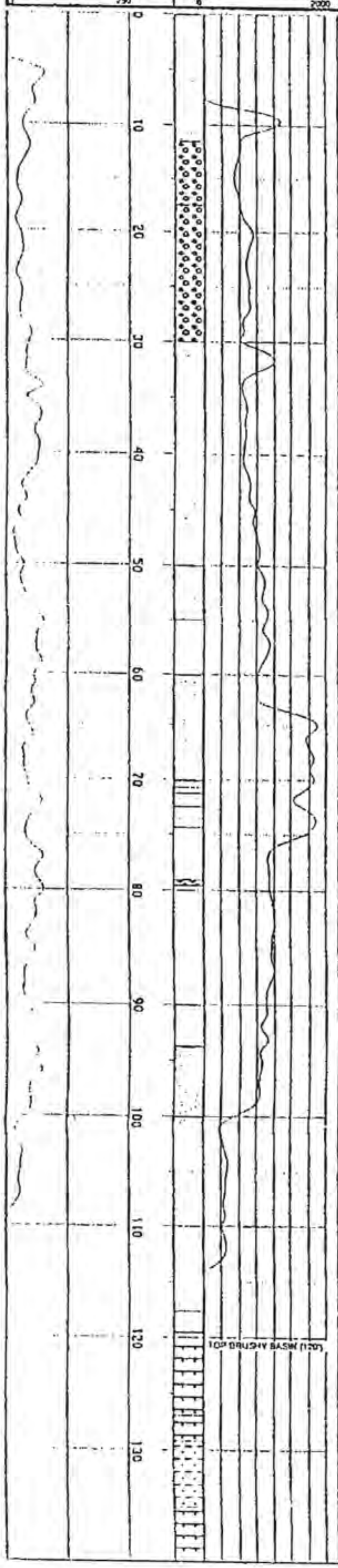
Missing Core



PEEL Environmental Services
Arvada, CO (303)423-5116

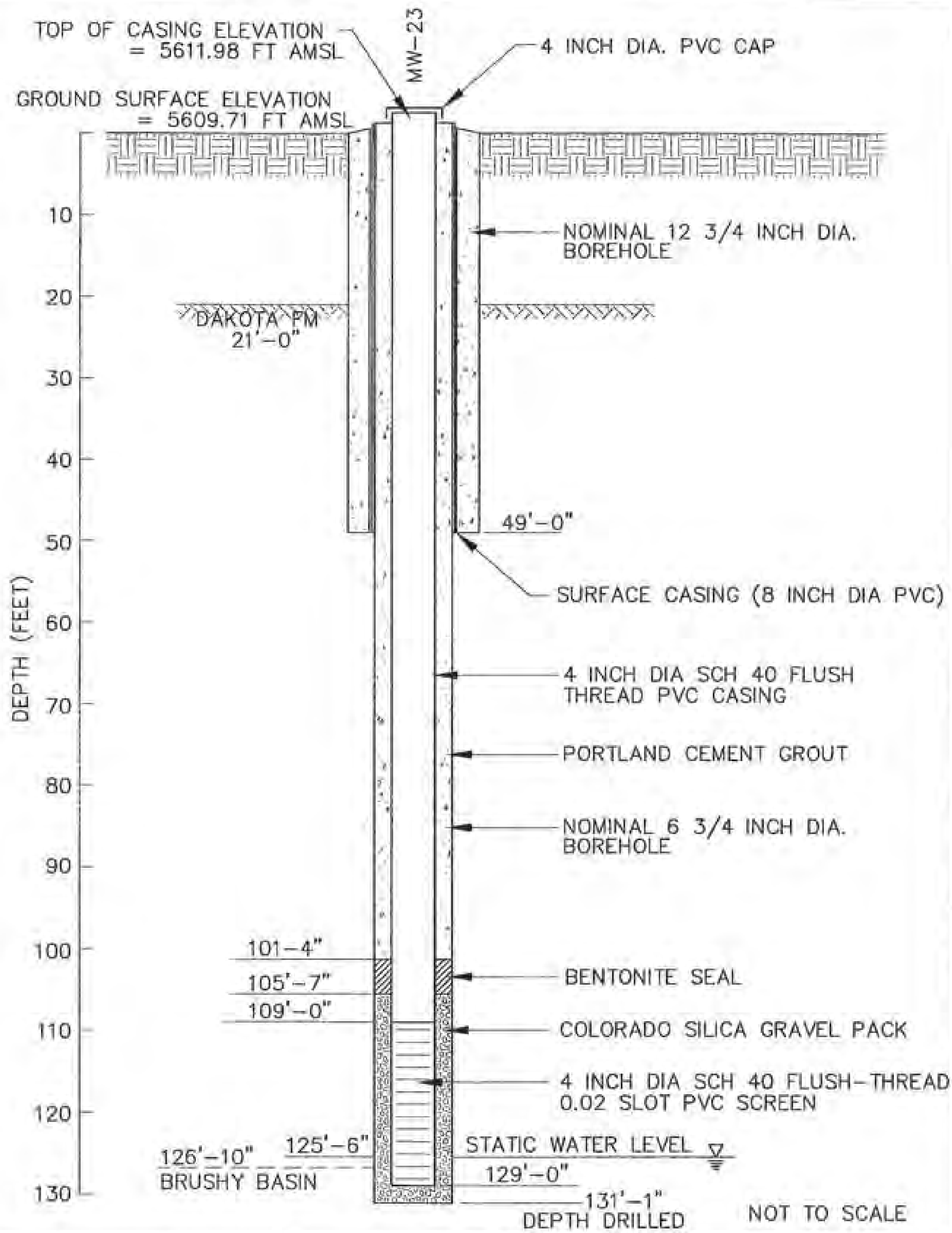
Bore Hole No.: WMMW-22			
Project: White Mesa	Surface Elev. 5516 Est	T. D. = 140'	PBTD = 120'
Date: 8/4/94	Depth to Water: 76	Geologist: C. Bilgood	

Gamma (Nat) | Neutron - API | Sample Description



Sample Description:

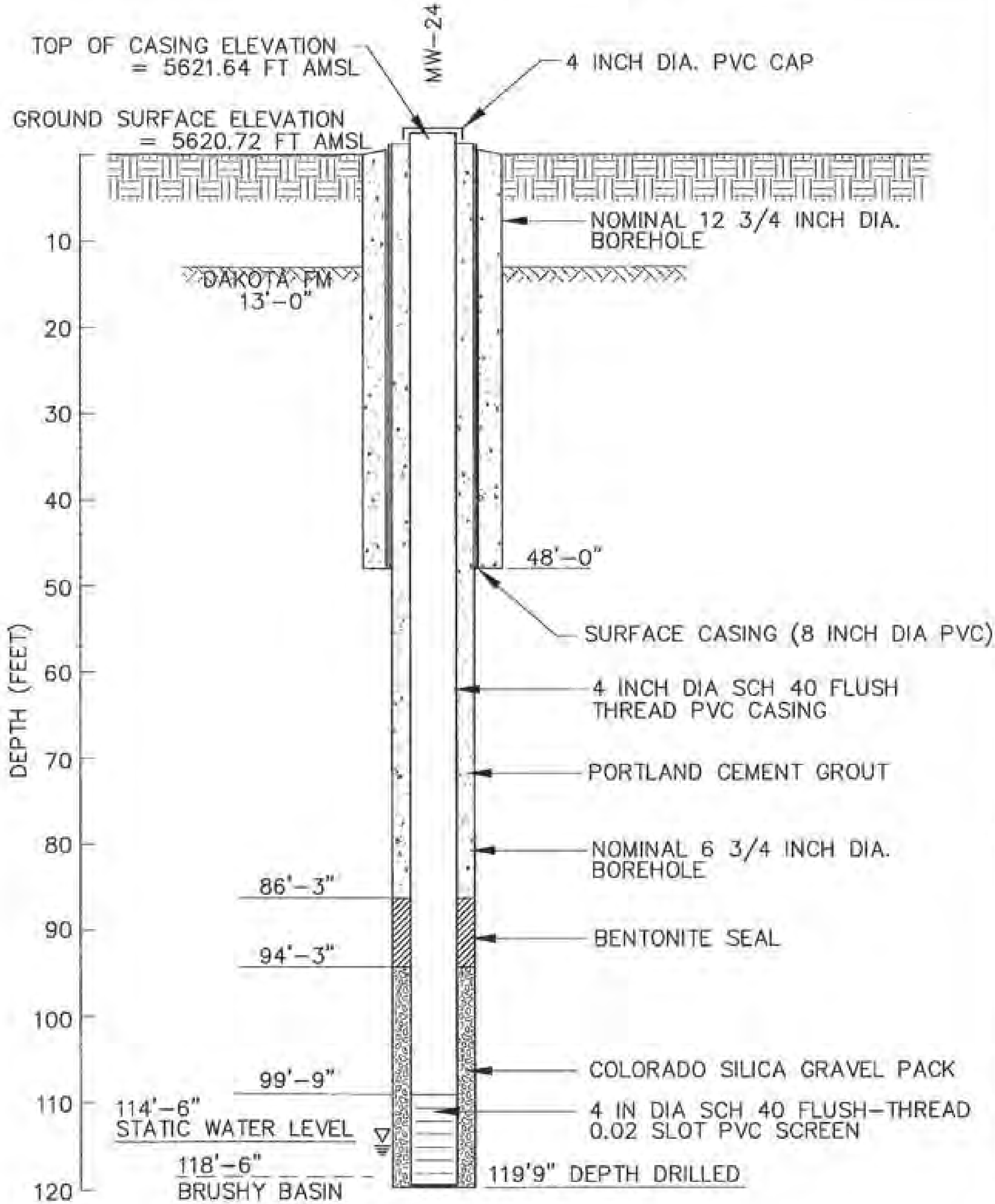
- Sandstone; eaolian sand, quartz, reddish brown.
- Conglomerate; chert, light gray to dark gray, occasional translucent, interbedded with light gray quartz sandstone, rounded, thin bedded.
- Conglomerate; sandstone and conglomerate as above.
- Sandstone; quartz, white to very light gray, fine- to medium-grained, argillaceous
- Sandstone; quartz, white to very light tan, fine-grained, well cemented, hard, tight
- Sandstone as above, very hard, siliceous cement
- Sandstone as above with trace light gray chert fragments, trace iron staining
- Sandstone, quartz, light gray to light tan, very fine-grained, subangular, chert clasts to 1/2", siliceous cement, well cemented, hard, iron staining, occasionally light green in color.
- Sandstone; as above with increase in chert clasts.
- Missing Core
- Sandstone: quartz, light tan to light gray, fine- to medium-grained, subangular to subrounded, siliceous cement, tight, becoming very conglomeratic at base, hard, well cemented.
- Sandstone; as above becoming conglomeratic at base. Conglomerate pebbles sub angular to subround, varicolored
- Missing Core
- Conglomerate: varicolored as above, chert and claystone fragments
- Sandstone; quartz, very light gray, very fine-grained, argillaceous, subrounded, occasional rock clasts, trace intergranular porosity, some horizontal bedding parting, some cross bedding
- Missing Core
- Sandstone; quartz, light gray to light green gray, fine- to very coarse-grained, subangular to rounded, poorly sorted, large 1" green gray claystone clasts, fair to good intergranular porosity, very friable.
- Sandstone: quartz, very light gray, fine- to medium-grained, subangular to subrounded, very friable, good intergranular porosity, massive, well sorted.
- Sandstone: quartz, light green gray, fine grained, argillaceous, rounded, fair intergranular porosity, friable
- Missing Core
- Sandstone: quartz, light green gray, fine- to coarse-grained, argillaceous at base, conglomeratic, varicolored, with green claystone, chert and other lithic fragments
- Claystone: green, waxy
- Missing Core
- Claystone: red brown, mottled green, some horizontal parting
- Claystone: gray green to bright green, some red mottling and banding
- Siltstone: light gray green, hard, very argillaceous, slightly sandy, lower 1' grading into light green claystone.
- Claystone: light gray mottled, with red brown claystone, hard, some platy ..., some 3" to 10" vertical fractures, some sealed, some ... calcite



HYDRO GEO CHEM, INC.

MW-23
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Revised	Date	Reference:	FIG.
SS	8/01/05			7180211A	3

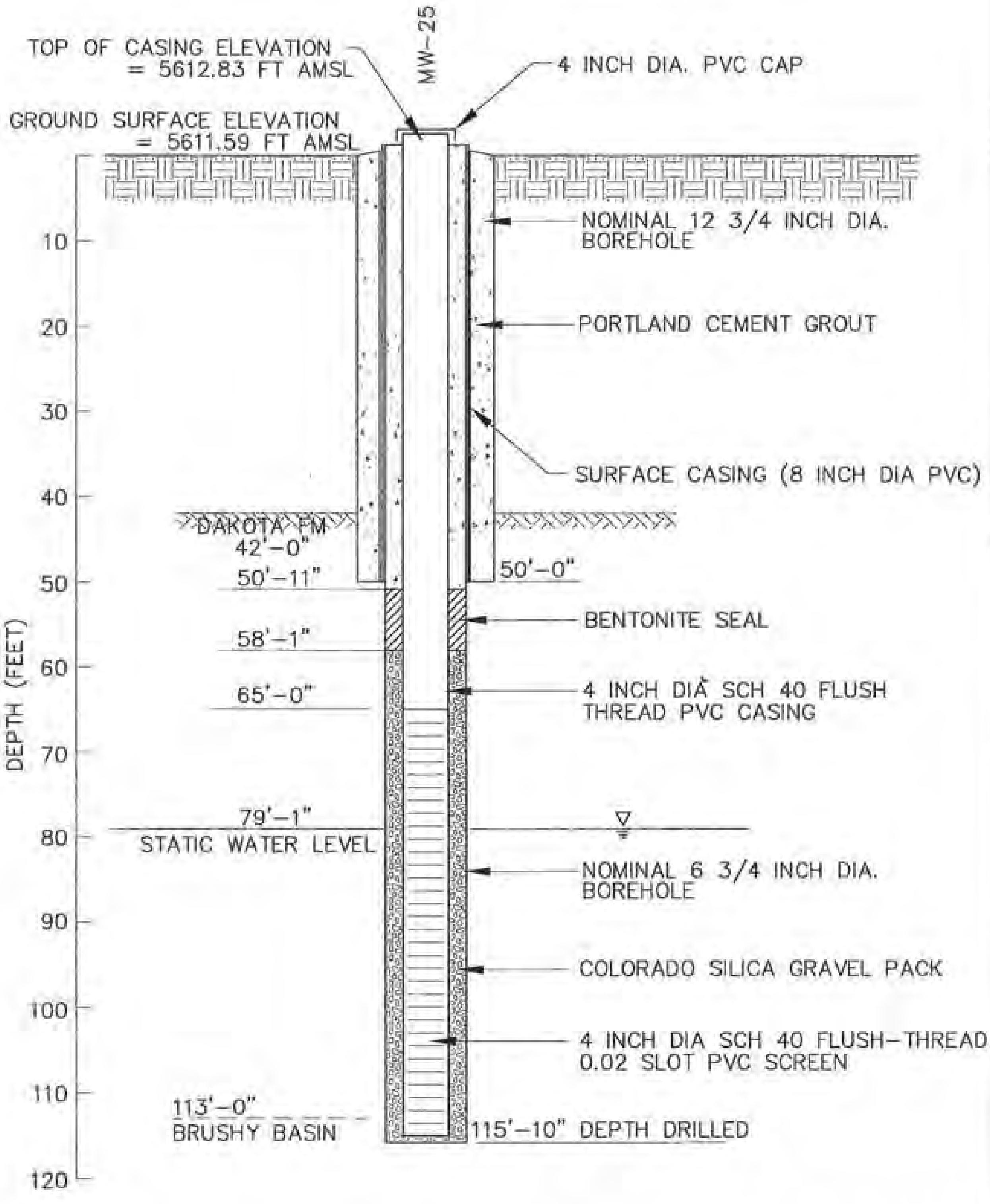


NOT TO SCALE

HYDRO GEO CHEM, INC.

MW-24
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Revised	Date	Reference:	FIG.
SS	8/01/05			7180212A	4

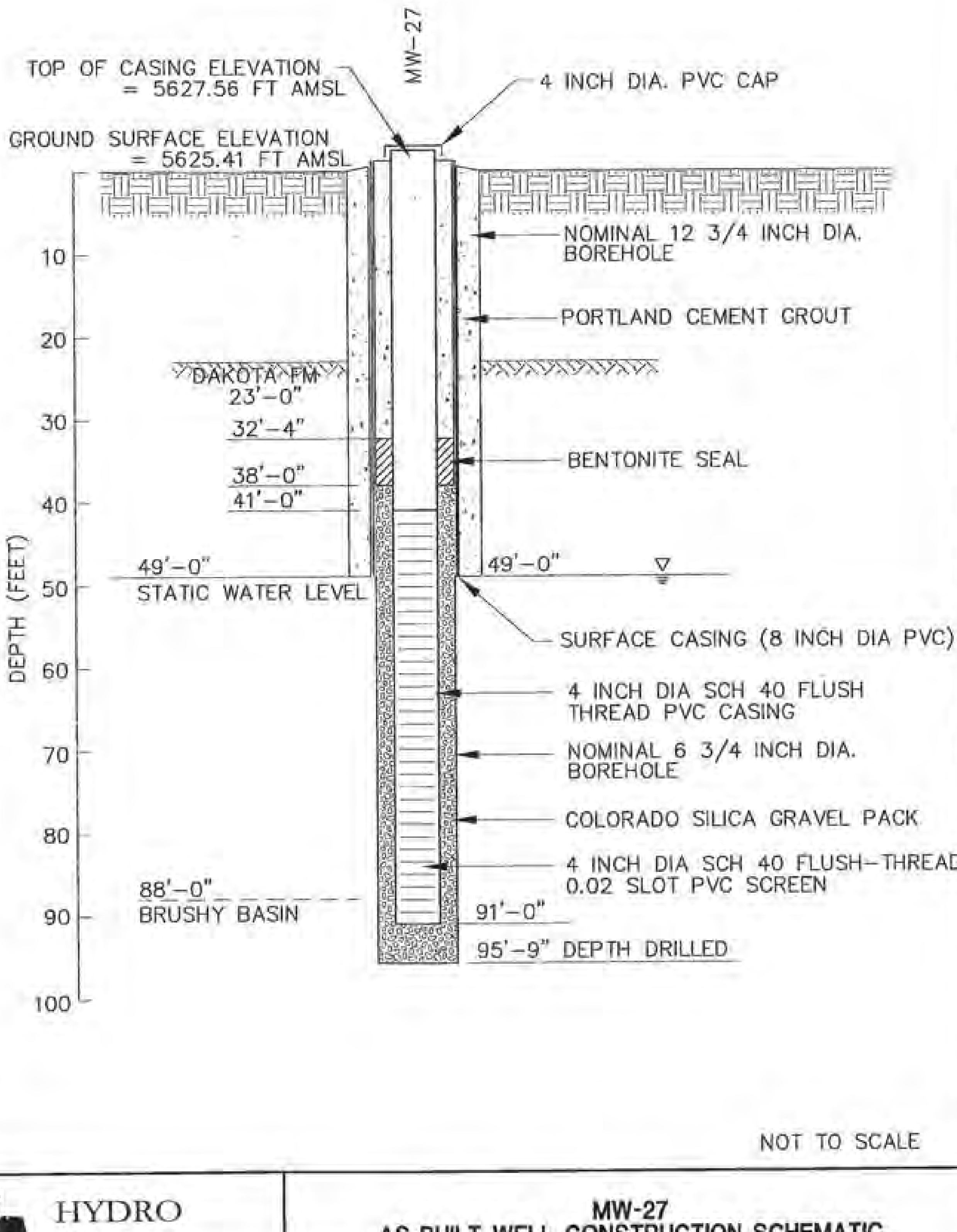


NOT TO SCALE

HYDRO GEO CHEM, INC.

MW-25
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Revised	Date	Reference:	FIG.
SS	8/01/05			7180213A	5

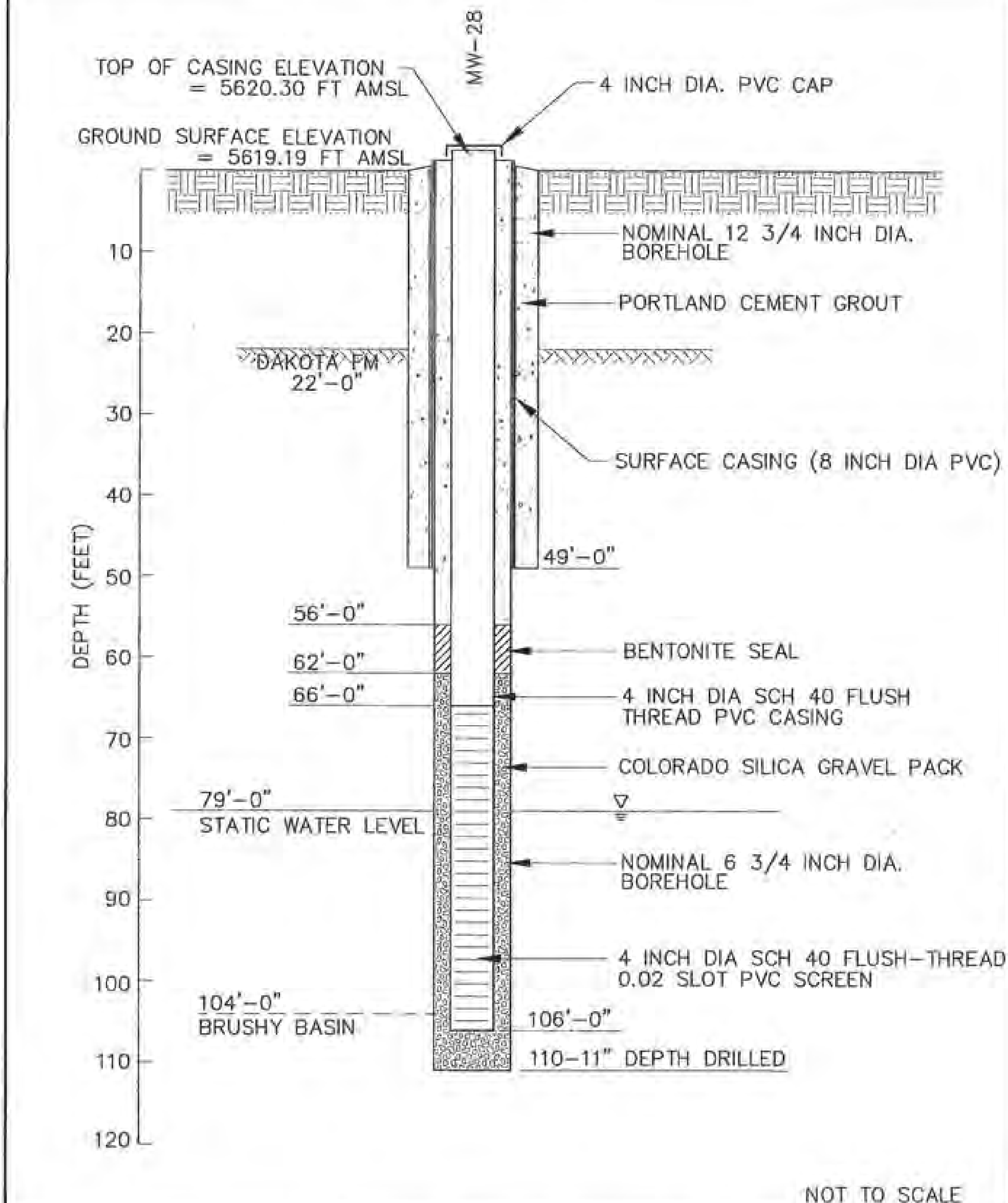


NOT TO SCALE

HYDRO GEO CHEM, INC.

MW-27
AS-BUILT WELL CONSTRUCTION SCHEMATIC

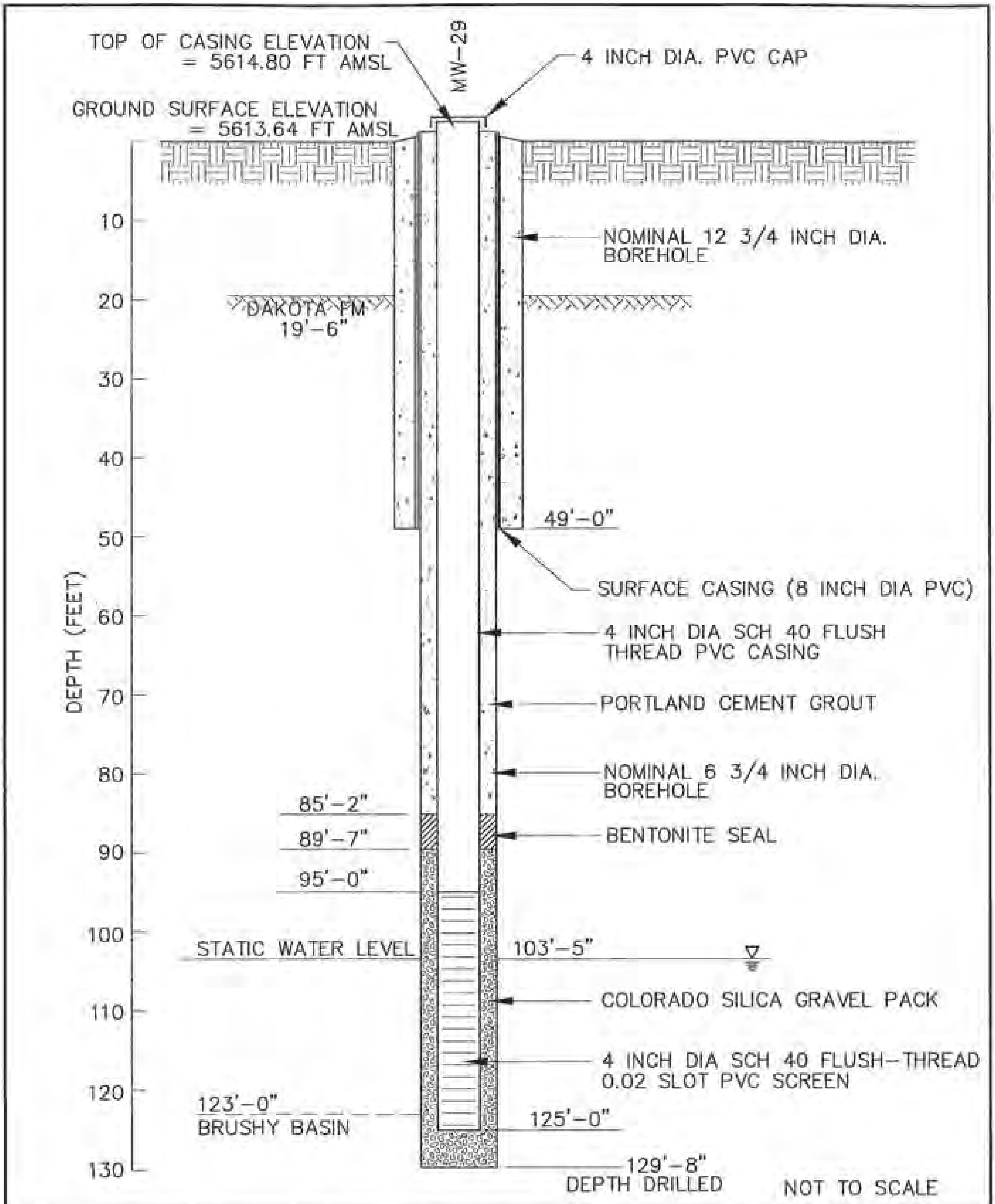
Approved	Date	Revised	Date	Reference:	FIG.
SS	8/01/05			7180214A	6



HYDRO GEO CHEM, INC.

MW-28
AS-BUILT WELL CONSTRUCTION SCHEMATIC

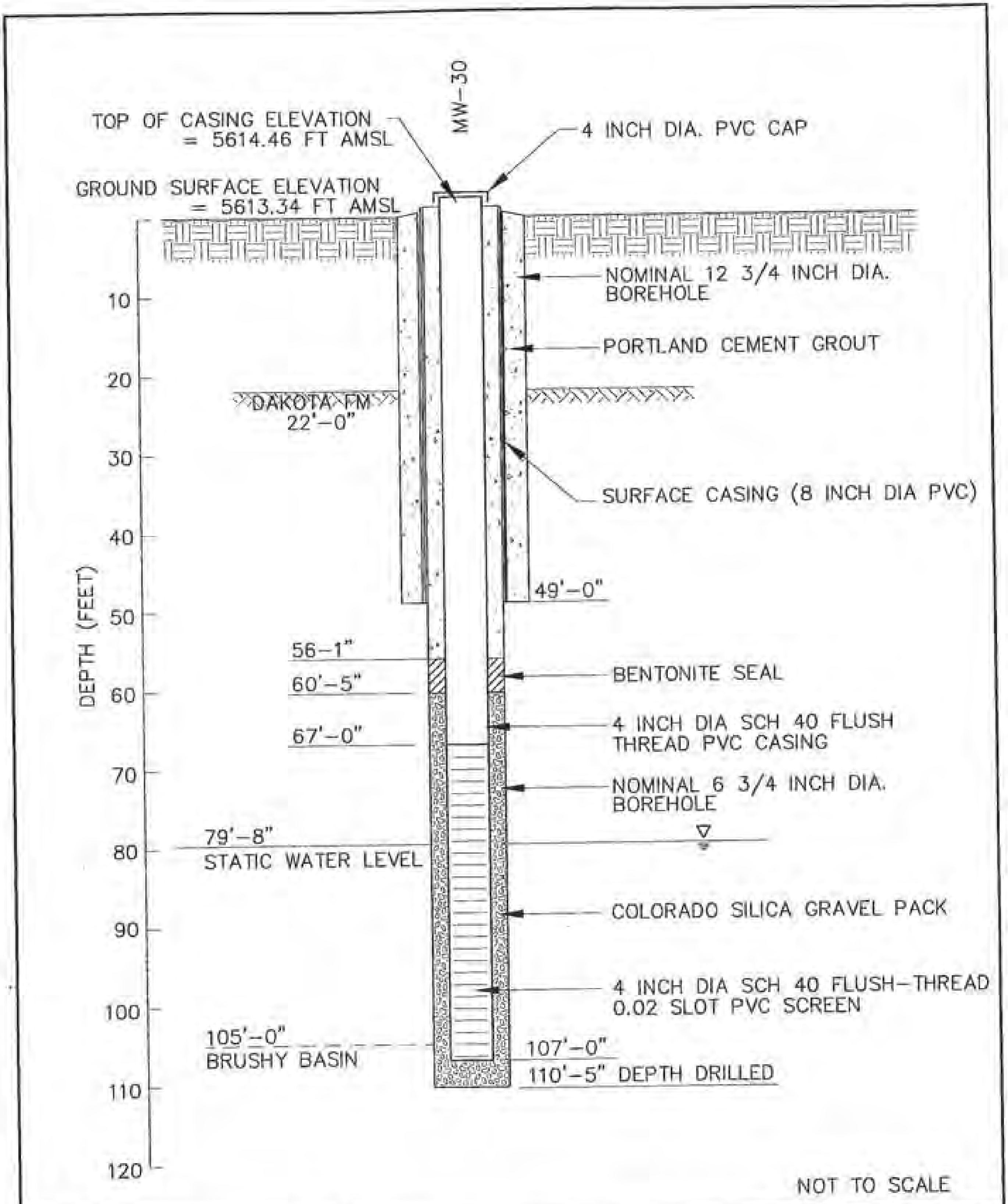
Approved	Date	Revised	Date	Reference:	FIG.
SS	8/01/05			7180215A	7



HYDRO
GEO
CHEM, INC.

MW-29
AS-BUILT WELL CONSTRUCTION SCHEMATIC

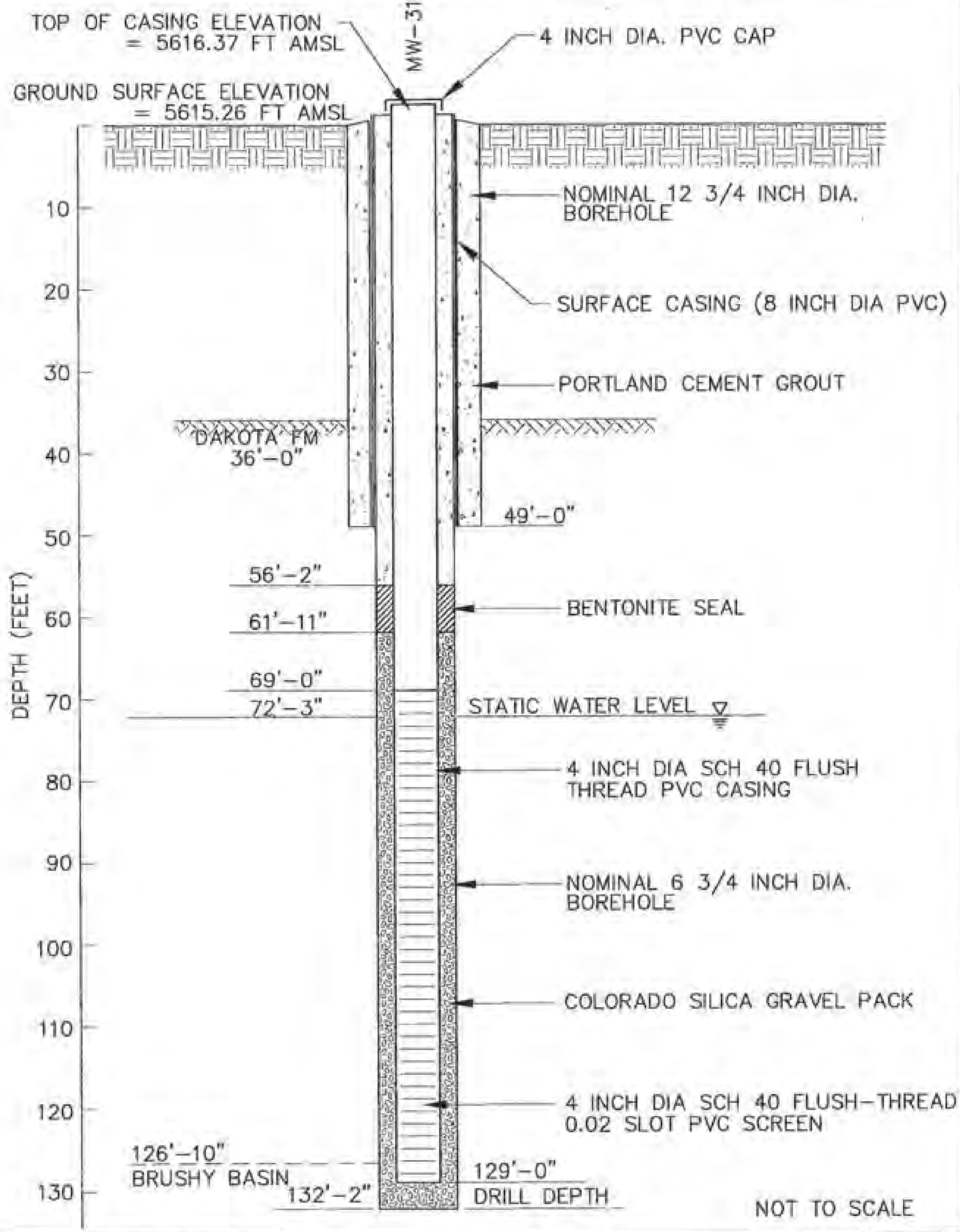
Approved	Date	Revised	Date	Reference:	FIG.
SS	8/01/05			7180216A	8



HYDRO GEO CHEM, INC.

MW-30
AS-BUILT WELL CONSTRUCTION SCHEMATIC

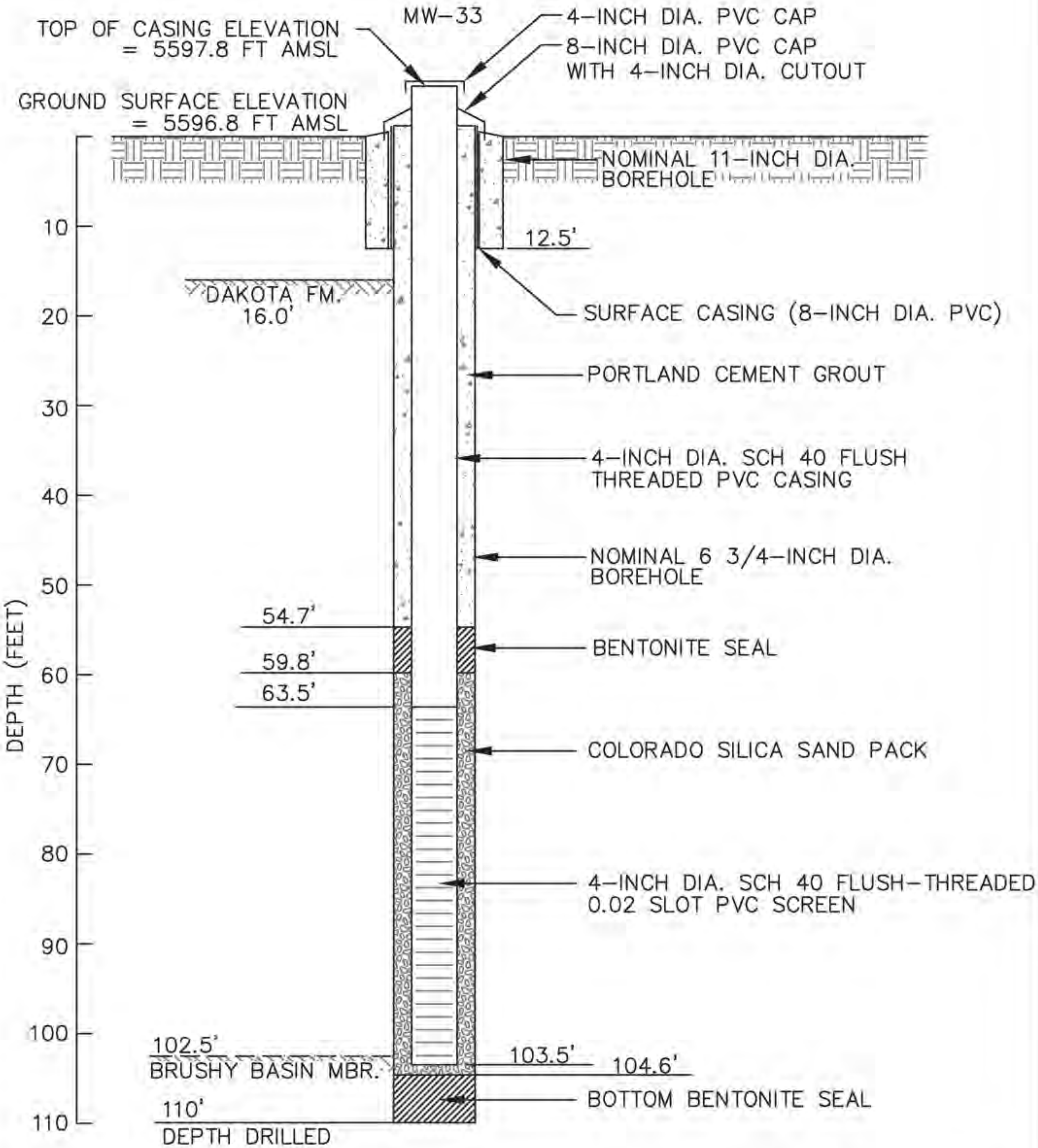
Approved	Date	Revised	Date	Reference:	FIG.
SS	8/01/05			7180217A	9



HYDRO GEO CHEM, INC.

MW-31
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Revised	Date	Reference:	FIG.
SS	8/01/05			7180218A	10



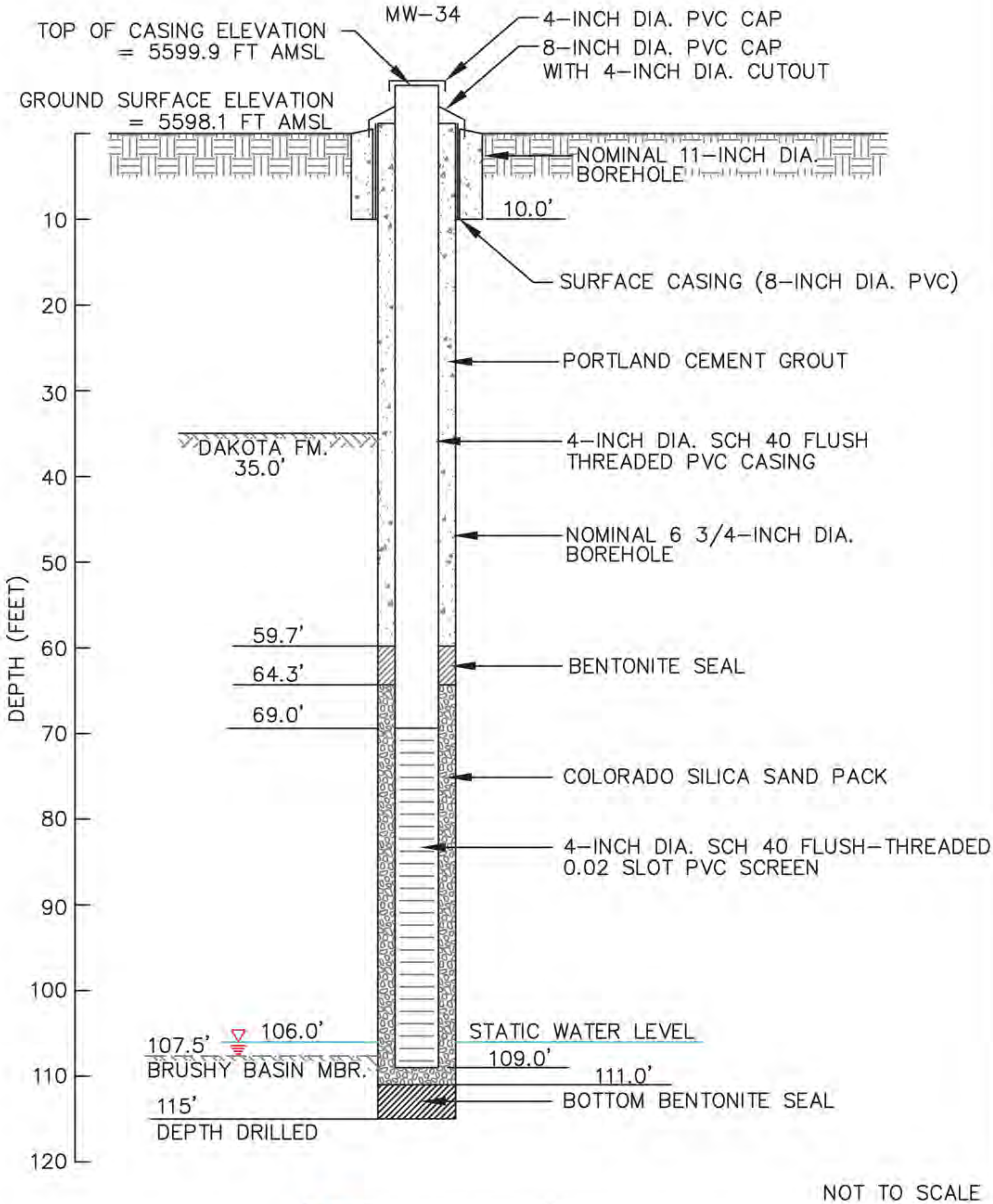
NOTE: WELL IS DRY

NOT TO SCALE

HYDRO GEO CHEM, INC.

MW-33
AS-BUILT WELL CONSTRUCTION SCHEMATIC

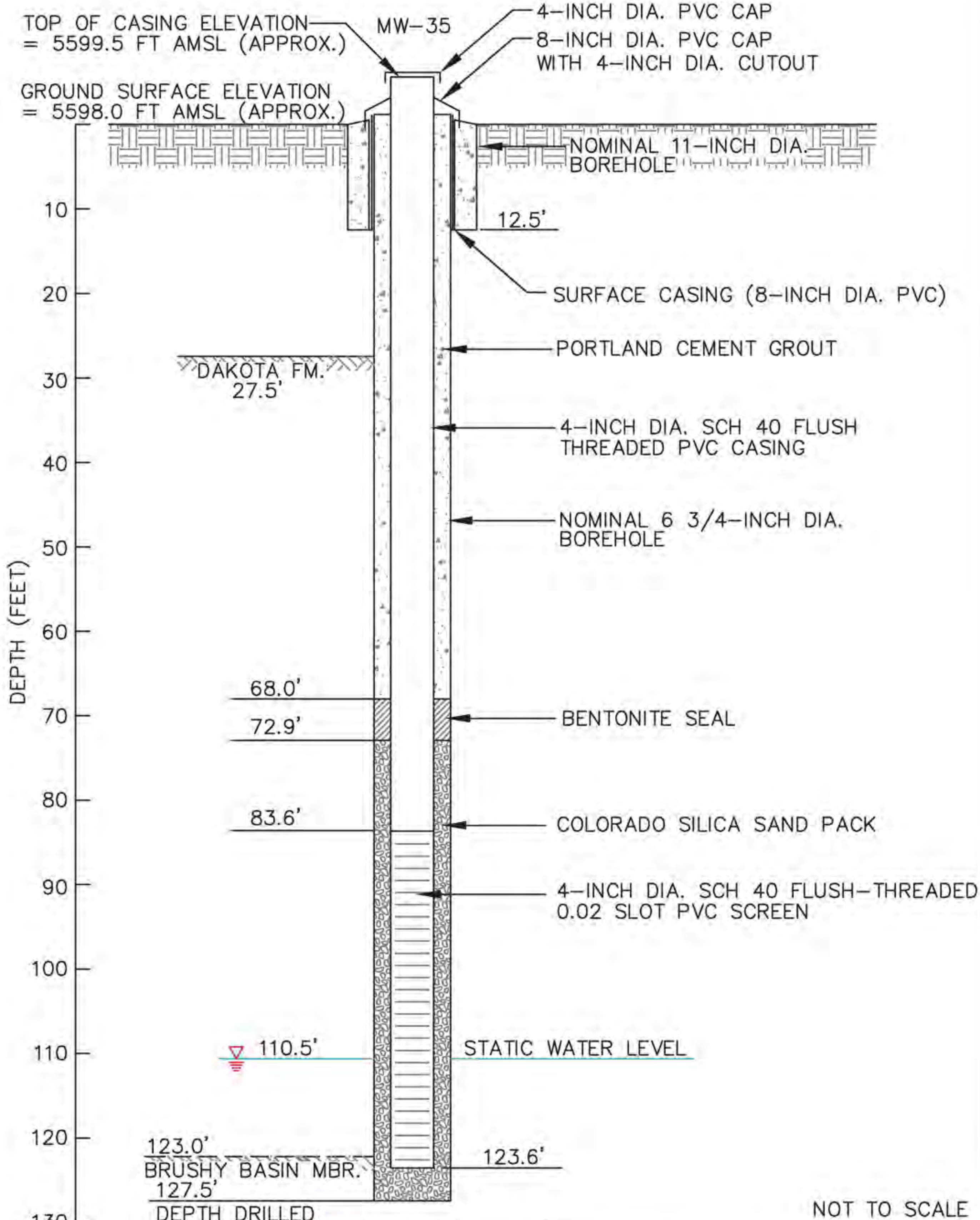
Approved	Date	Author	Date	File Name	Figure
RKZ	9/21/10	JAA	9/21/10	7180248A	2



HYDRO GEO CHEM, INC.

MW-34
AS-BUILT WELL CONSTRUCTION SCHEMATIC

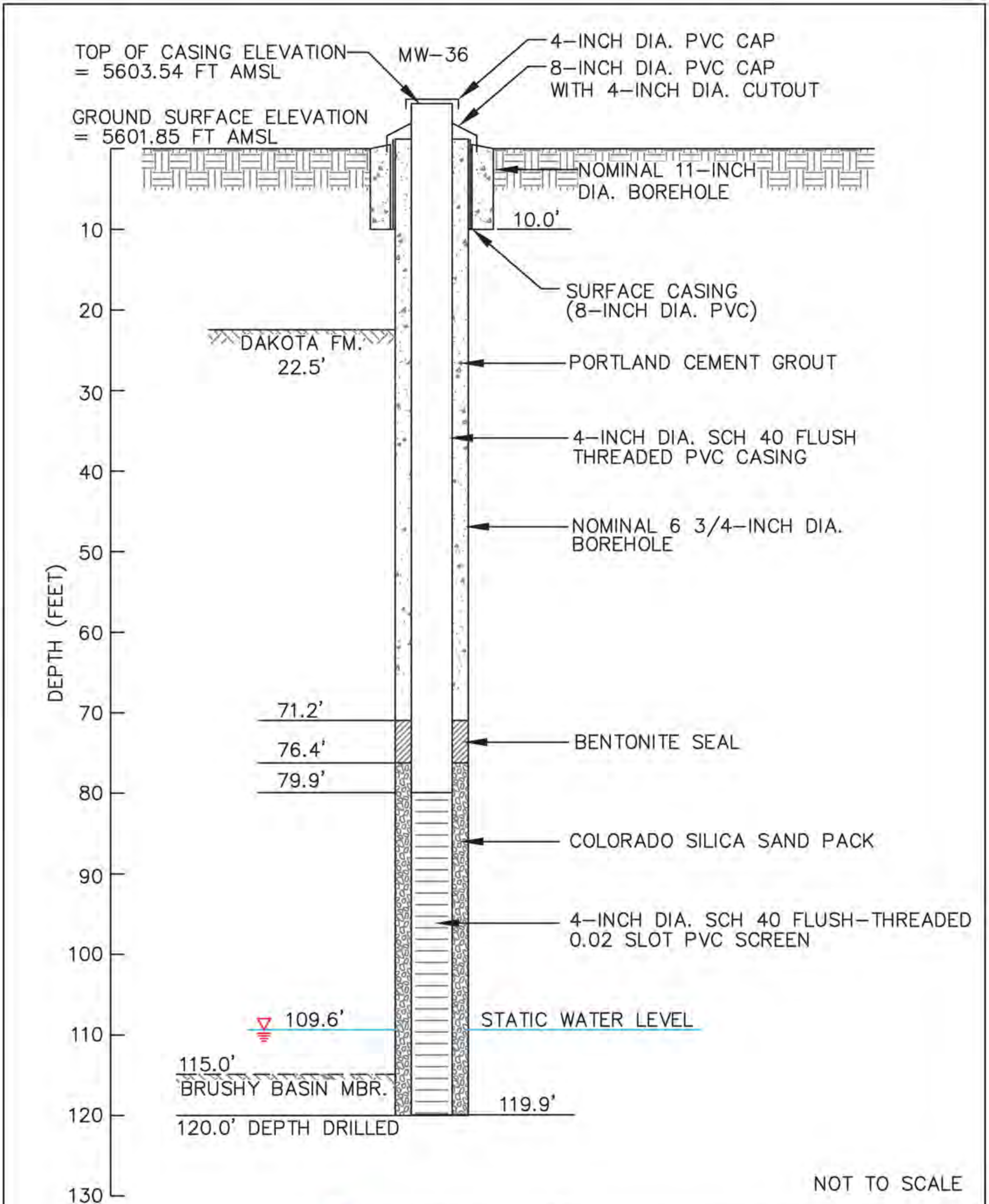
Approved	Date	Author	Date	File Name	Figure
RKZ	9/21/10	JAA	9/21/10	7180248A	3



HYDRO GEO CHEM, INC.

MW-35
AS-BUILT WELL CONSTRUCTION SCHEMATIC

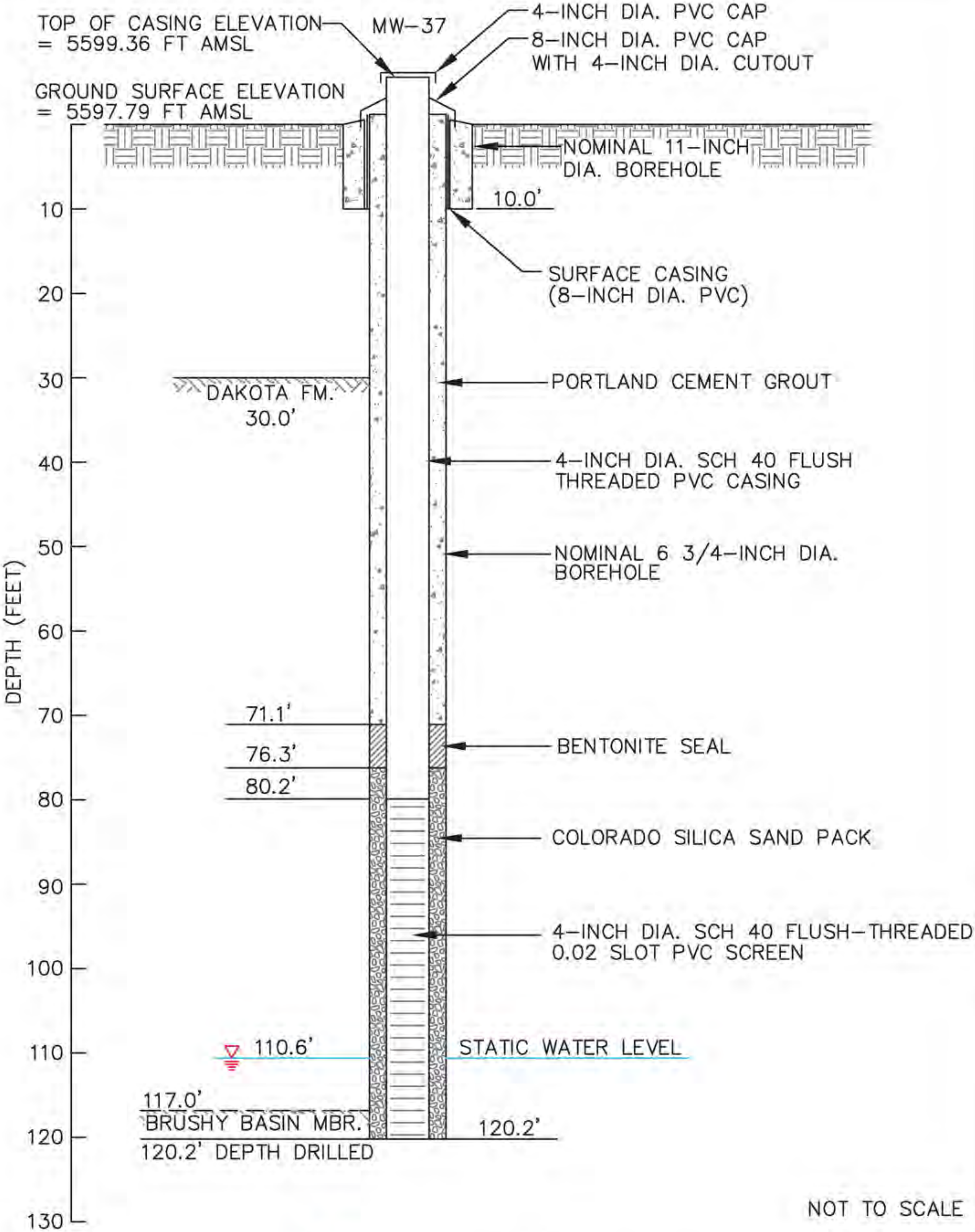
Approved	Date	Author	Date	File Name	Figure
RKZ	9/21/10	JAA	9/21/10	7180248A	4



HYDRO GEO CHEM, INC.

MW-36
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SJS	6/21/11	JAA	6/21/11	7180249A	2



HYDRO GEO CHEM, INC.

MW-37
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SJS	6/21/11	JAA	6/21/11	7180249A	3

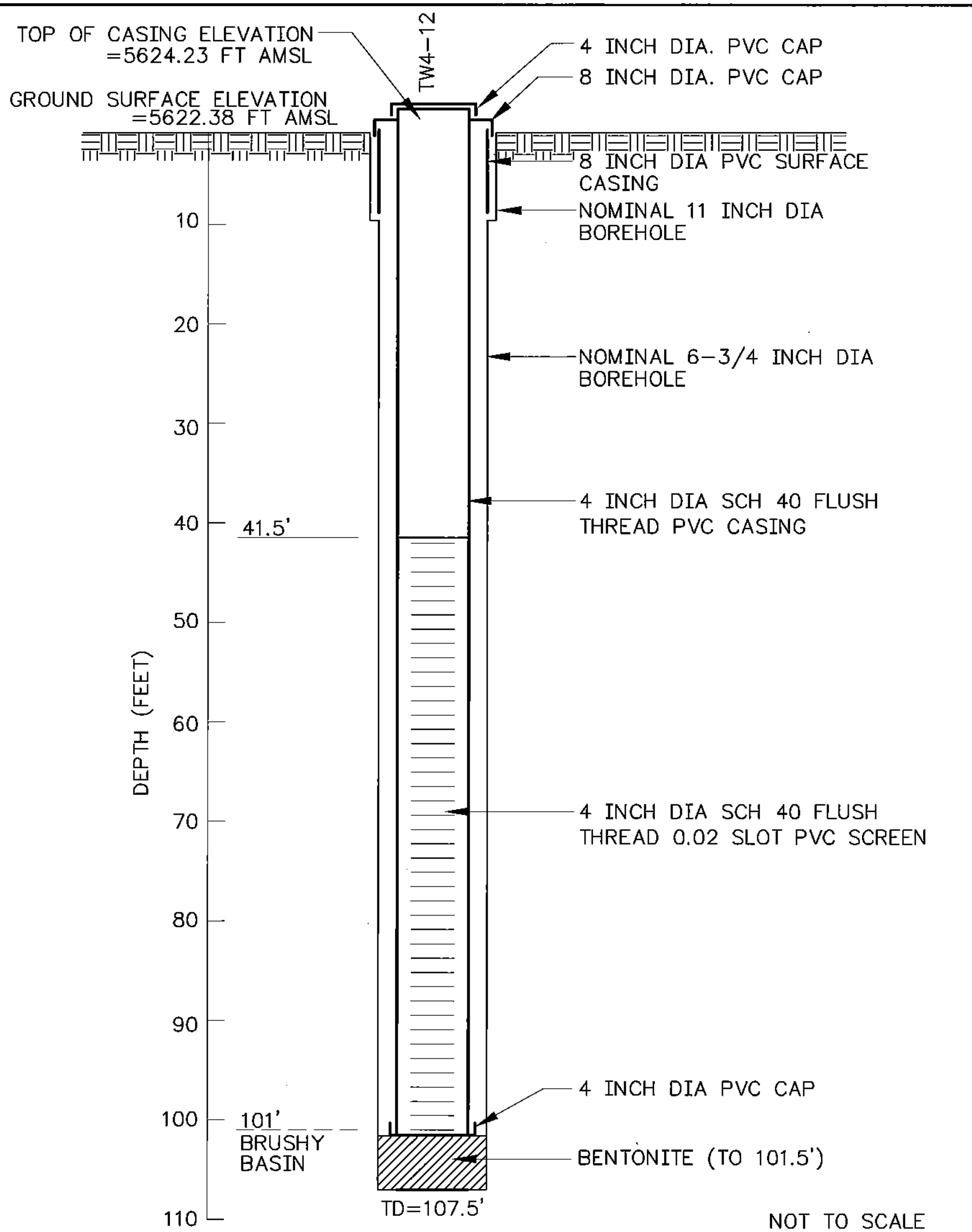
APPENDIX B.3

TW4 - SERIES

TABLE 3
Temporary Perched Well Completion and Analytical Parameters

	TW 4-1	TW 4-2	TW 4-3	TW 4-4	TW 4-5	TW 4-6	TW 4-7	TW 4-8	TW 4-9
Approximate screened interval (feet bls)	70-110	80-120	67-97	72-112	80-120	57.5-97.5	80-120	85-125	80-120
Depth to water[1] (feet below measuring point)	81.1	76.4	65.3	90.5[2]	61.4	86.5[2]	67.5	75.2	60.5
pH	6.80	7.06	6.72	NS	6.24	NS	6.87	6.97	6.26
Electrical conductivity (mS/cm)	4,063	3,581	3,655	2,100	1,787	3,487	4,056	3,402	3,049
Temperature (°C)	13.1	14.4	13.4	14.8	14.5	15.0	14.4	14.2	13.3
Chloroform (µg/L) (1st sampling)	5.8	2,510	702	NS	29.5	NS	256	<1	4.2
Chloroform (µg/L) (2nd sampling)	1,100	5,520	834	NS	49	NS	616	21.8	1.88
Chloroform (µg/L) (3rd sampling)	1,490	NS	NS	NS	NS	NS	NS	NS	NS
Chloroform (µg/L) (initial sampling of TW 4-4 and TW 4-6)	NS	NS	NS	<0.5	NS	<0.5	NS	NS	NS
Chloroform (µg/L) (4th sampling) (2nd sampling of TW 4-4 and TW 4-6)	2,320	5,220	836	<1	124	<1	698	102	14.2

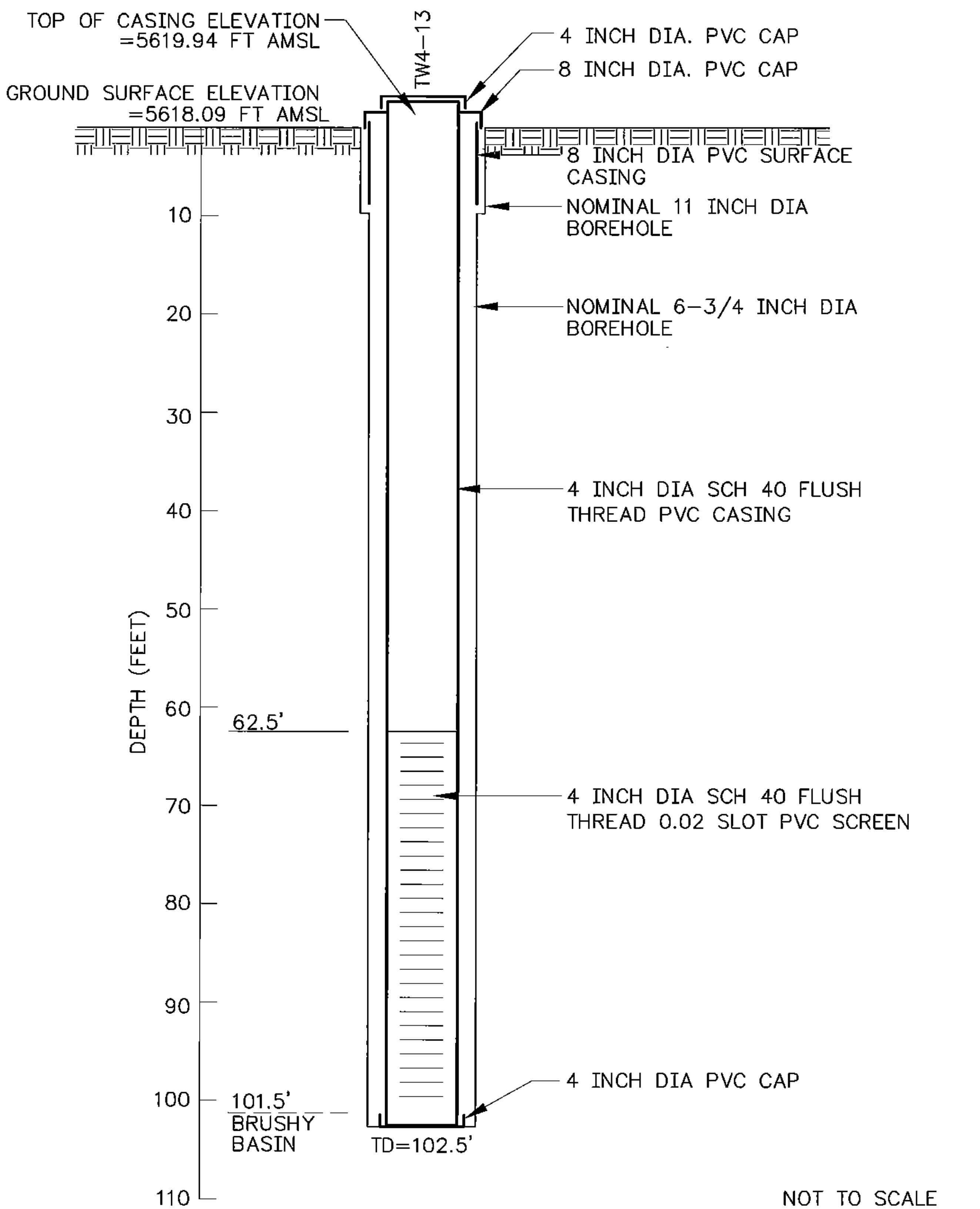
Note: *1 = Depth to water measured on January 3, 2000*
2 = Depth to water measured on July 27, 2000
NS = not sampled



HYDRO GEO CHEM, INC.

TW4-12
WELL CONSTRUCTION SCHEMATIC

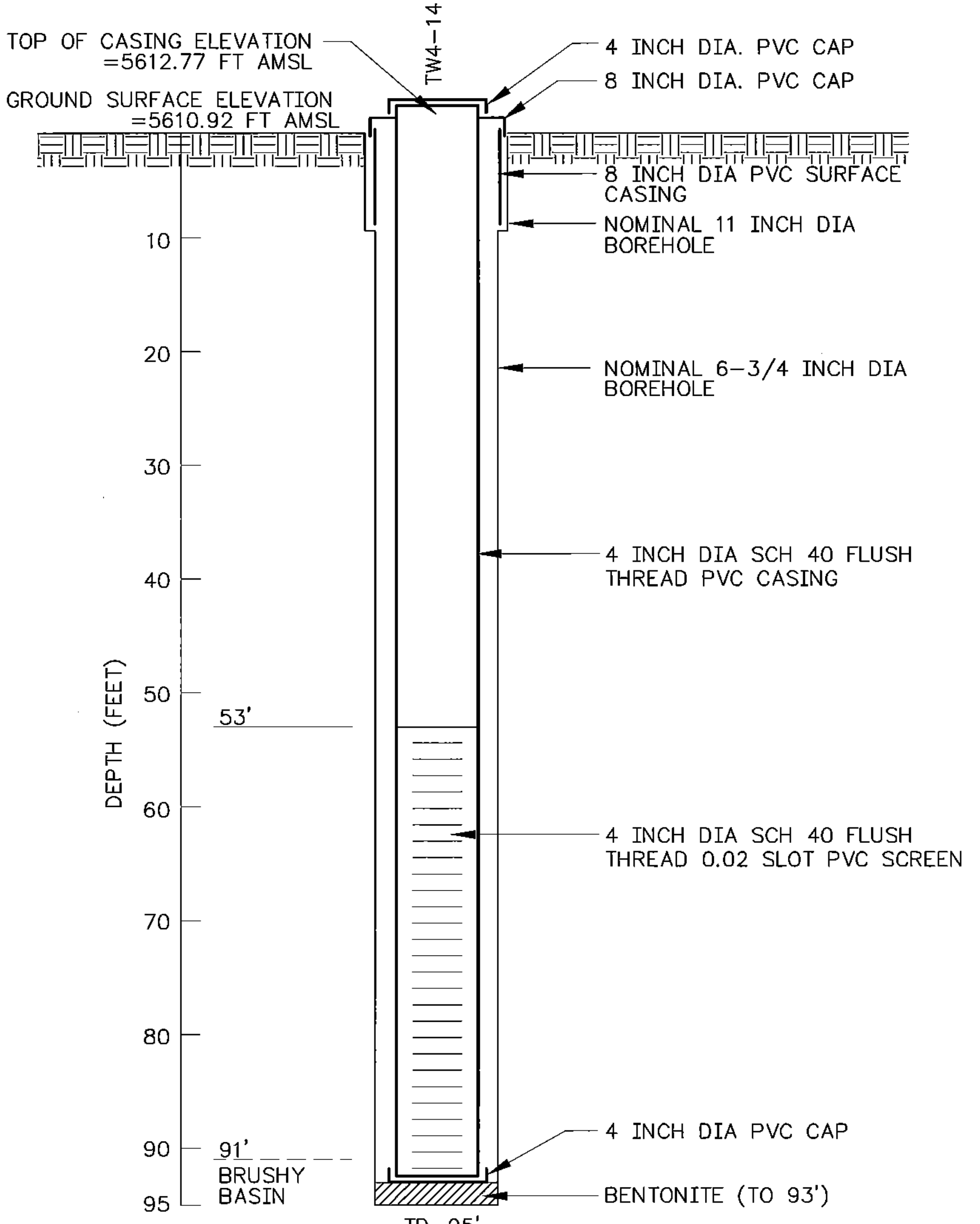
Approved	Date	Revised	Date	Reference:	FIG.
SS	8/30/02			7180203A	2



HYDRO GEO CHEM, INC.

TW4-13
WELL CONSTRUCTION SCHEMATIC

Approved	Date	Revised	Date	Reference:	FIG.
SS	8/30/02			7180202A	3

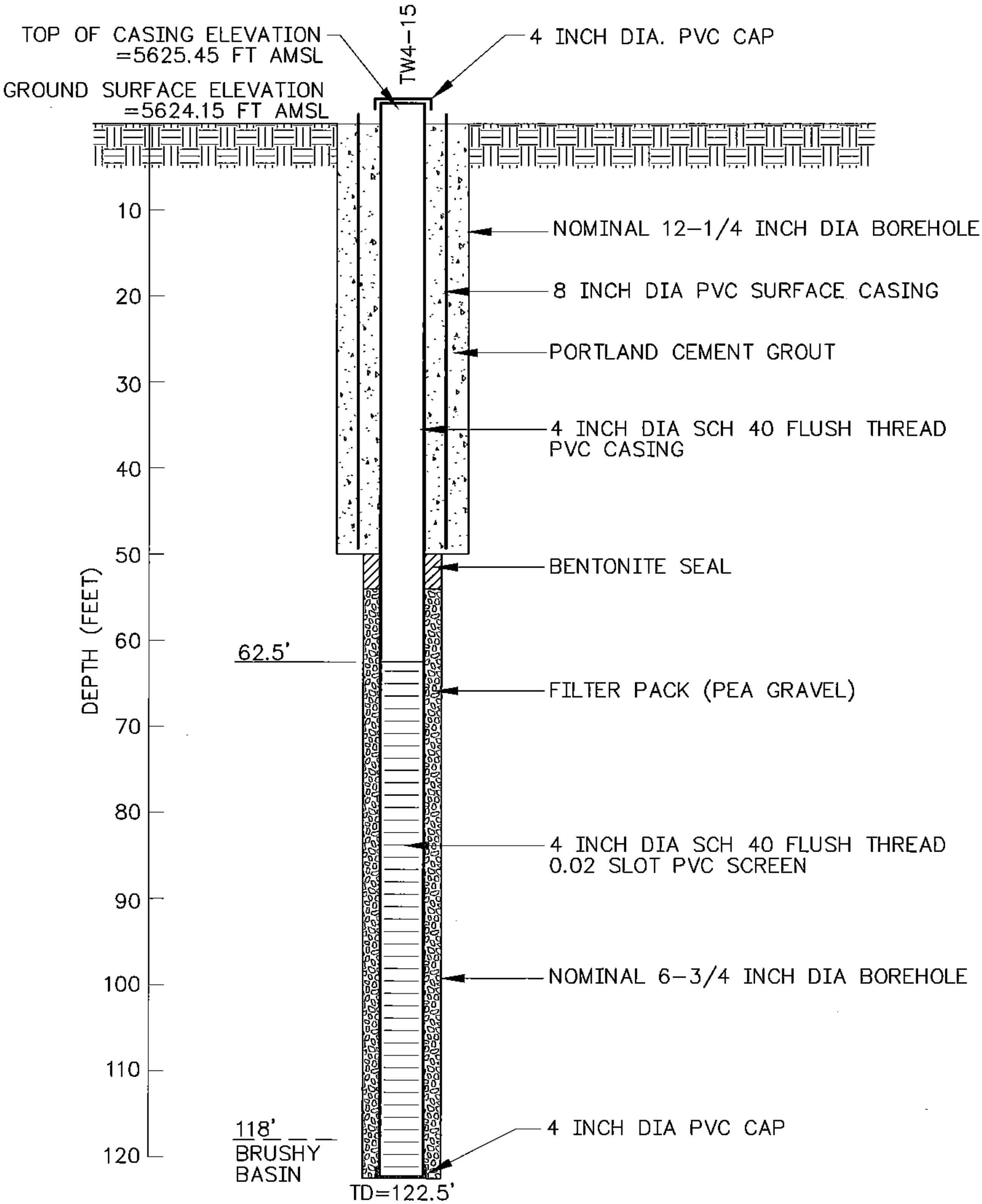


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-14
WELL CONSTRUCTION SCHEMATIC

Approved	Date	Revised	Date	Reference:	FIG.
SS	8/30/02			7180201A	4

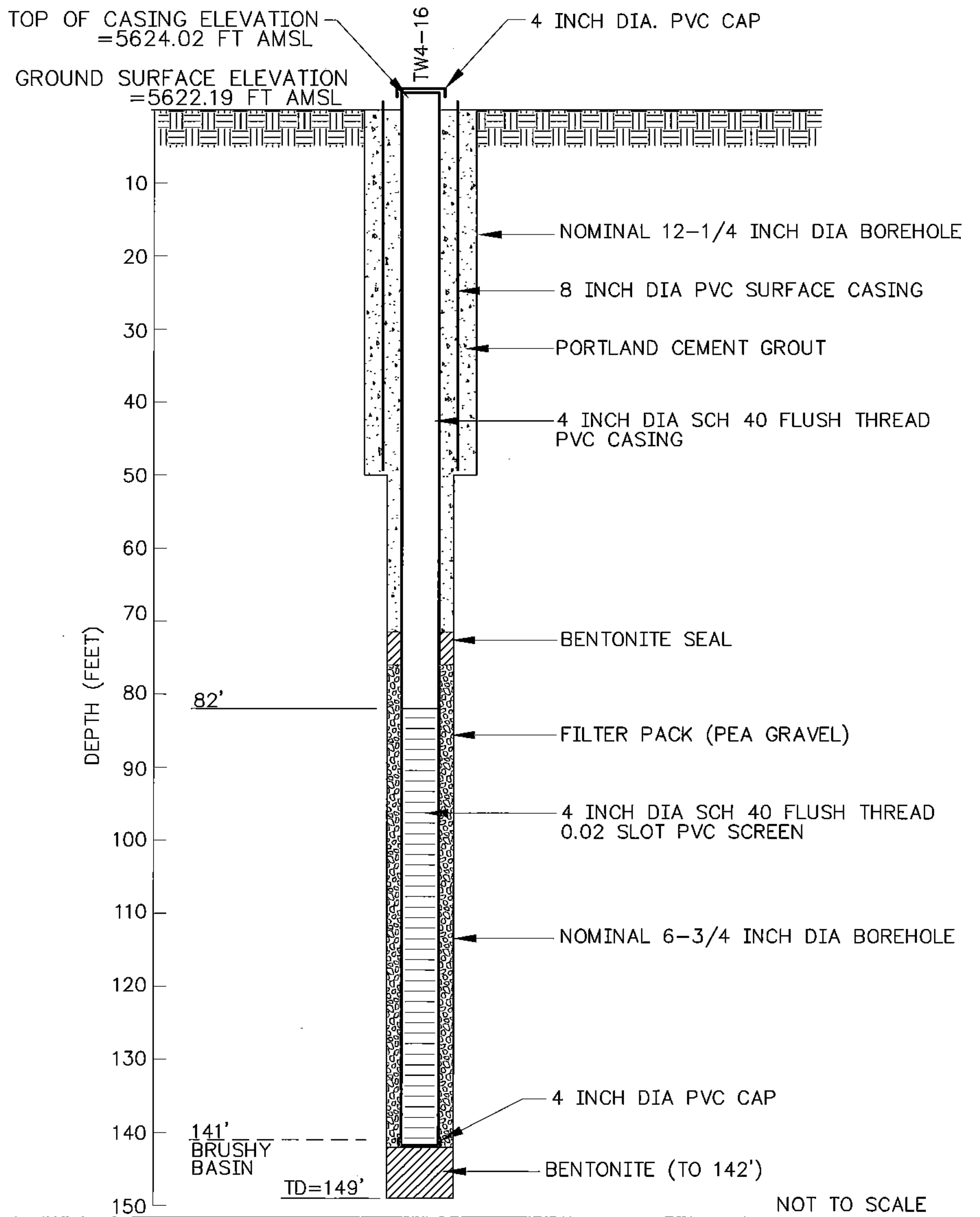


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-15
WELL CONSTRUCTION SCHEMATIC

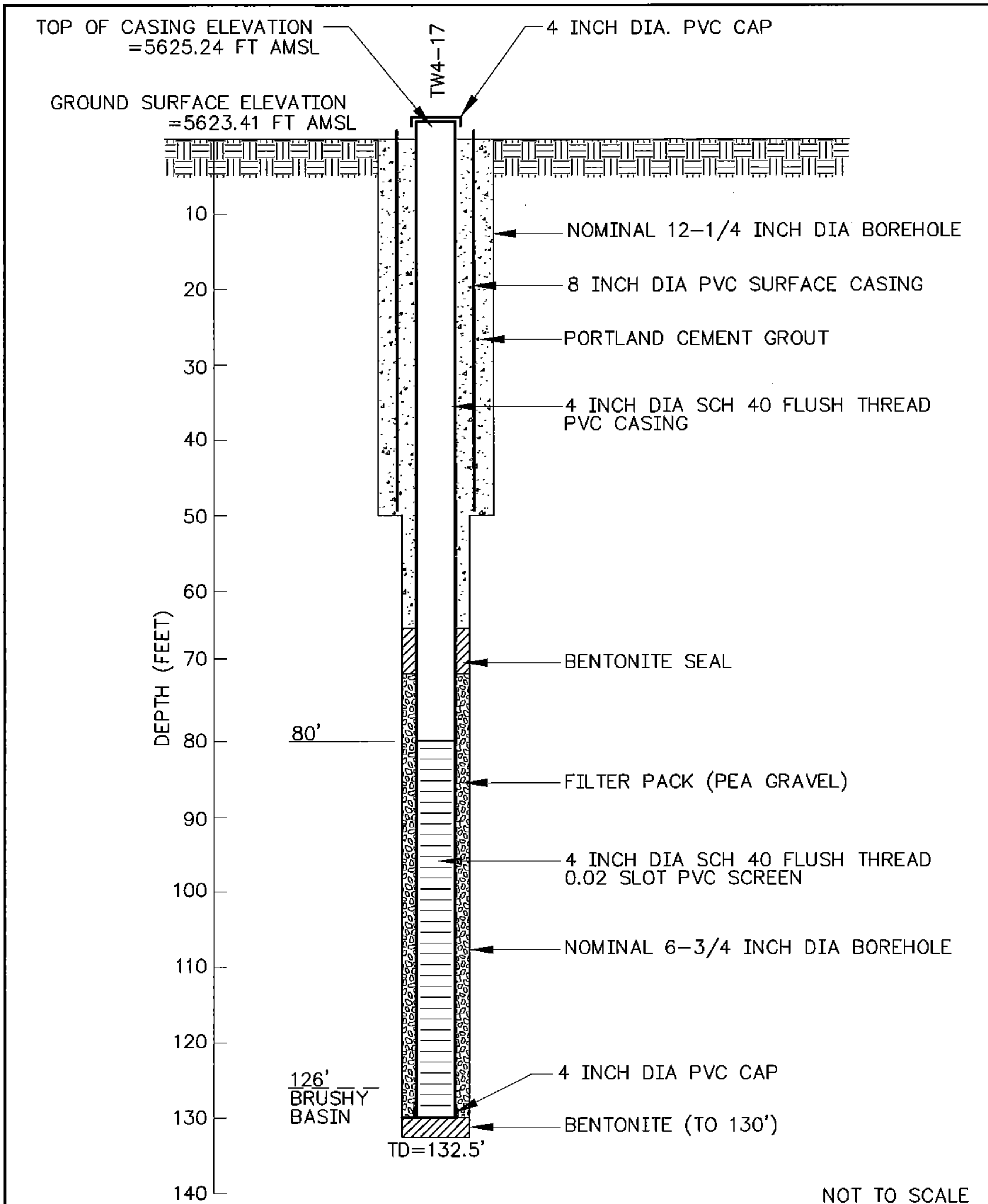
Approved	Date	Revised	Date	Reference:	FIG.
SS	8/30/02			7180204A	5



HYDRO GEO CHEM, INC.

TW4-16
WELL CONSTRUCTION SCHEMATIC

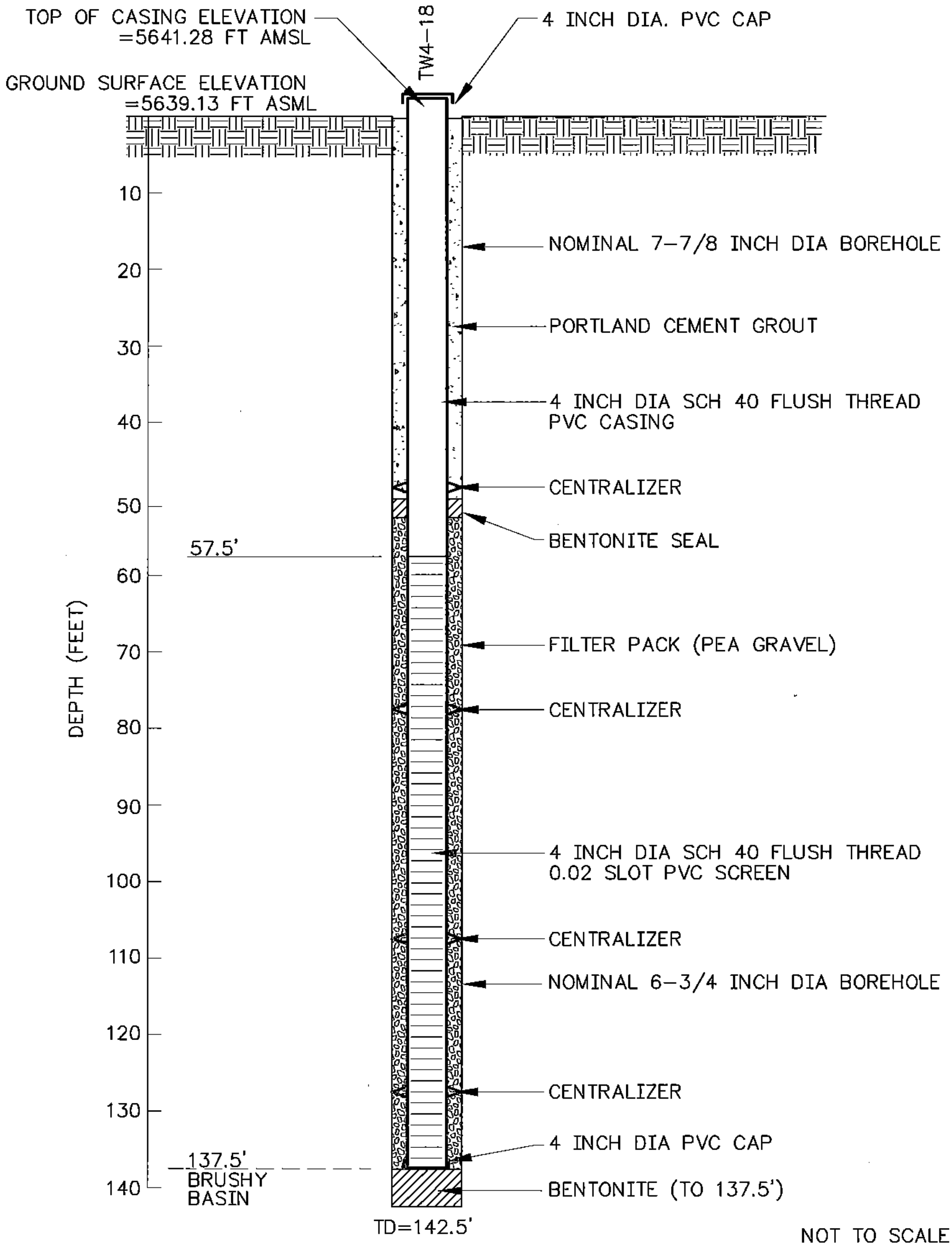
Approved	Date	Revised	Date	Reference:	FIG.
SS	8/30/02			7180205A	6



HYDRO GEO CHEM, INC.

TW4-17
WELL CONSTRUCTION SCHEMATIC

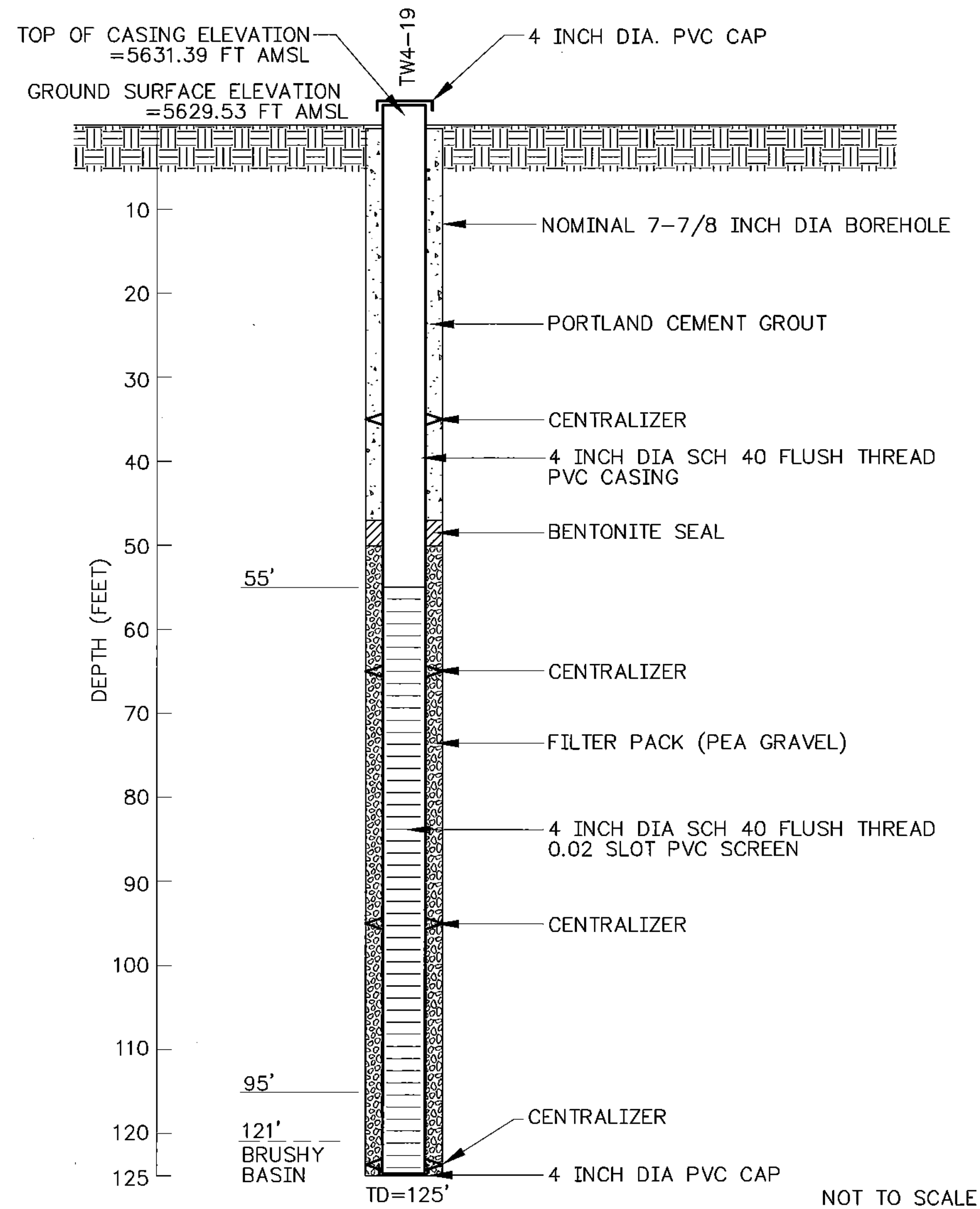
Approved	Date	Revised	Date	Reference:	FIG.
SS	8/30/02			7180206A	7



HYDRO GEO CHEM, INC.

TW4-18
WELL CONSTRUCTION SCHEMATIC

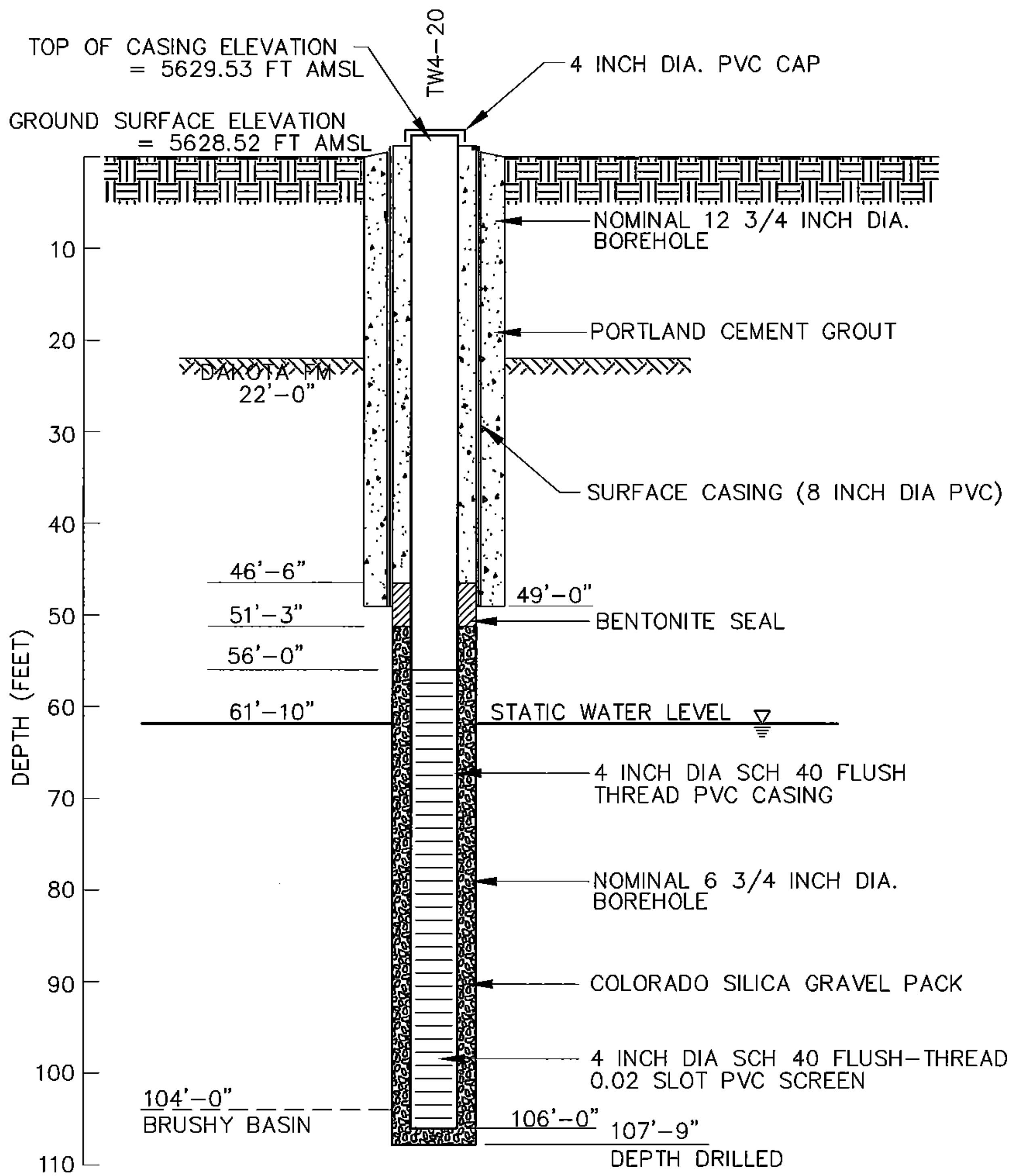
Approved	Date	Revised	Date	Reference:	FIG.
SS	8/30/02			7180207A	8



HYDRO GEO CHEM, INC.

TW4-19
WELL CONSTRUCTION SCHEMATIC

Approved	Date	Revised	Date	Reference:	FIG.
SS	8/30/02			7180208A	9

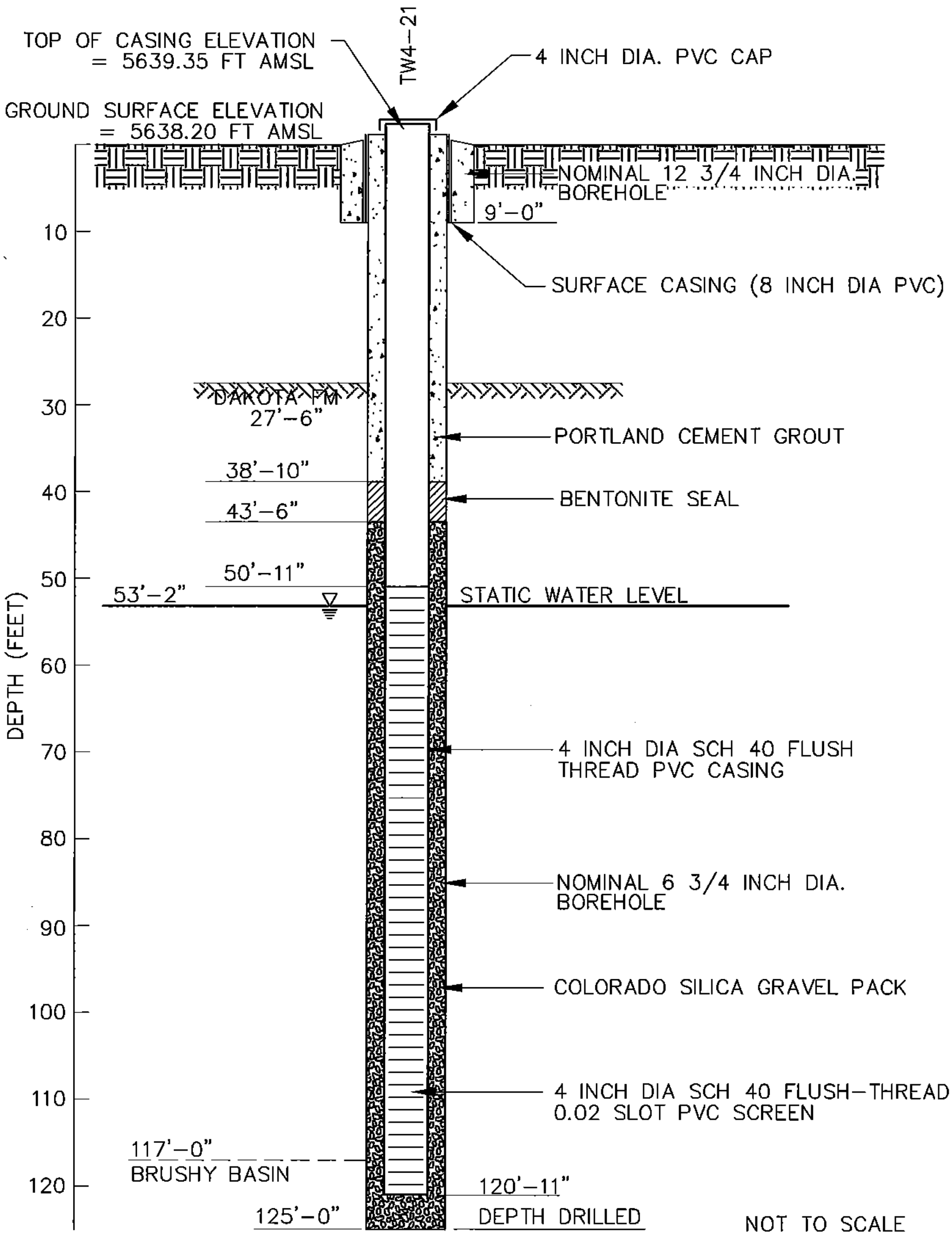


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-20
AS-BUILT WELL CONSTRUCTION SCHEMATIC

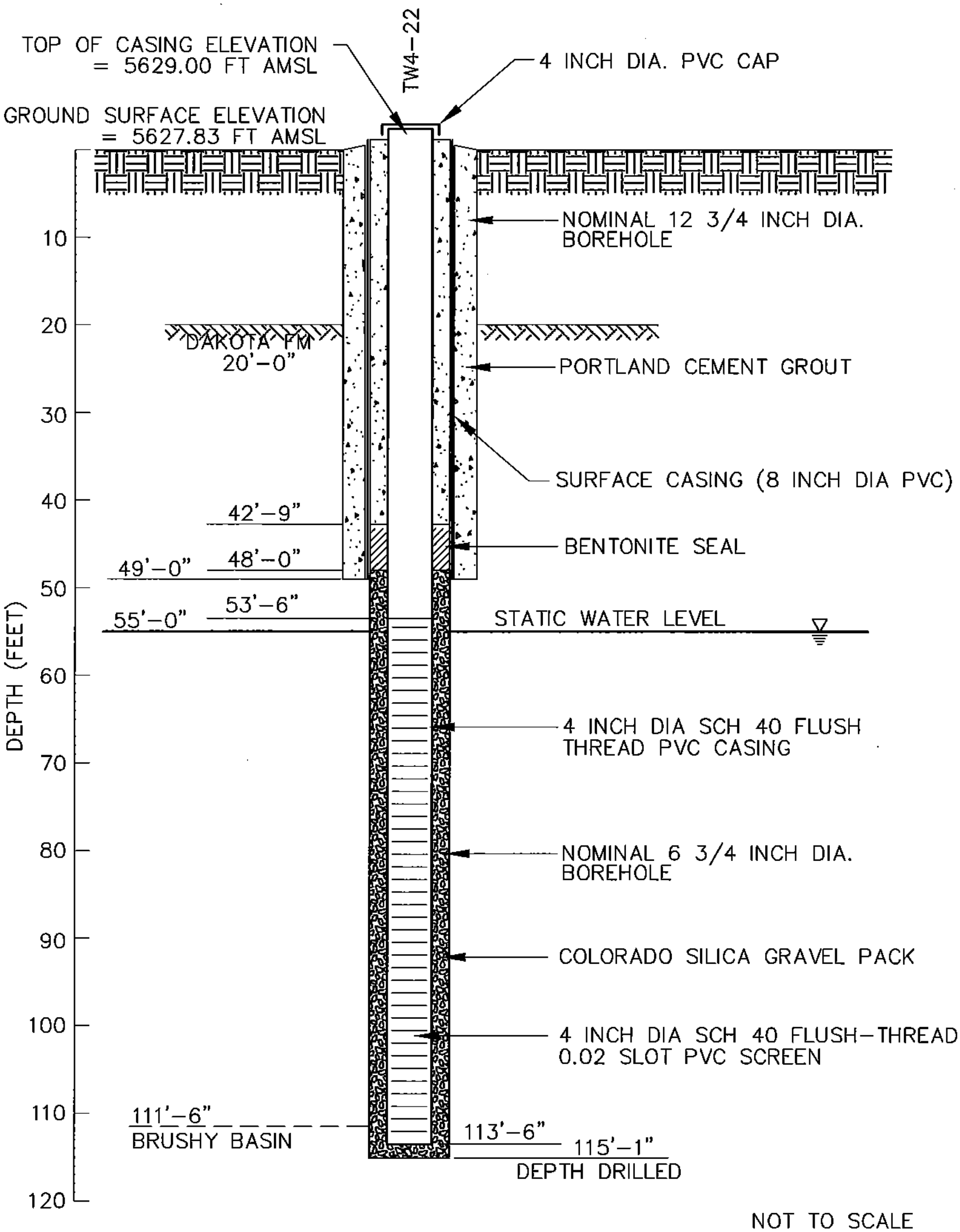
Approved	Date	Author	Date	File Name	Figure
SS	8/01/05			7180219A	11



HYDRO GEO CHEM, INC.

TW4-21
AS-BUILT WELL CONSTRUCTION SCHEMATIC

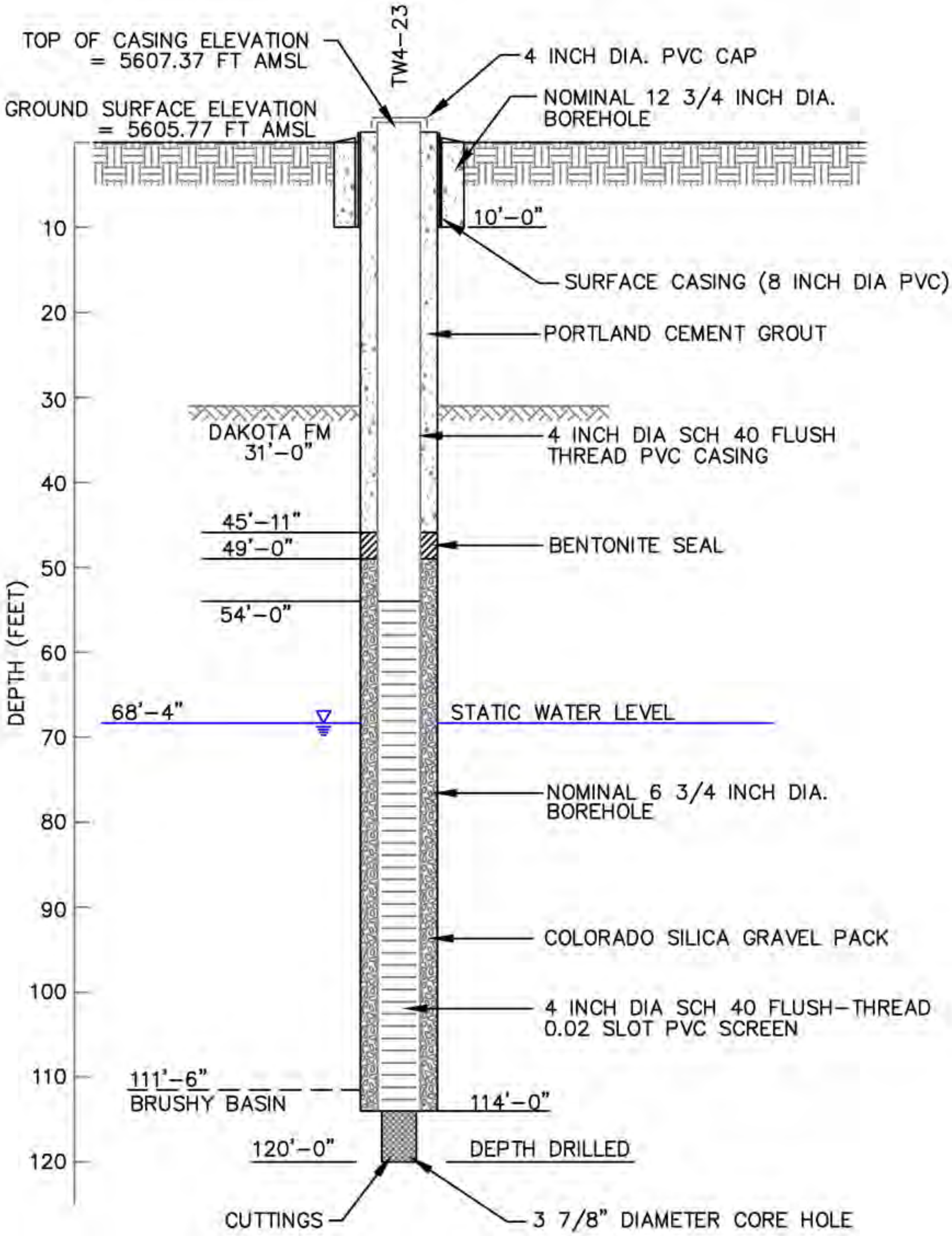
Approved	Date	Author	Date	File Name	Figure
SS	8/01/05			7180220A	12



HYDRO GEO CHEM, INC.

TW4-22
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	8/01/05			7180221A	13

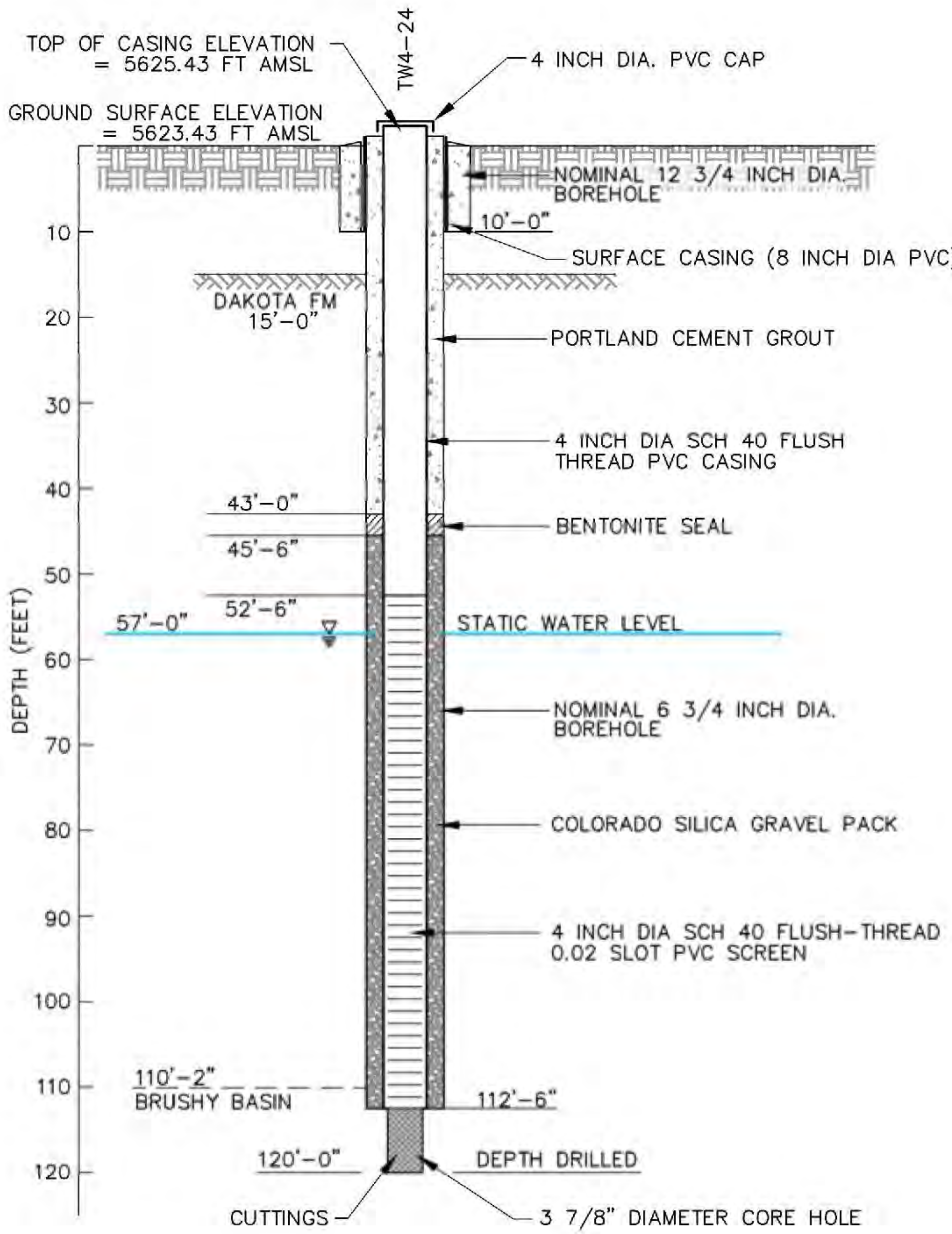


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-23
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SJS	06/16/11	JAA	06/16/11	7180244A	2

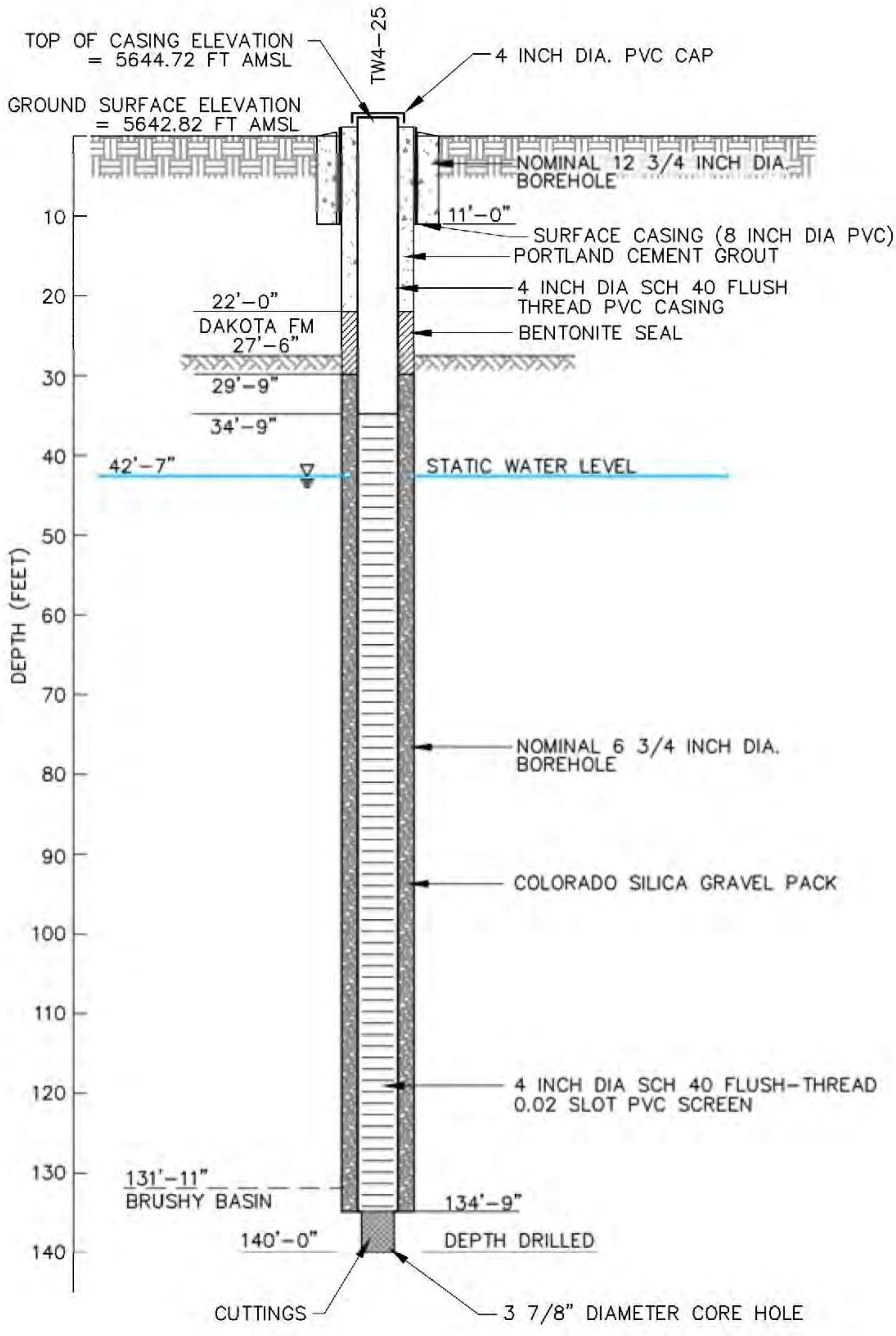


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-24
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/17/10	AMC	03/17/10	7180245A	3

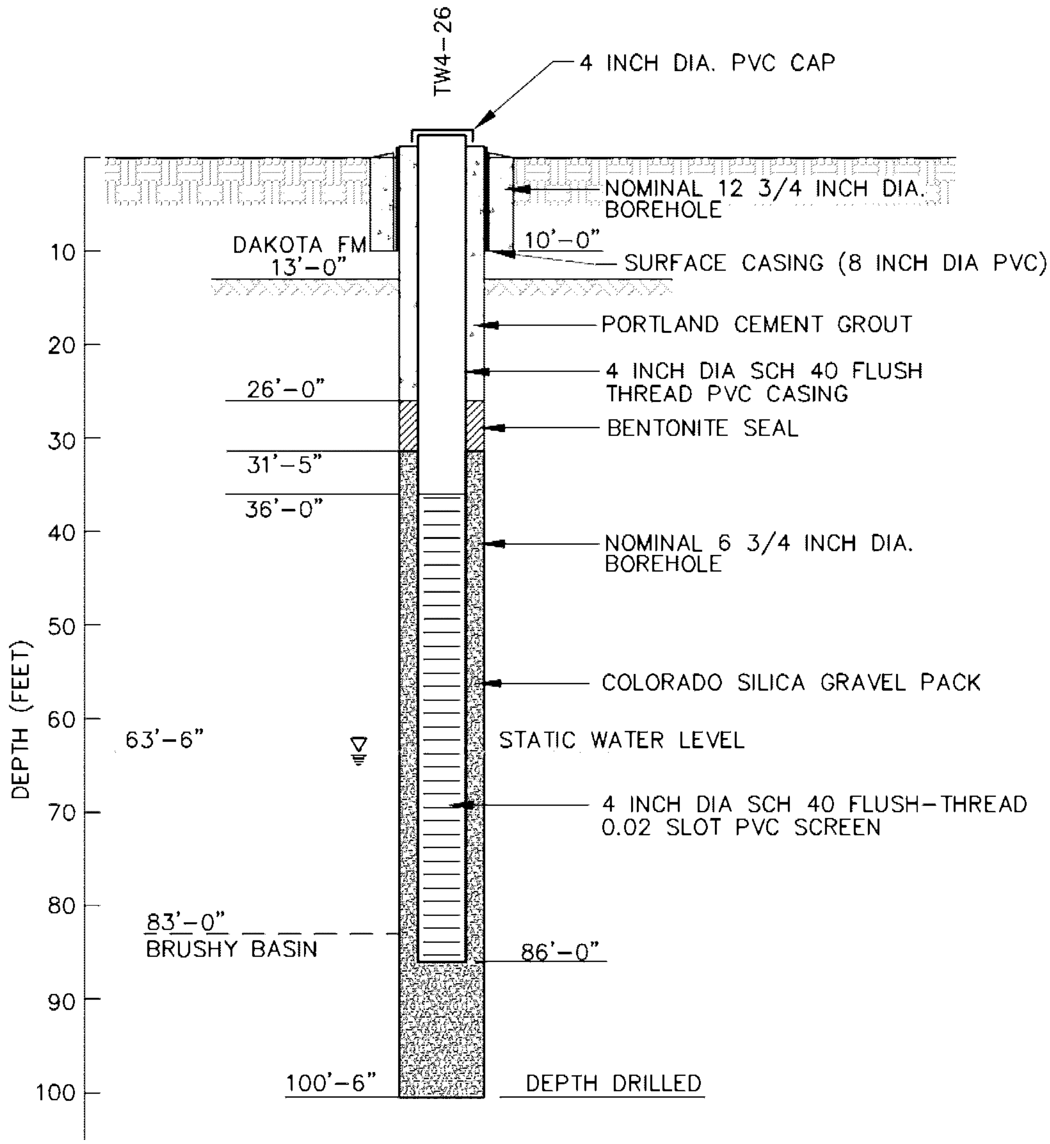


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-25
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/17/10	AMC	03/17/10	7180246A	4

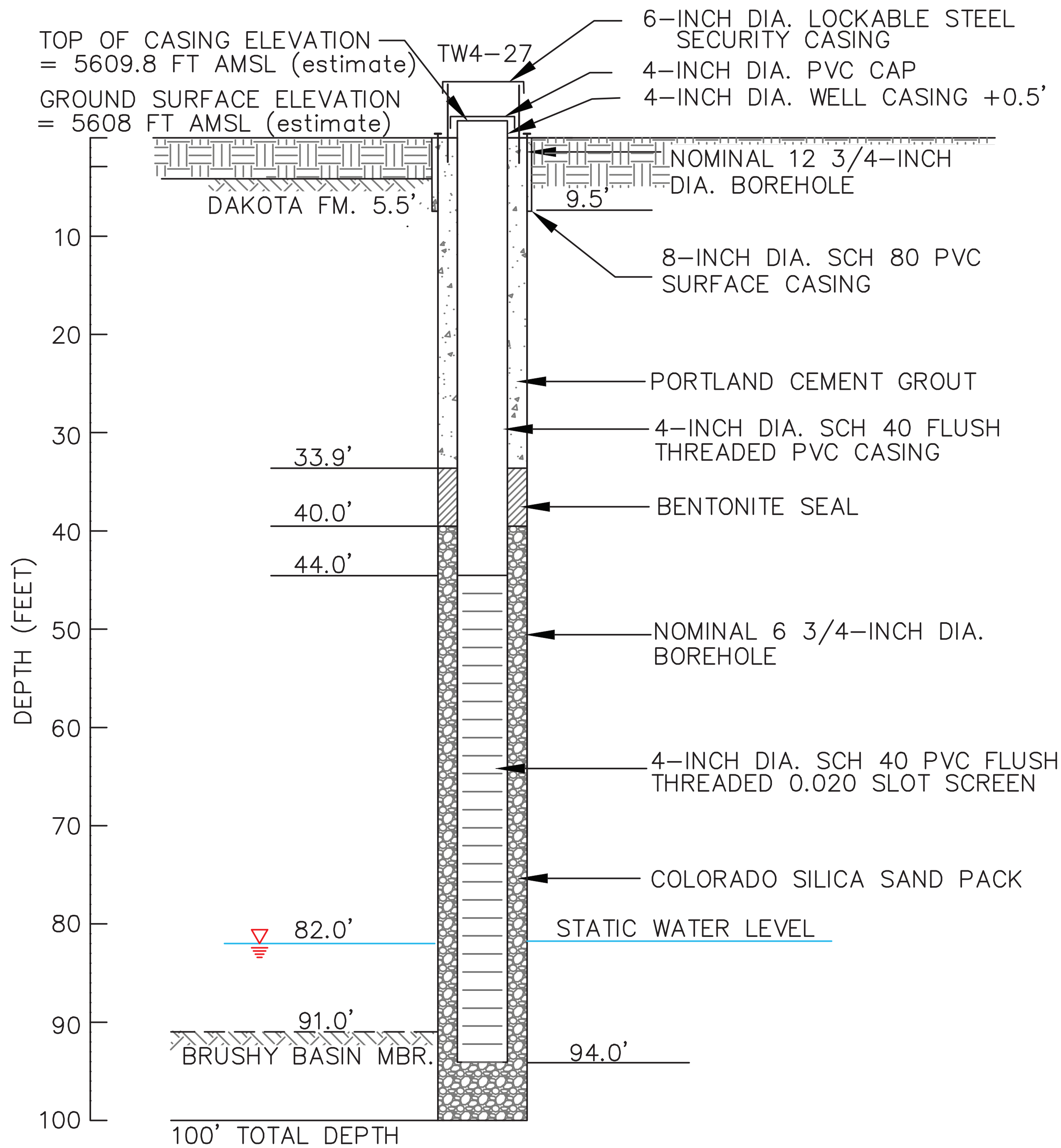


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-26
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	07/21/10	AMC	07/21/10	7180247A	**2**

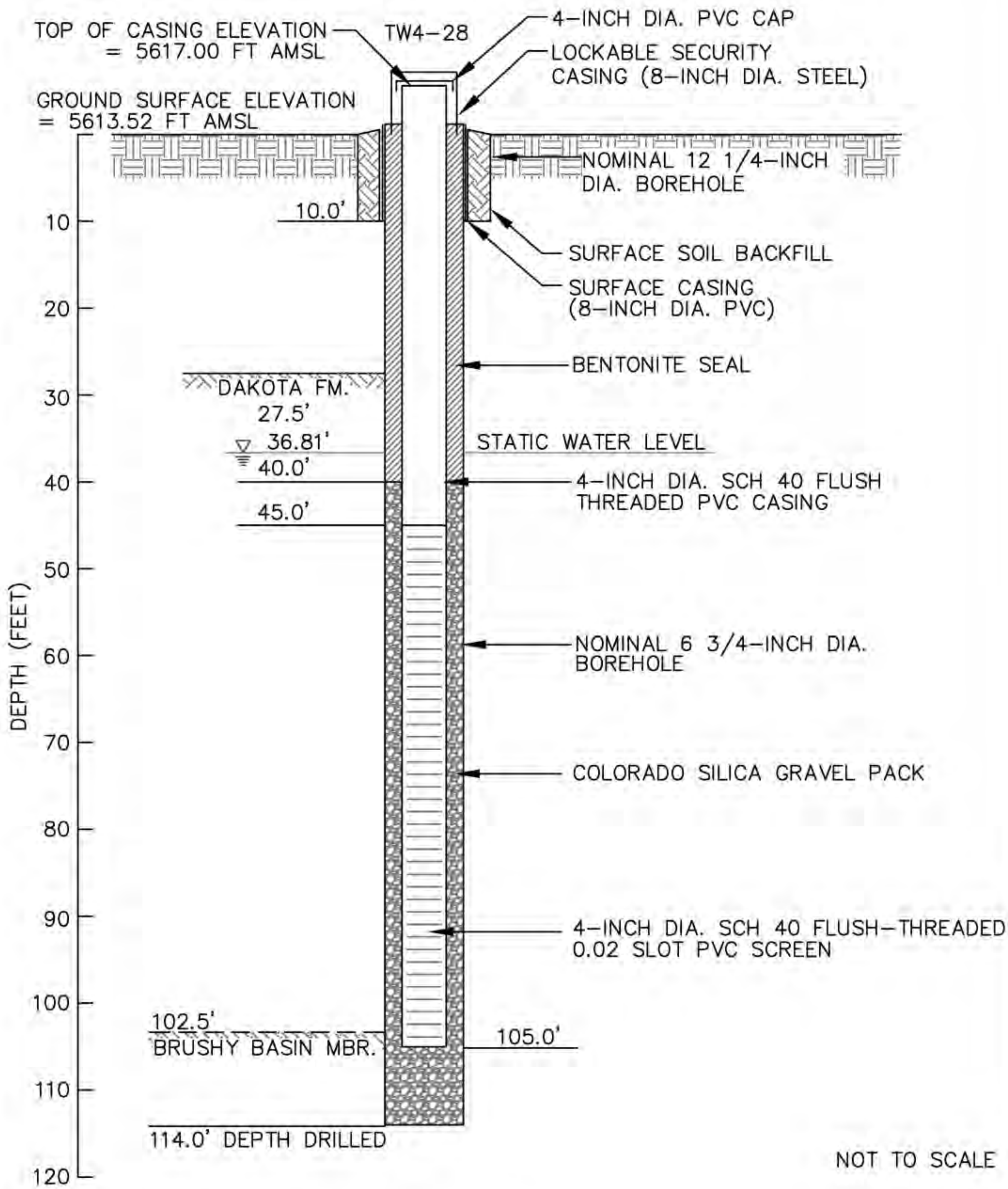


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-27
AS-BUILT WELL CONSTRUCTION SCHEMATIC

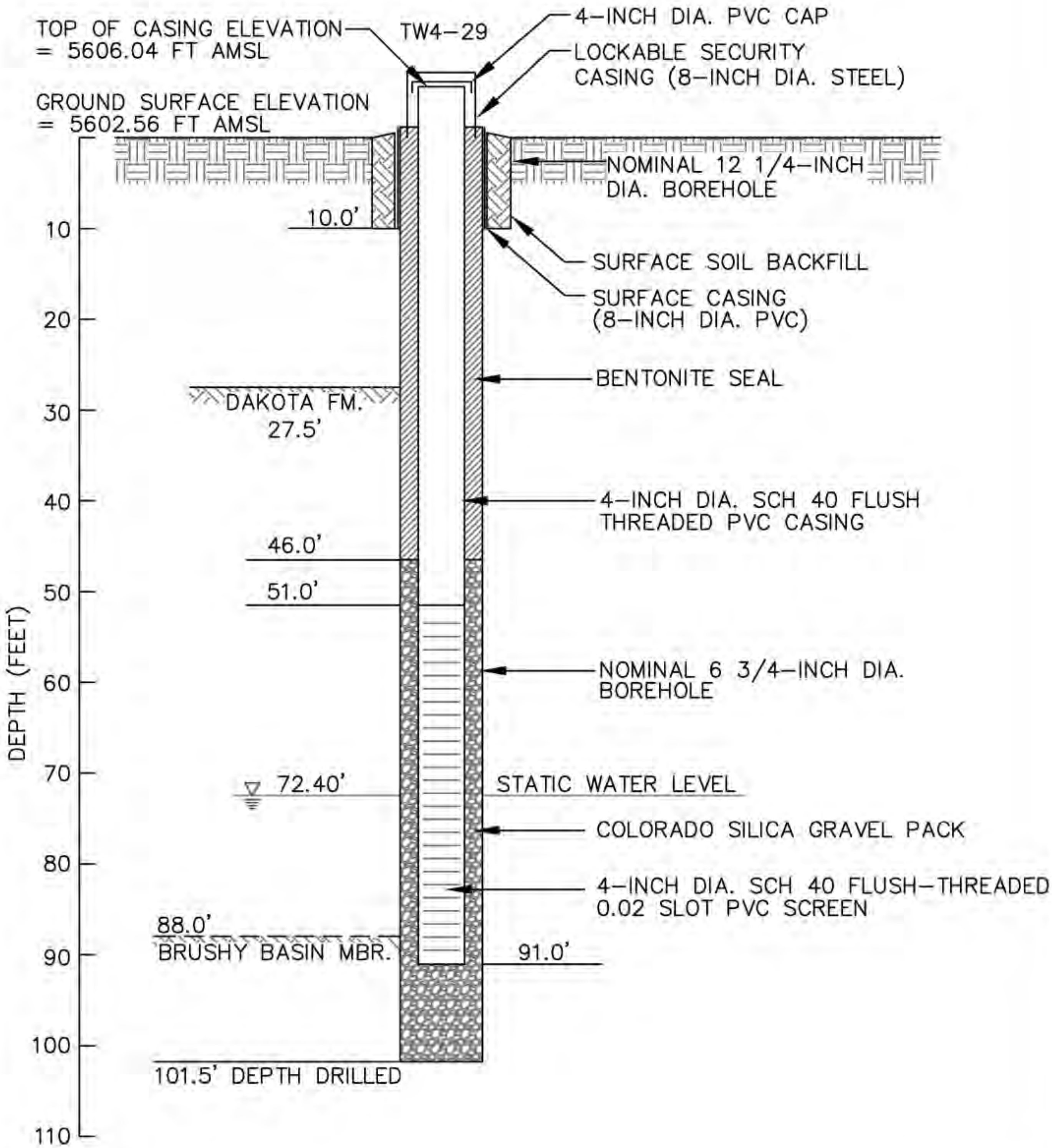
Approved	Date	Reference	Figure
SJS	10/25/11	K:\7180272A Well Construction Diagram	2



HYDRO GEO CHEM, INC.

TW4-28
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SJS	3/29/13	CAD	4/19/13	7180273A	2

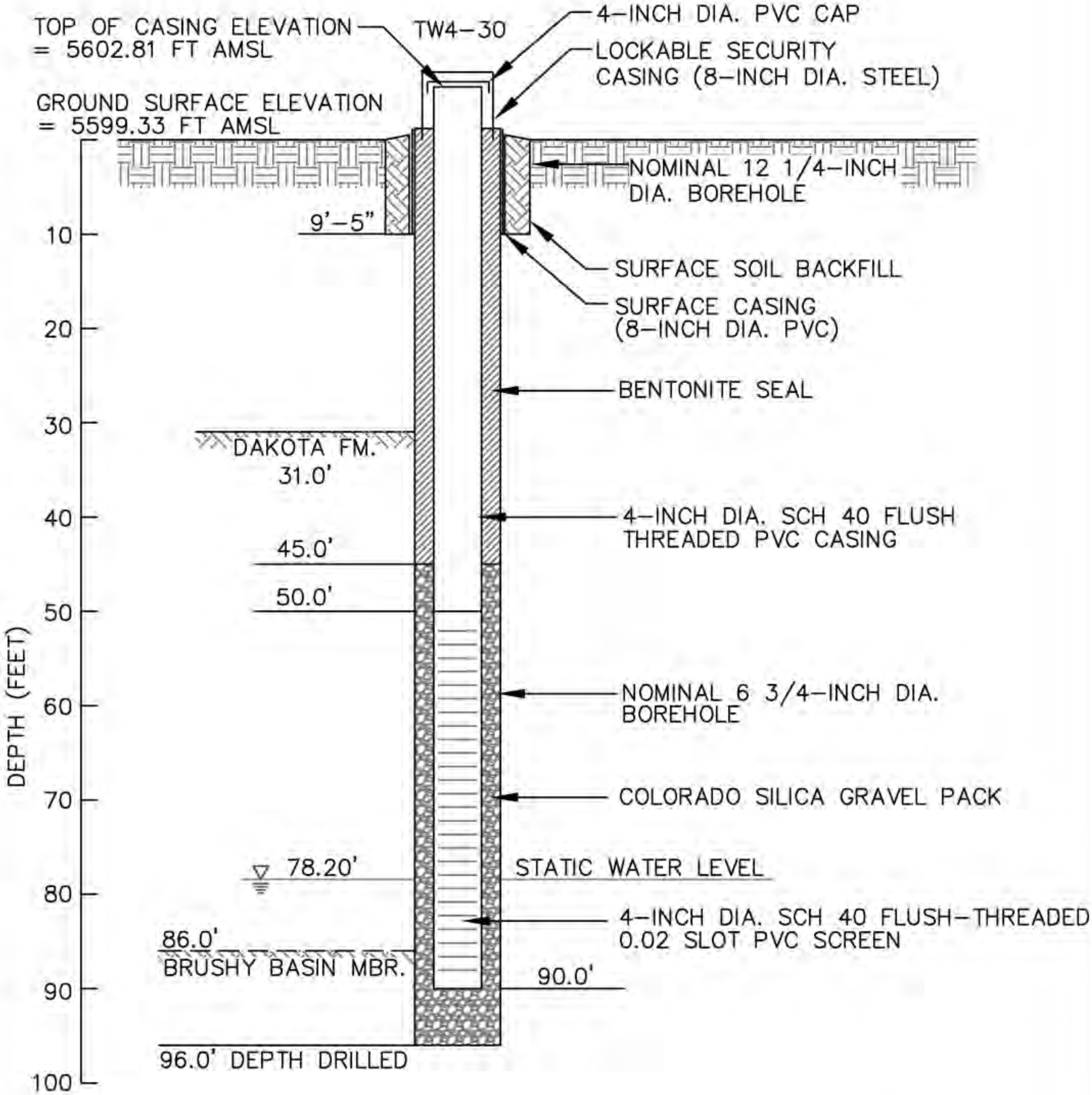


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-29
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SJS	4/02/13	CAD	4/19/13	7180274A	3

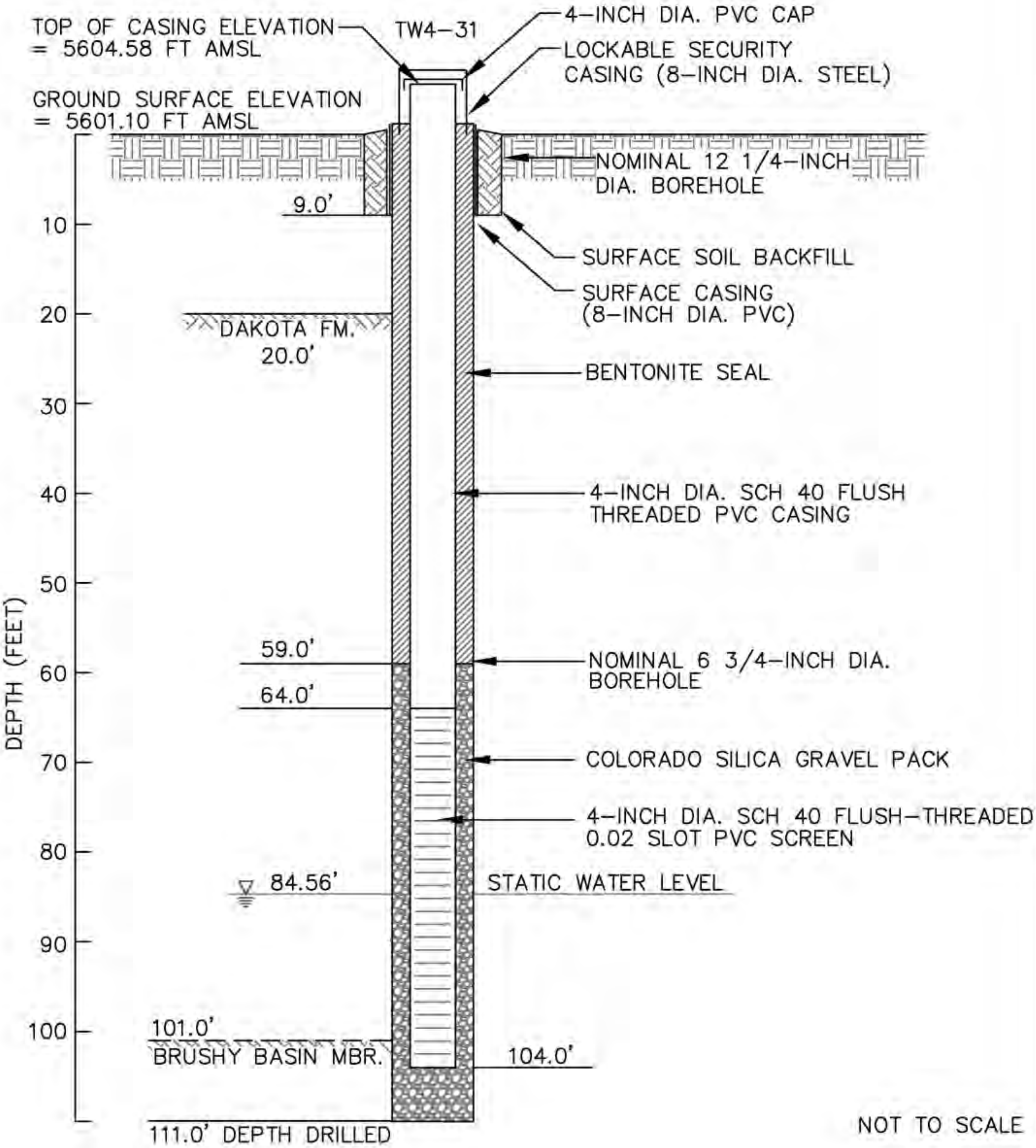


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-30
AS-BUILT WELL CONSTRUCTION SCHEMATIC

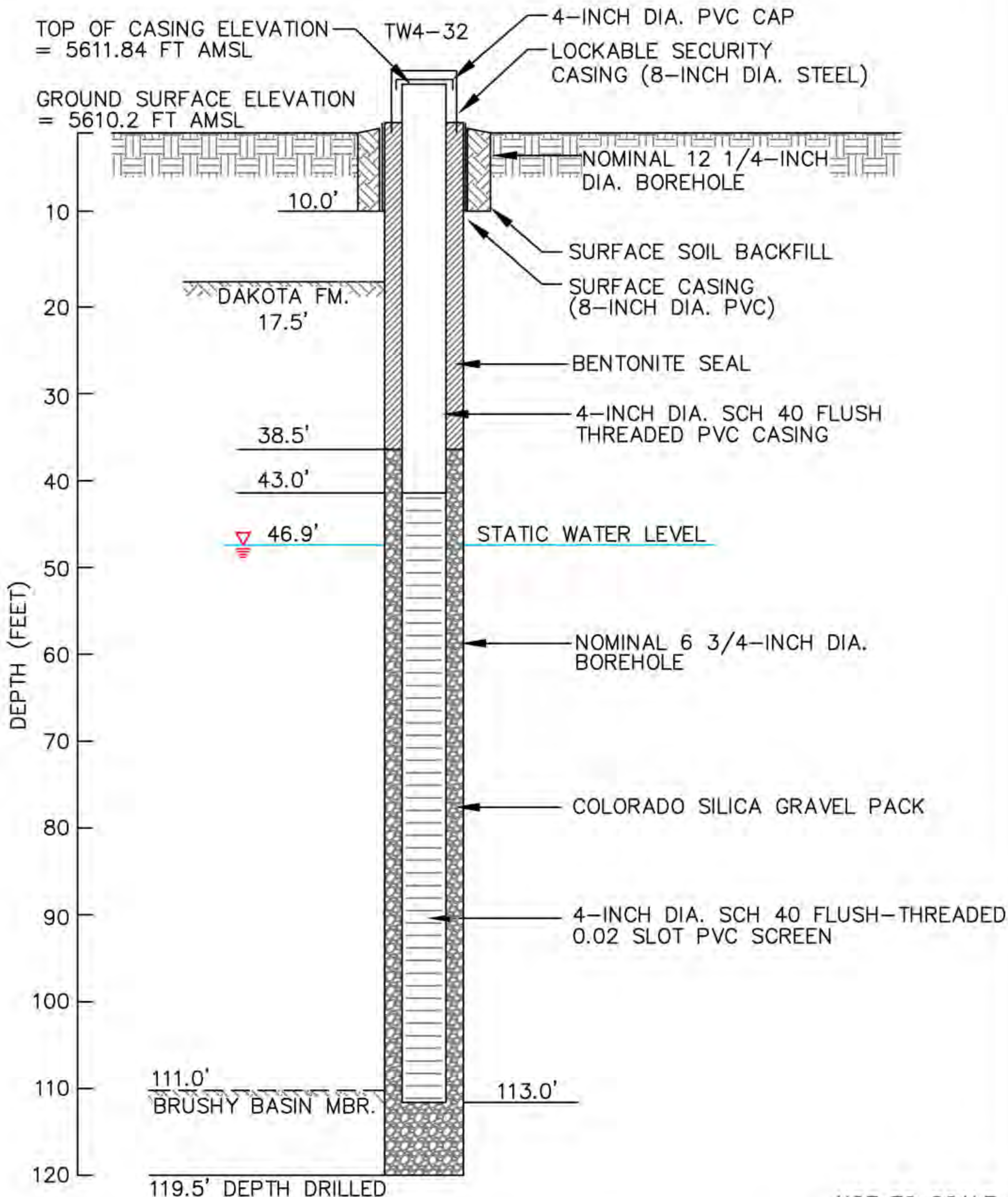
Approved	Date	Author	Date	File Name	Figure
SJS	4/02/13	CAD	4/19/13	7180275A	4



HYDRO GEO CHEM, INC.

TW4-31
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SJS	4/02/13	CAD	4/19/13	7180276A	5

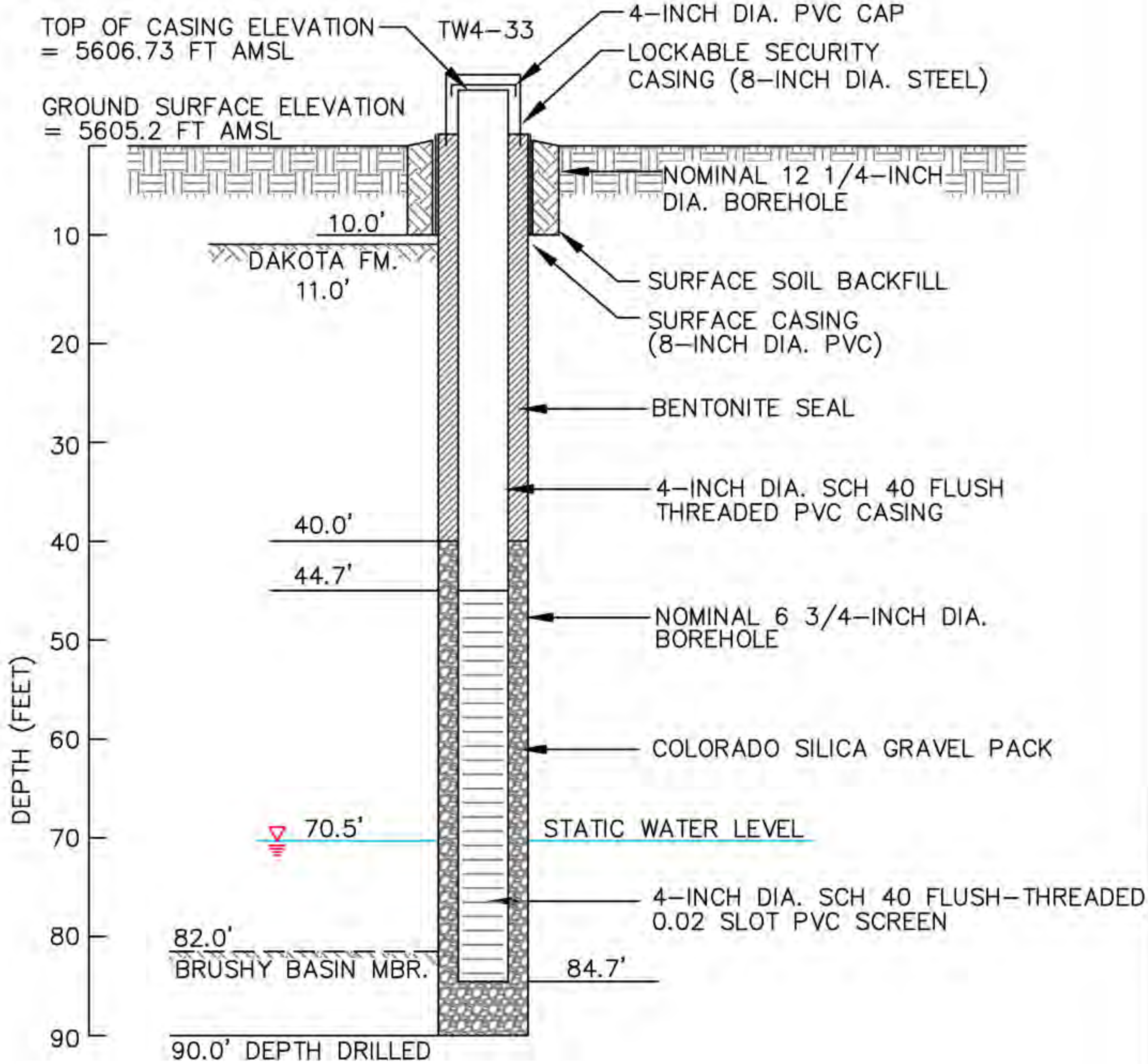


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-32
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SJS	10/04/13	JAA	10/04/13	7180277A	2

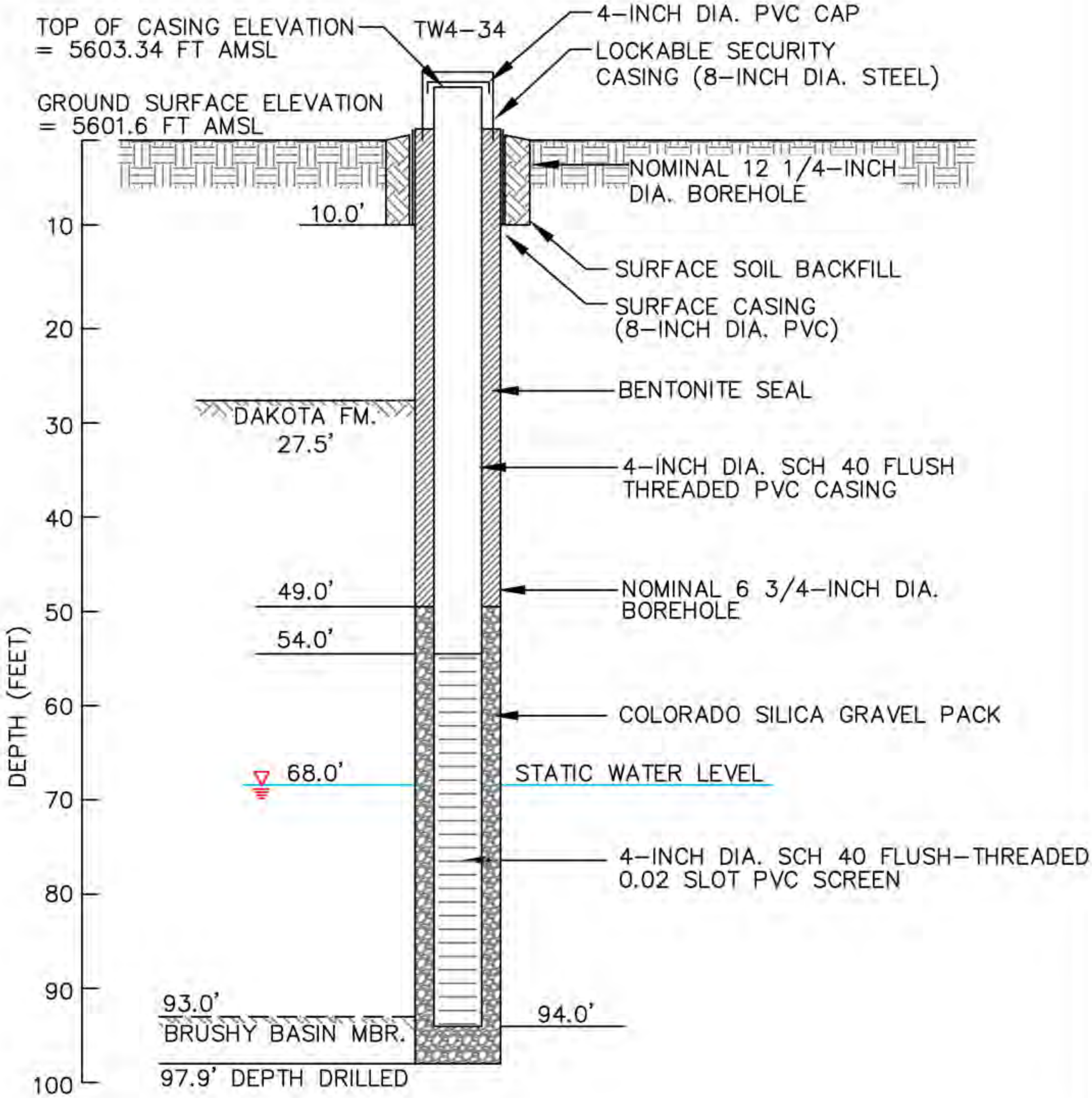


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-33
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SJS	10/04/13	JAA	10/04/13	7180278A	3

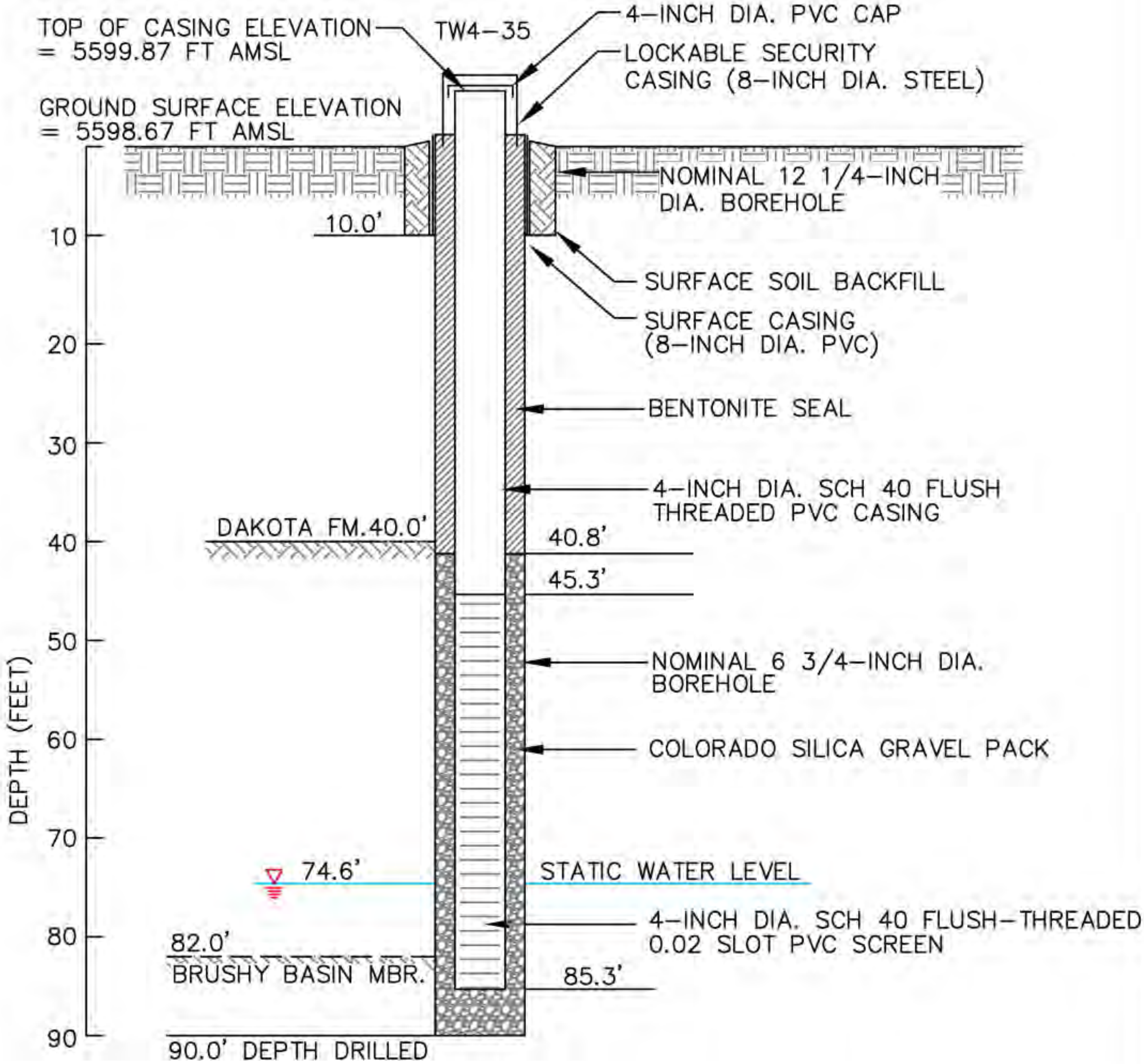


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-34
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SJS	10/04/13	JAA	10/04/13	7180279A	4

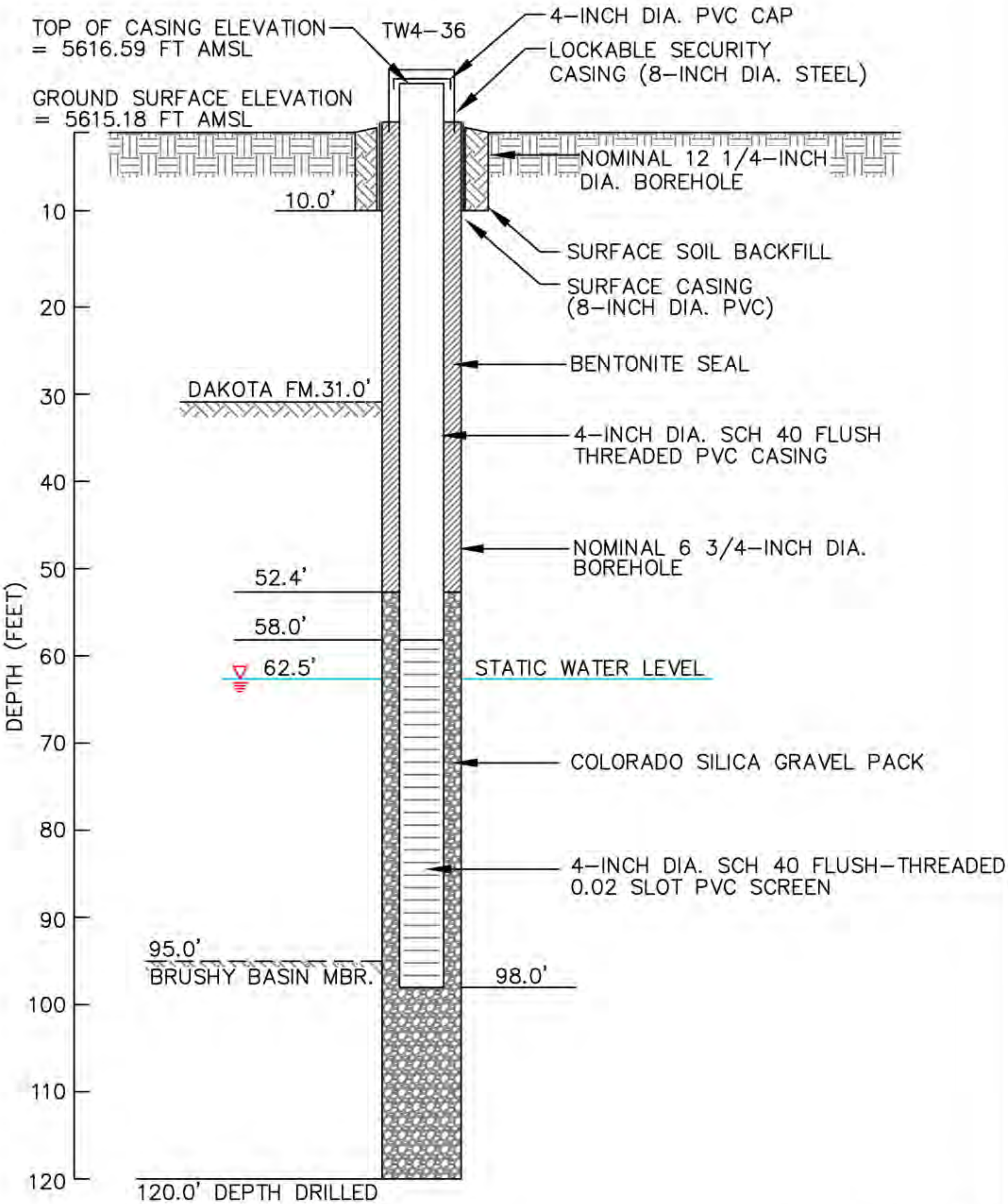


NOT TO SCALE

HYDRO GEO CHEM, INC.

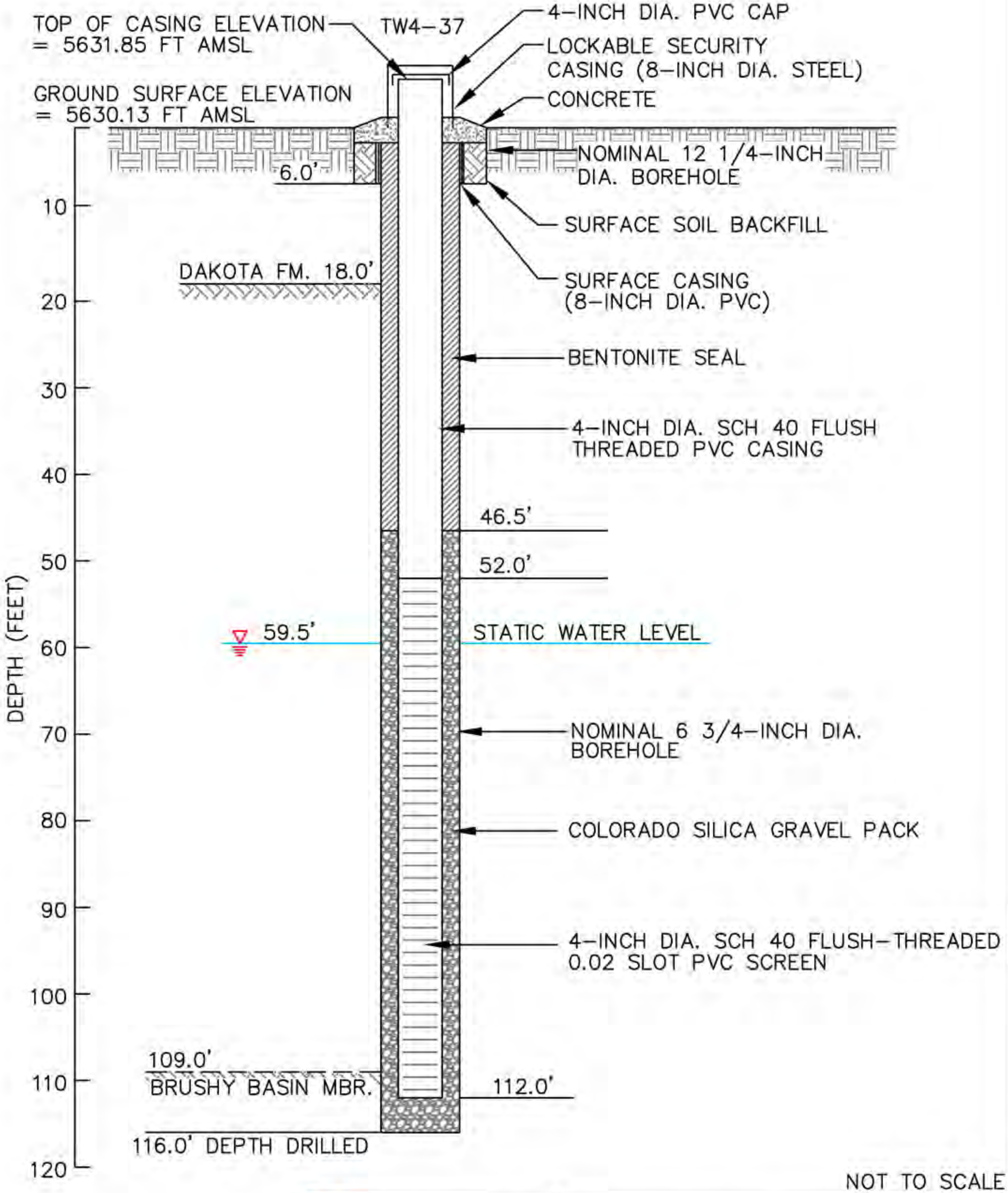
TW4-35
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SJS	6/18/14	JAA	6/18/14	7180280A	2



NOT TO SCALE

HYDRO GEO CHEM, INC.	TW4-36 AS-BUILT WELL CONSTRUCTION SCHEMATIC				
Approved	Date	Author	Date	File Name	Figure
SJS	6/18/14	JAA	6/18/14	7180281A	3

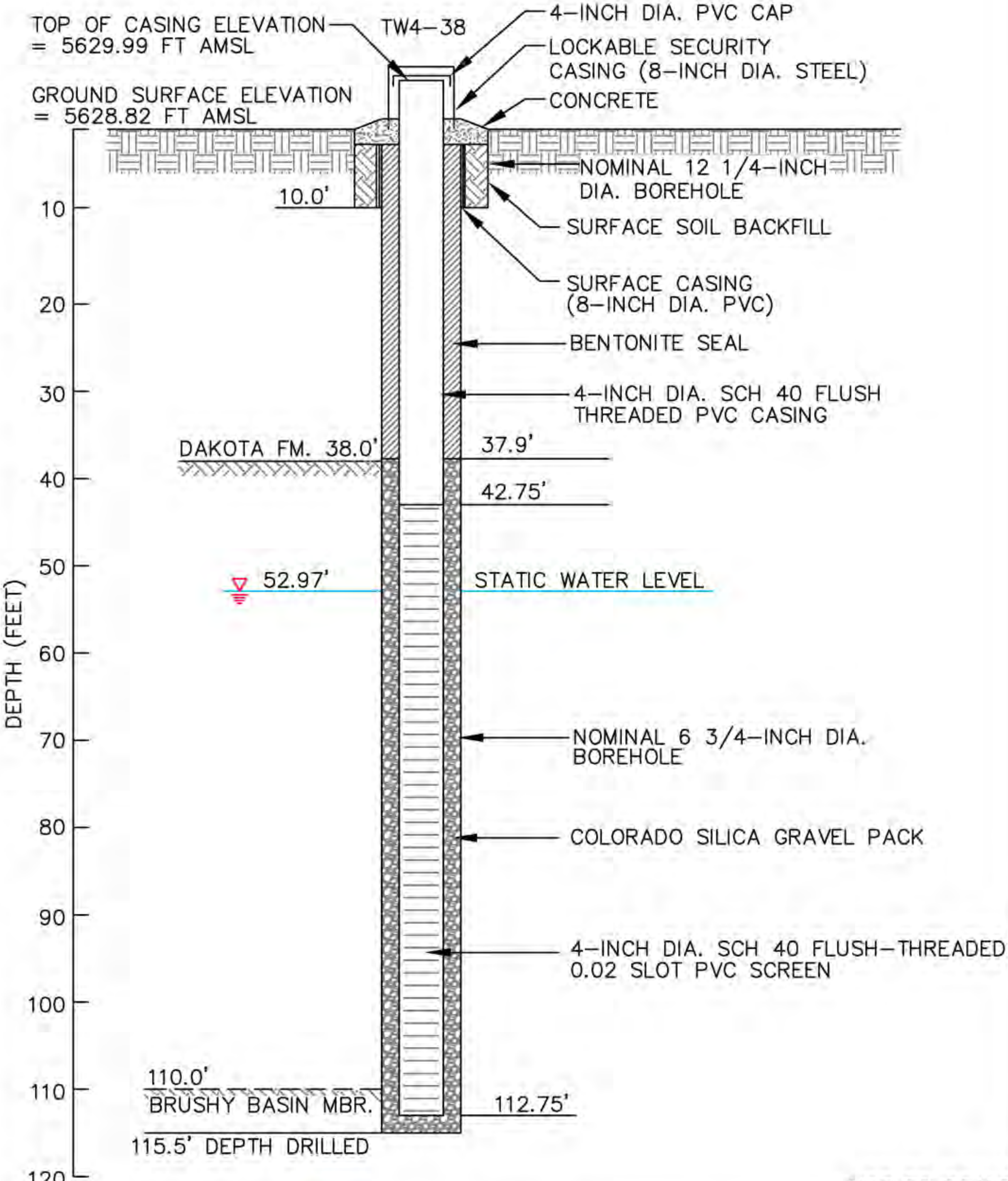


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-37
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SJS	4/14/15	JAA	4/14/15	7180282A	2

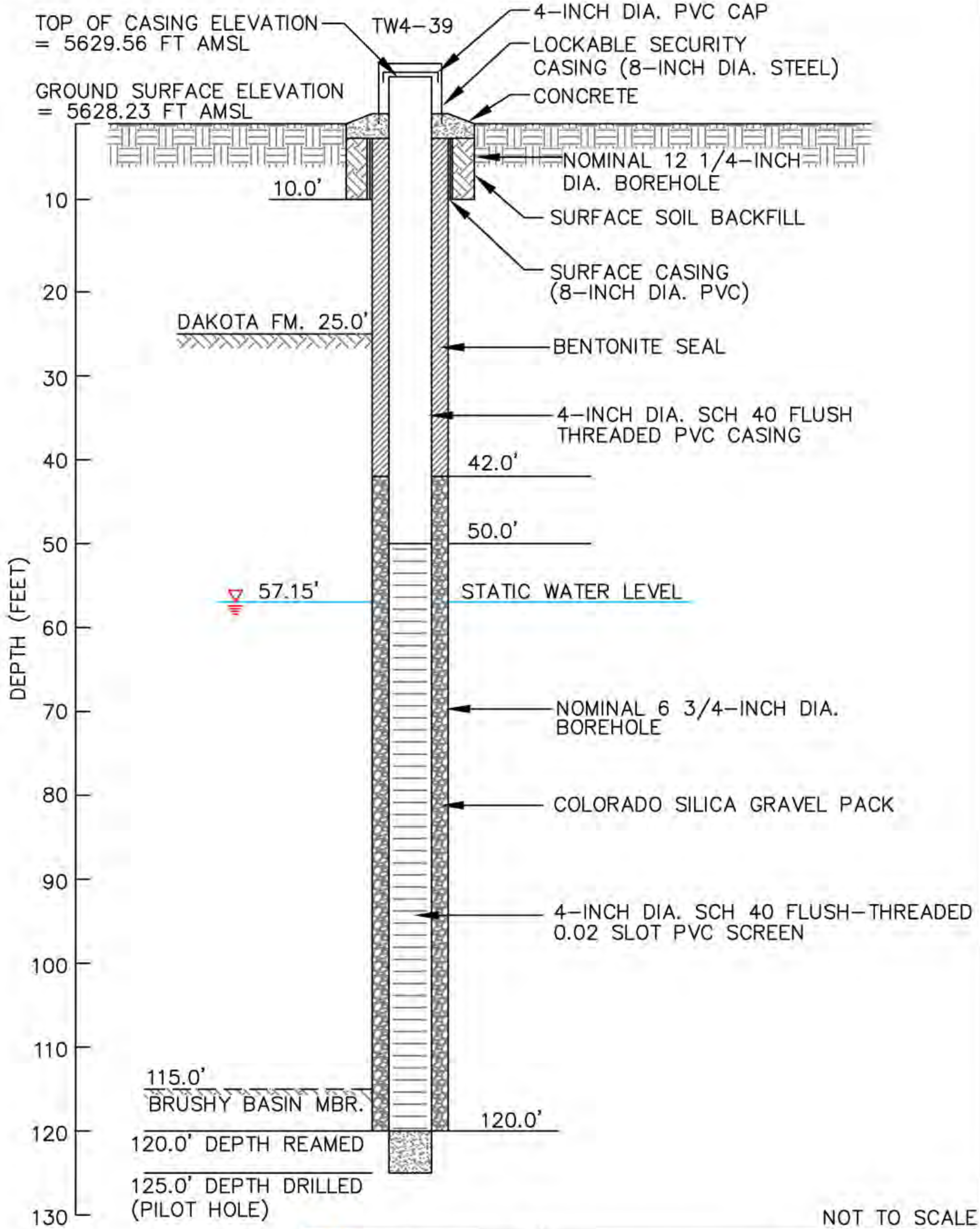


NOT TO SCALE

HYDRO GEO CHEM, INC.

TW4-38
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SJS	11/4/16	JAA	11/4/16	7180286A	2

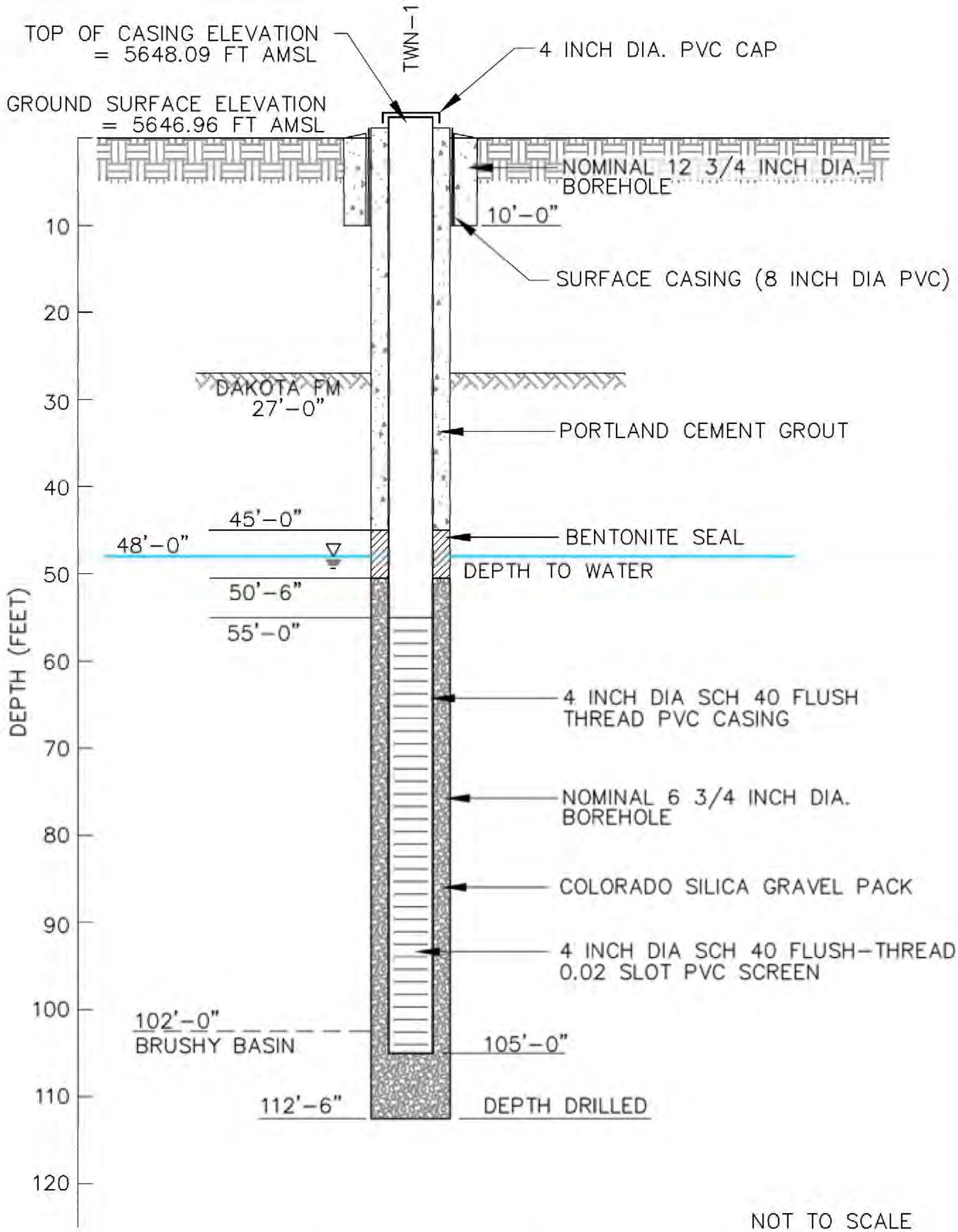


NOT TO SCALE

HYDRO GEO CHEM, INC.	TW4-39 AS-BUILT WELL CONSTRUCTION SCHEMATIC					
Approved	Date	Author	Date	File Name	Figure	
SJS	11/4/16	JAA	11/4/16	7180285A	3	

APPENDIX B.4

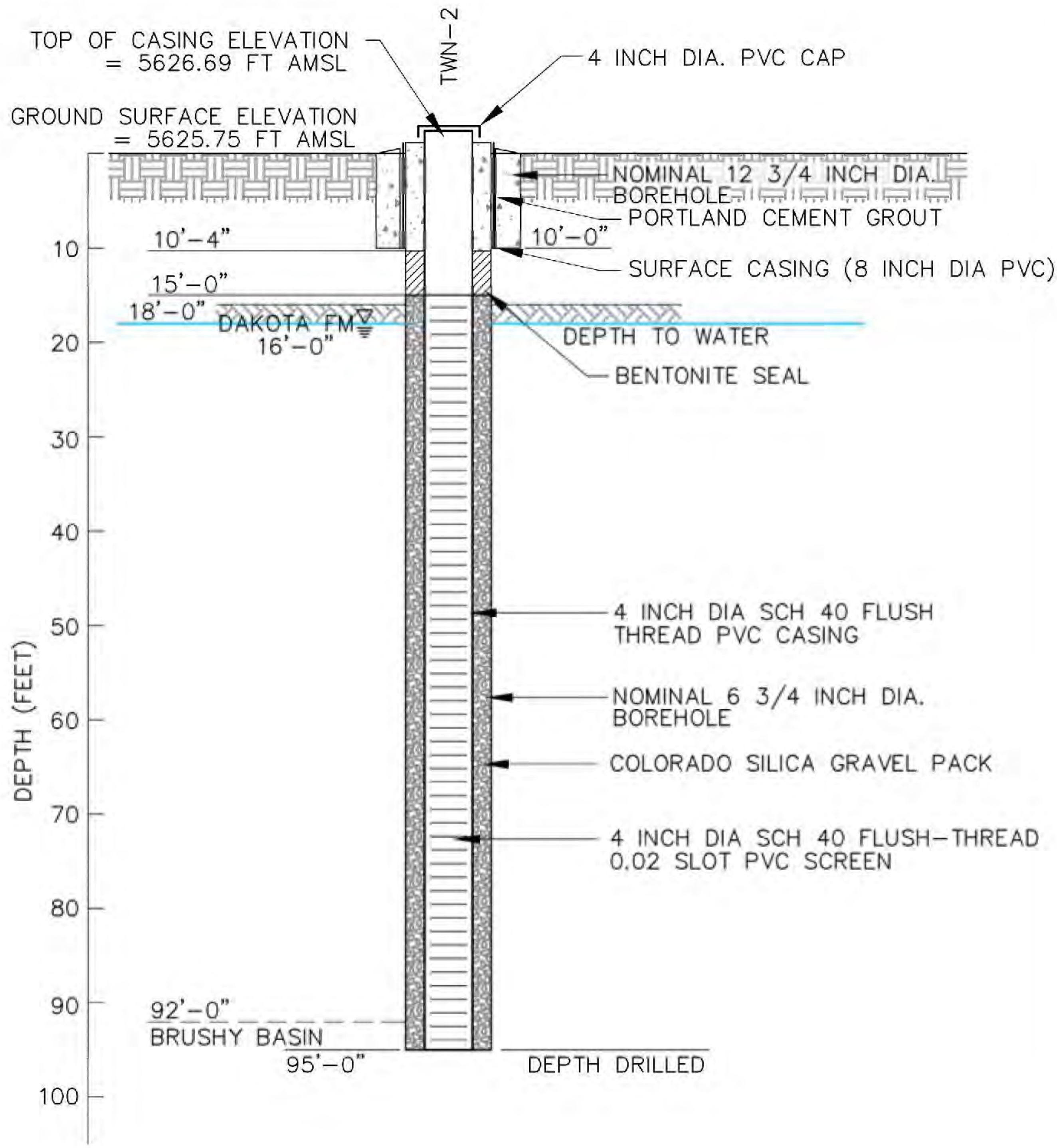
TWN - SERIES



HYDRO GEO CHEM, INC.

TWN-1
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180222A	2

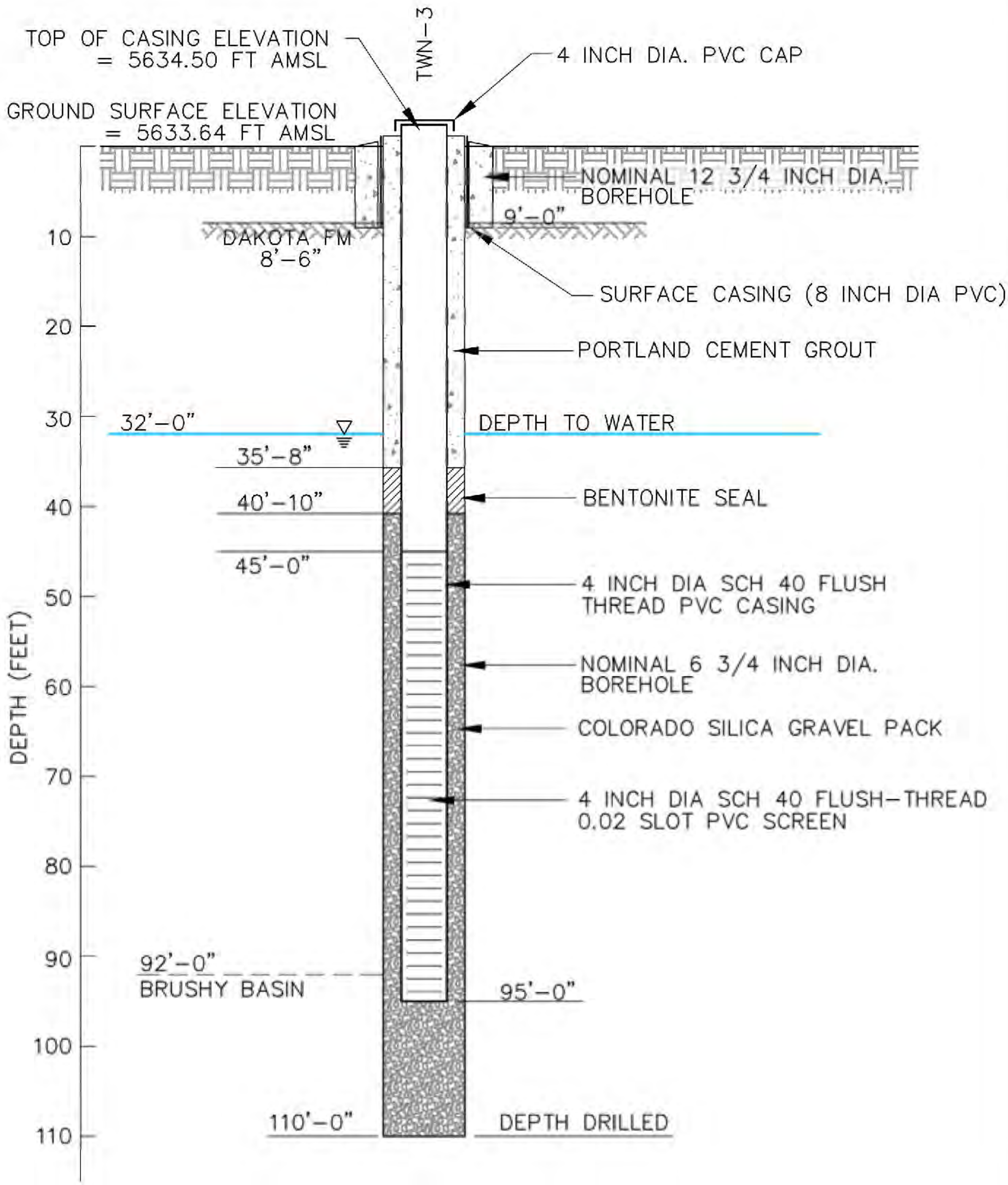


NOT TO SCALE

HYDRO GEO CHEM, INC.

TWN-2
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180223A	3

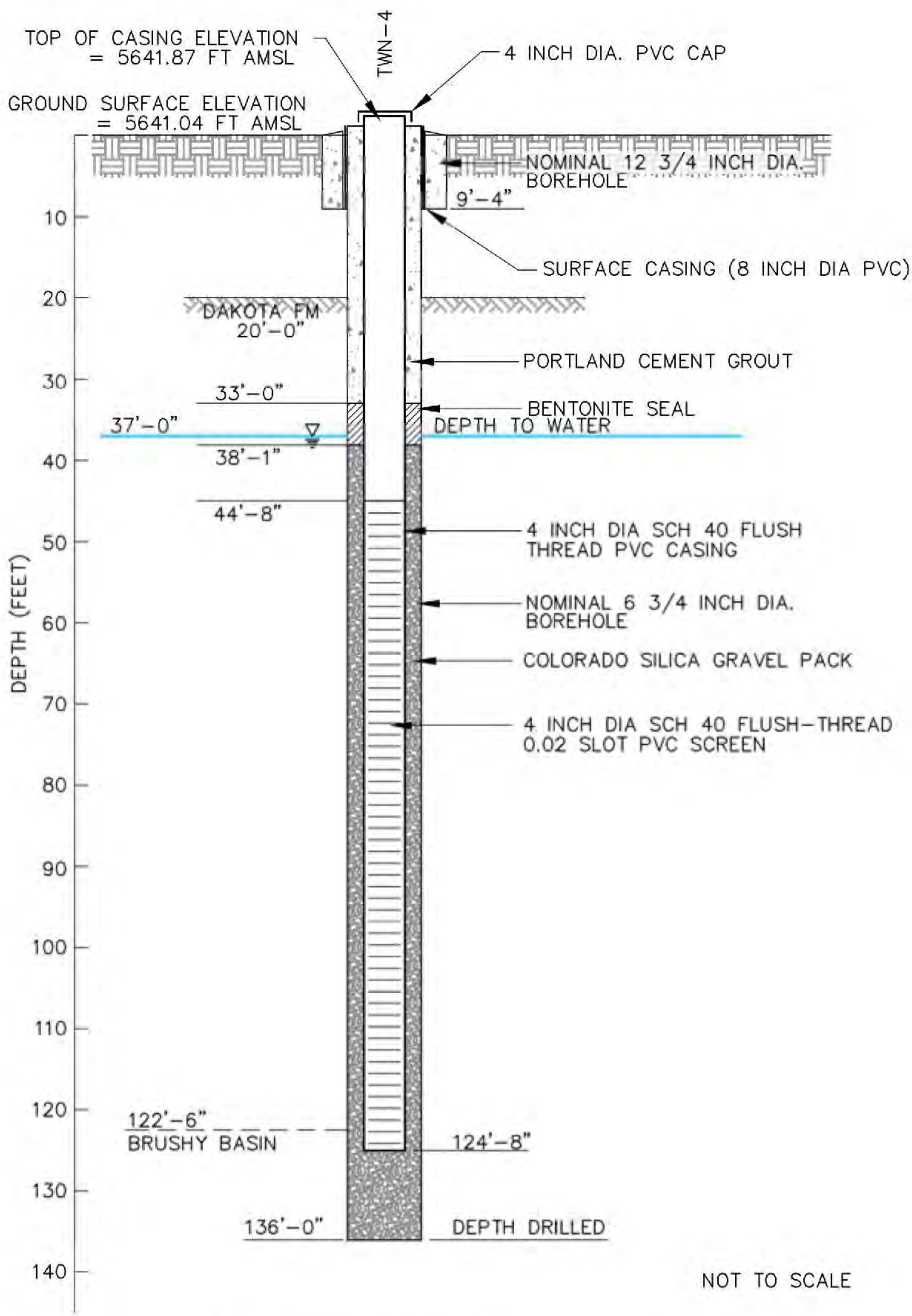


NOT TO SCALE

HYDRO GEO CHEM, INC.

TWN-3
AS-BUILT WELL CONSTRUCTION SCHEMATIC

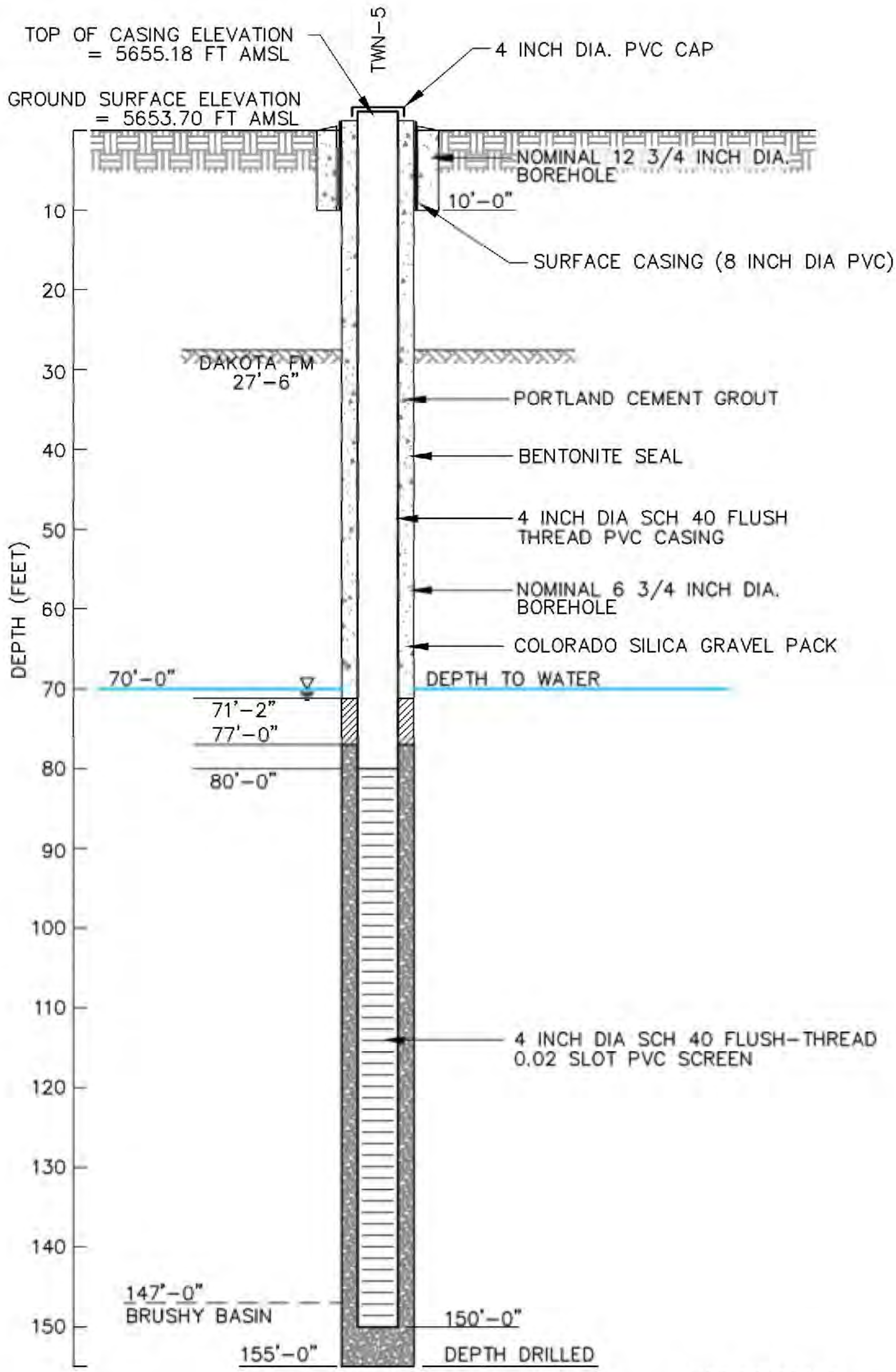
Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180224A	4



HYDRO GEO CHEM, INC.

TWN-4
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180225A	5

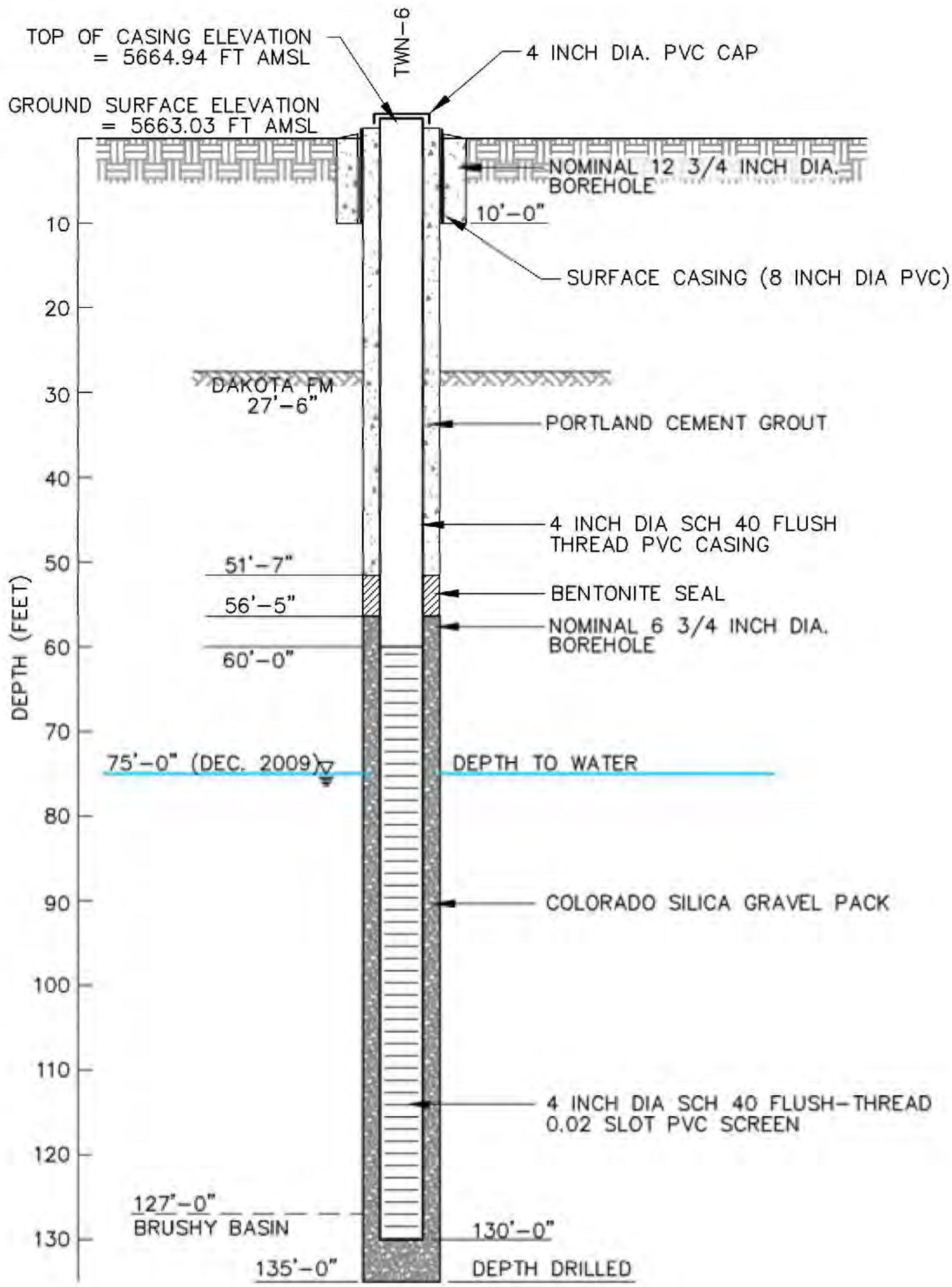


NOT TO SCALE

HYDRO GEO CHEM, INC.

TWN-5
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180226A	6

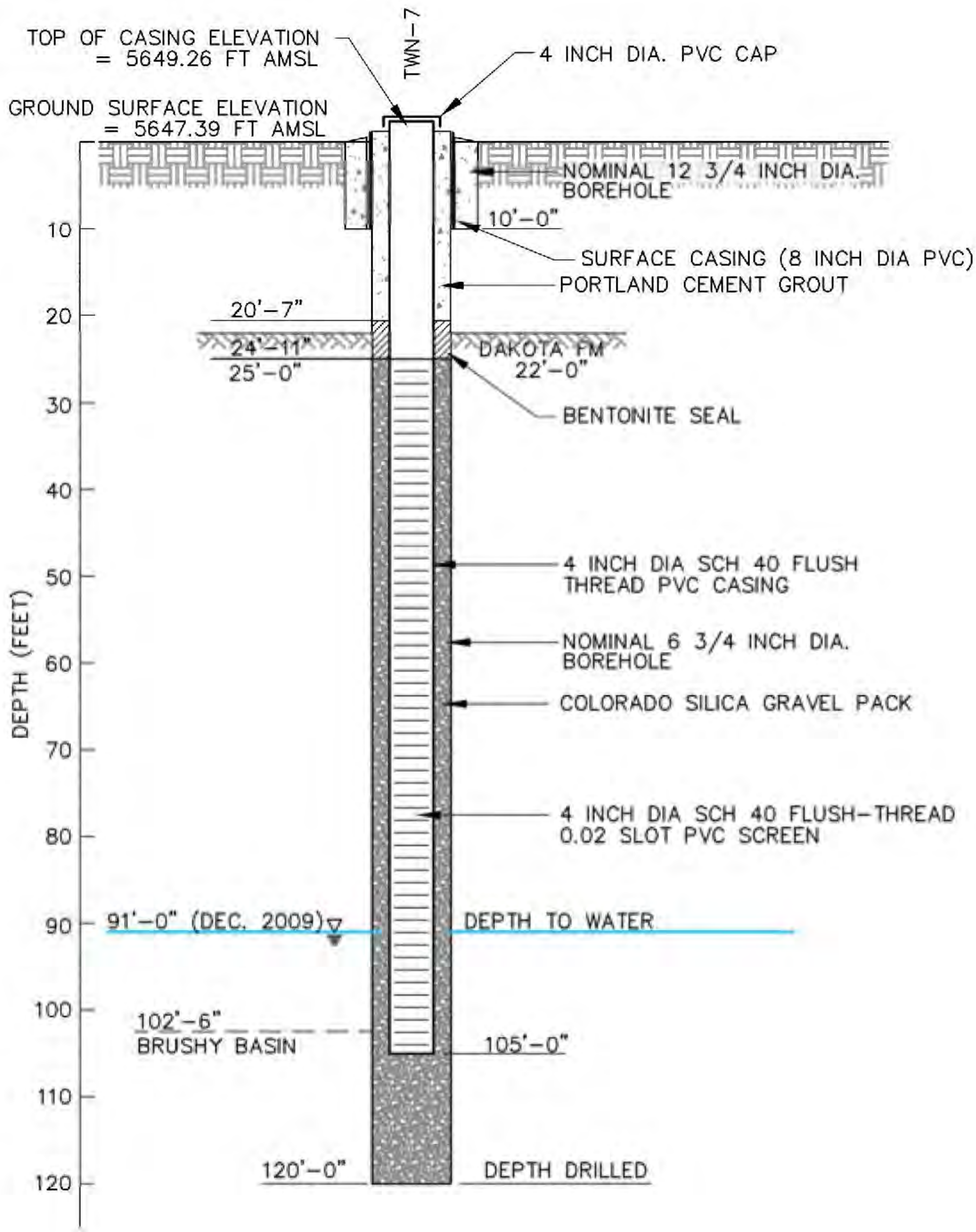


NOT TO SCALE

HYDRO GEO CHEM, INC.

TWN-6
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180227A	7



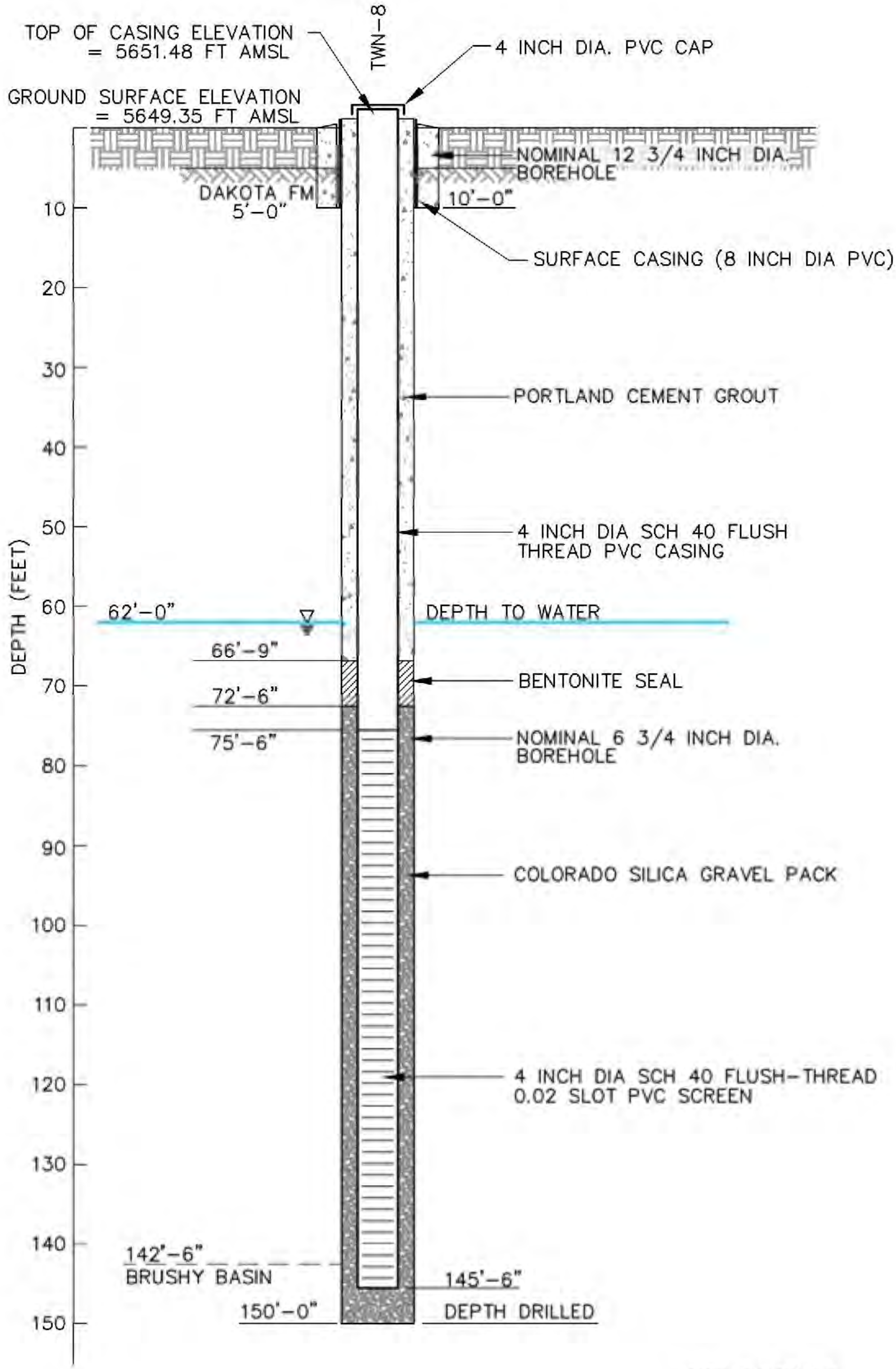
NOTE: TWN-7 WAS INSTALLED DRY

NOT TO SCALE

HYDRO GEO CHEM, INC.

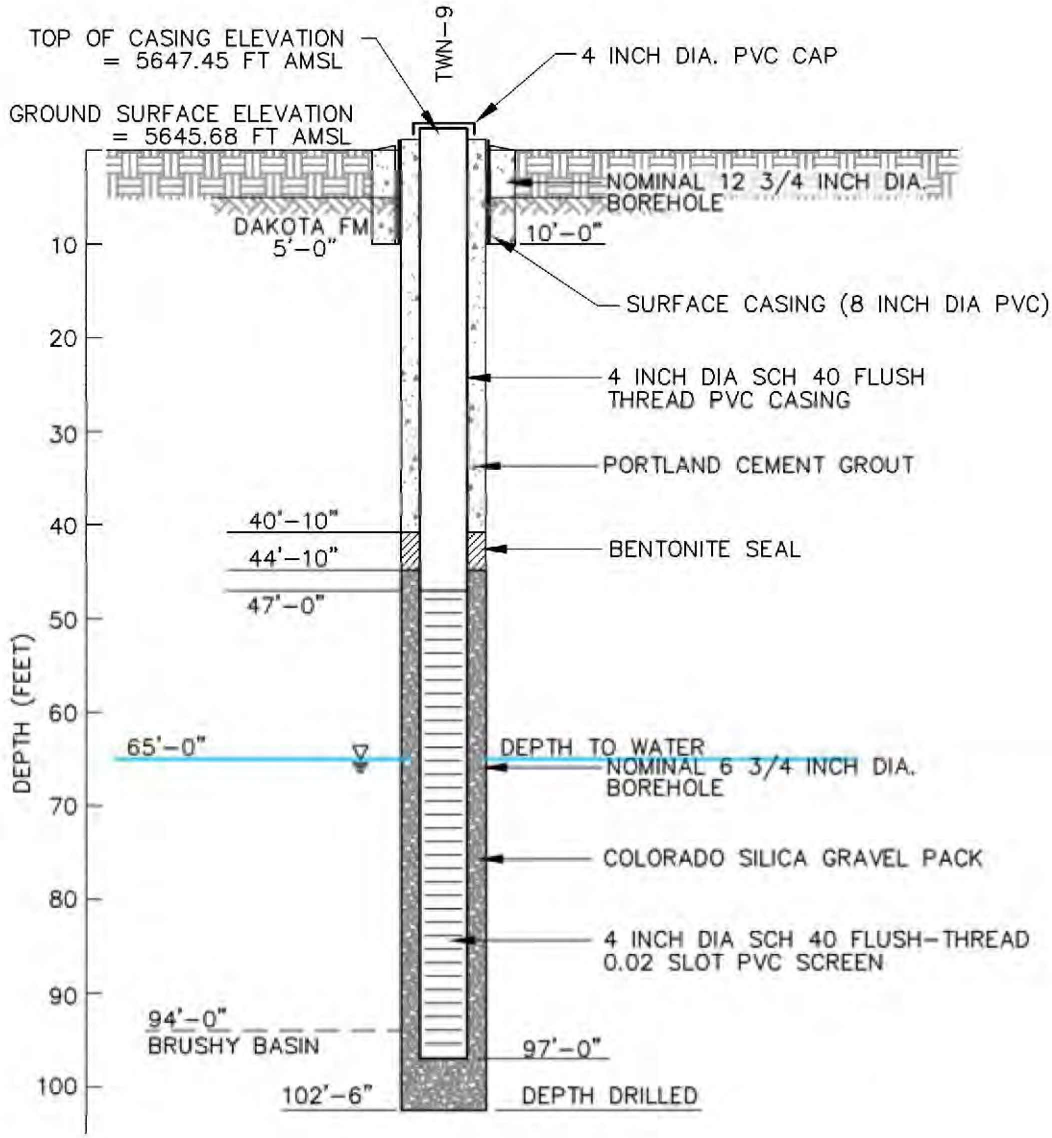
TWN-7
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180228A	8



NOT TO SCALE

HYDRO GEO CHEM, INC.	TWN-8 AS-BUILT WELL CONSTRUCTION SCHEMATIC					
Approved	Date	Author	Date	File Name	Figure	
SS	03/04/10	AMC	03/04/10	7180229A	9	

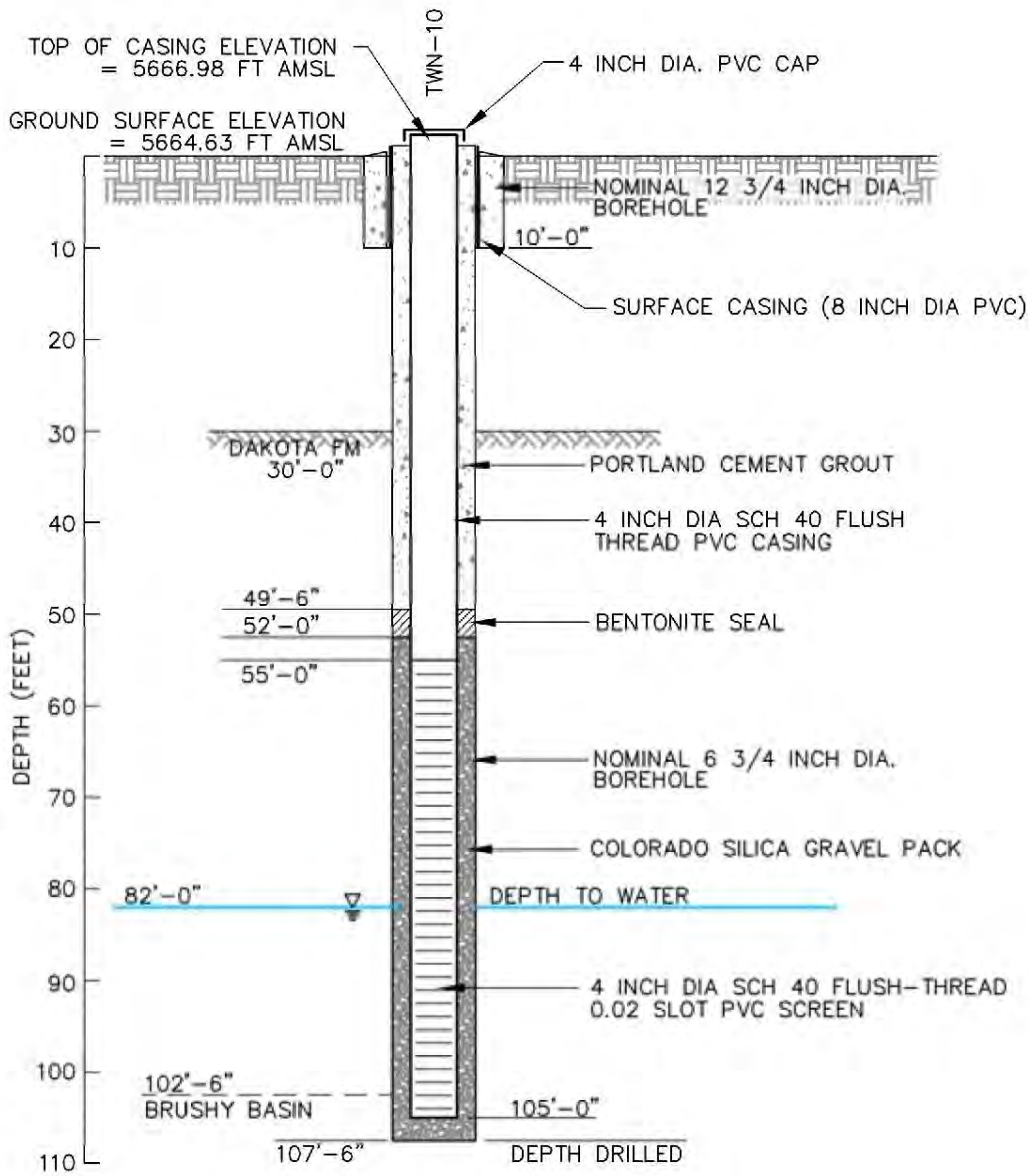


NOT TO SCALE

HYDRO GEO CHEM, INC.

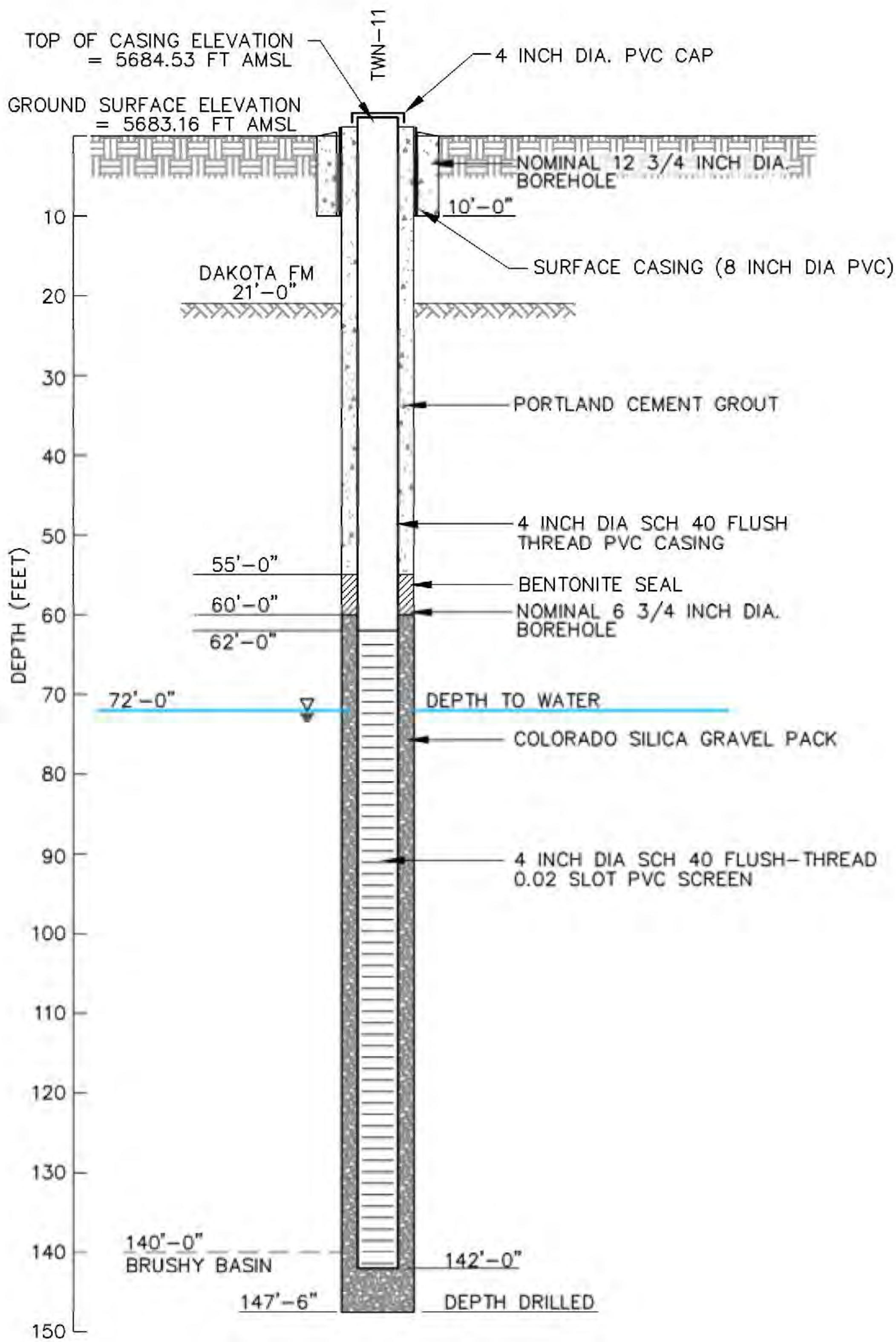
TWN-9
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180230A	10



NOT TO SCALE

HYDRO GEO CHEM, INC.	TWN-10 AS-BUILT WELL CONSTRUCTION SCHEMATIC				
Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180231A	11

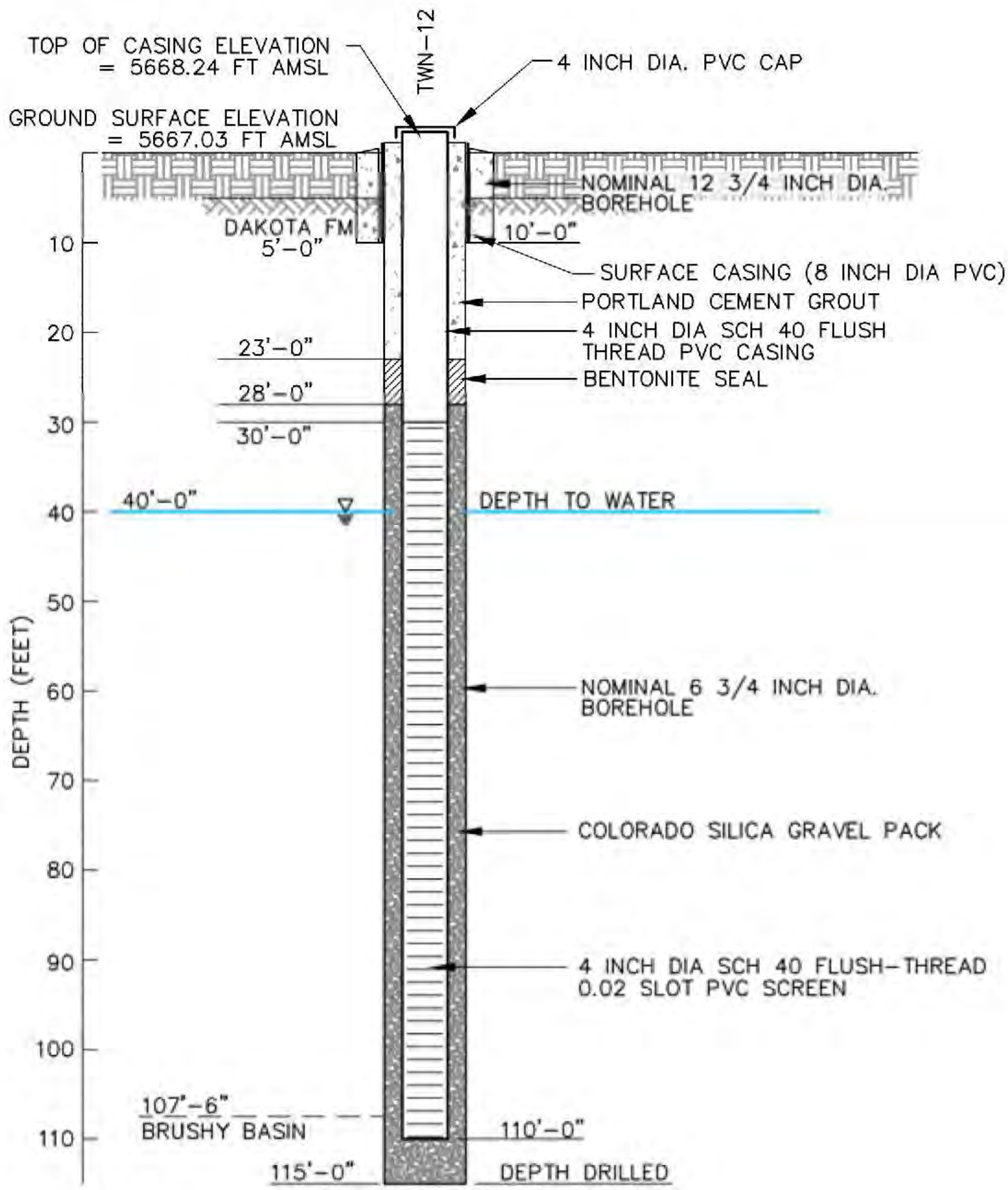


NOT TO SCALE

HYDRO GEO CHEM, INC.

TWN-11
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180232A	12

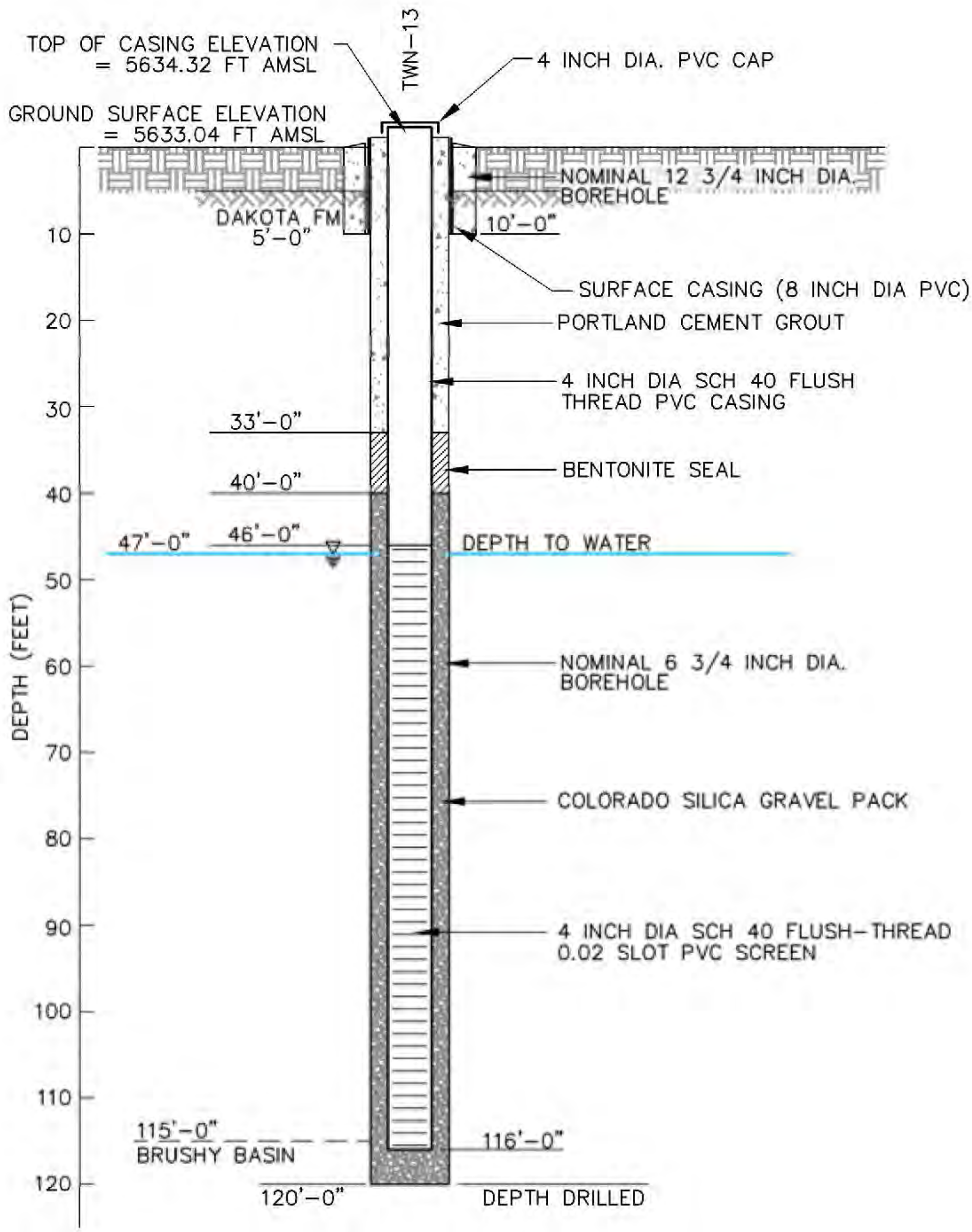


NOT TO SCALE

HYDRO GEO CHEM, INC.

TWN-12
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180233A	13

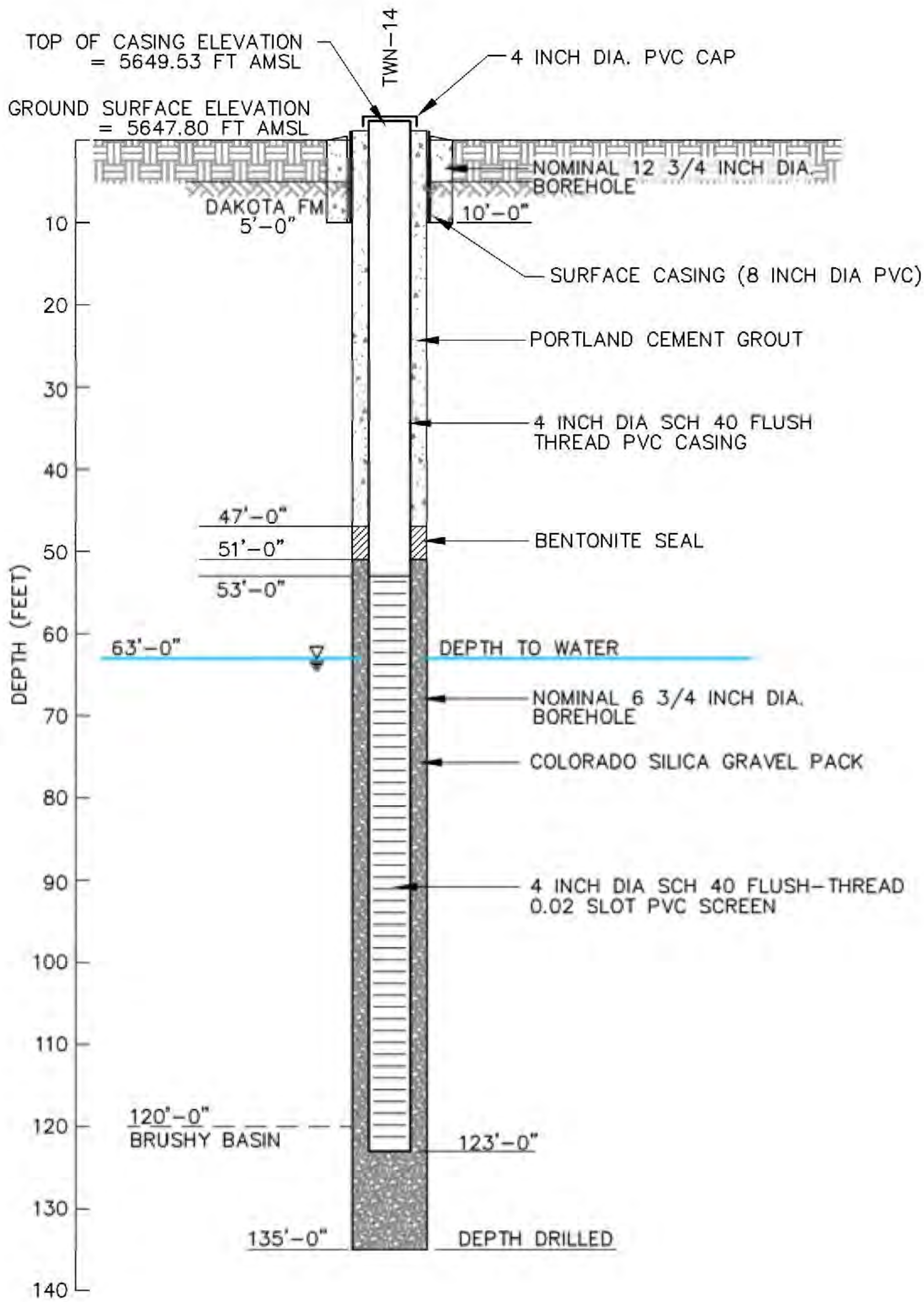


NOT TO SCALE

HYDRO GEO CHEM, INC.

TWN-13
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180234A	14

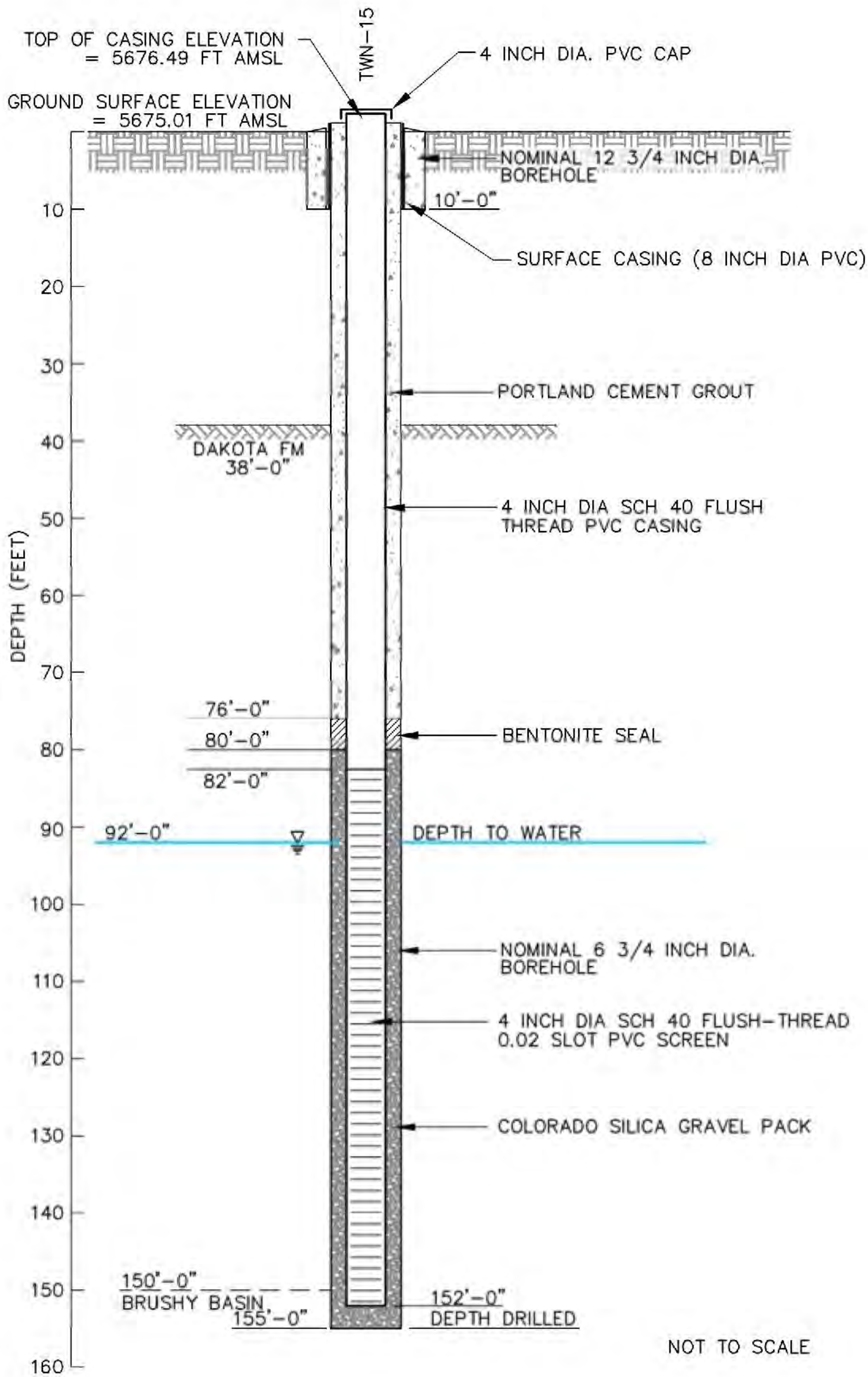


NOT TO SCALE

HYDRO GEO CHEM, INC.

TWN-14
AS-BUILT WELL CONSTRUCTION SCHEMATIC

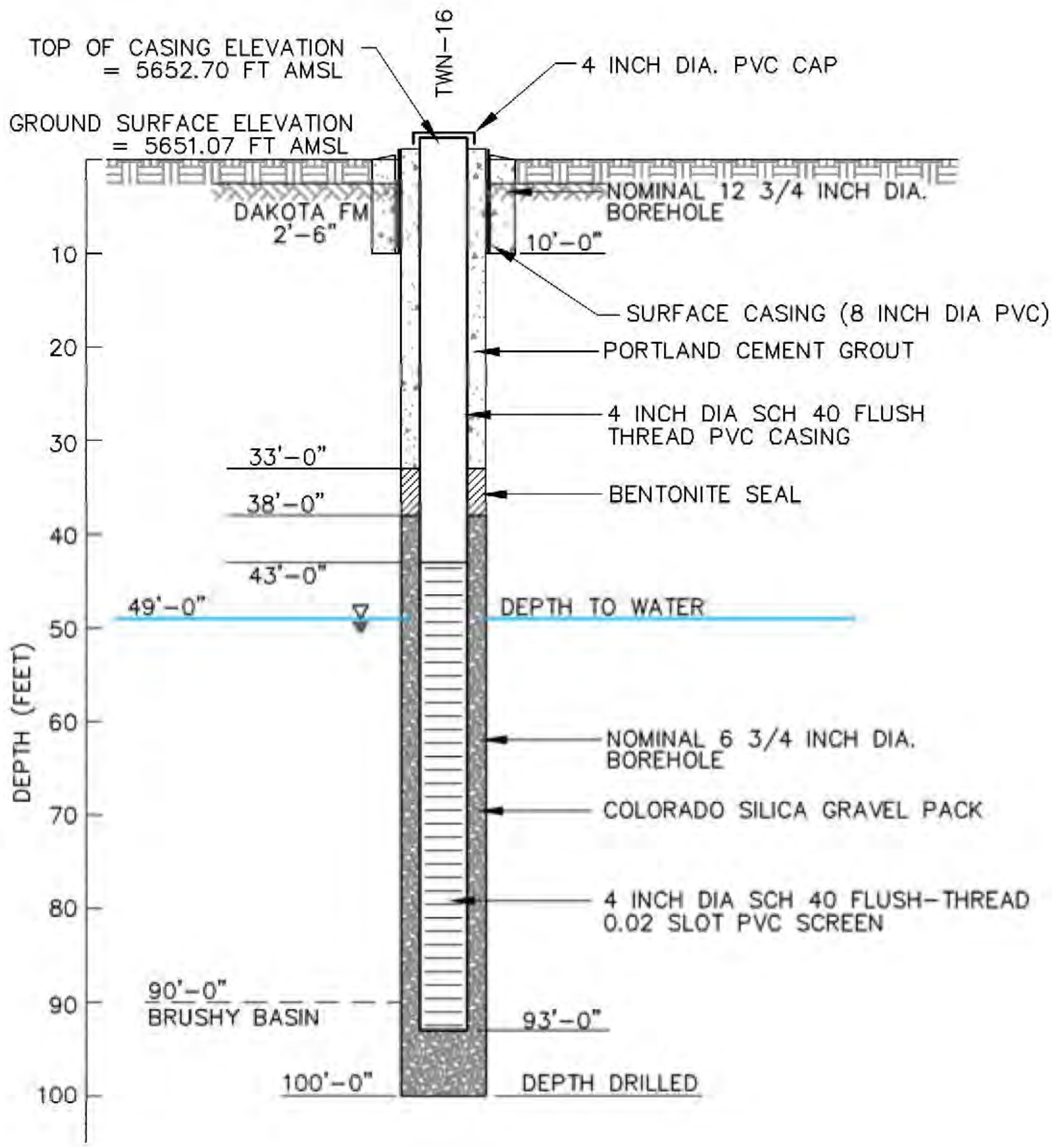
Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180235A	15



HYDRO GEO CHEM, INC.

TWN-15
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180236A	16

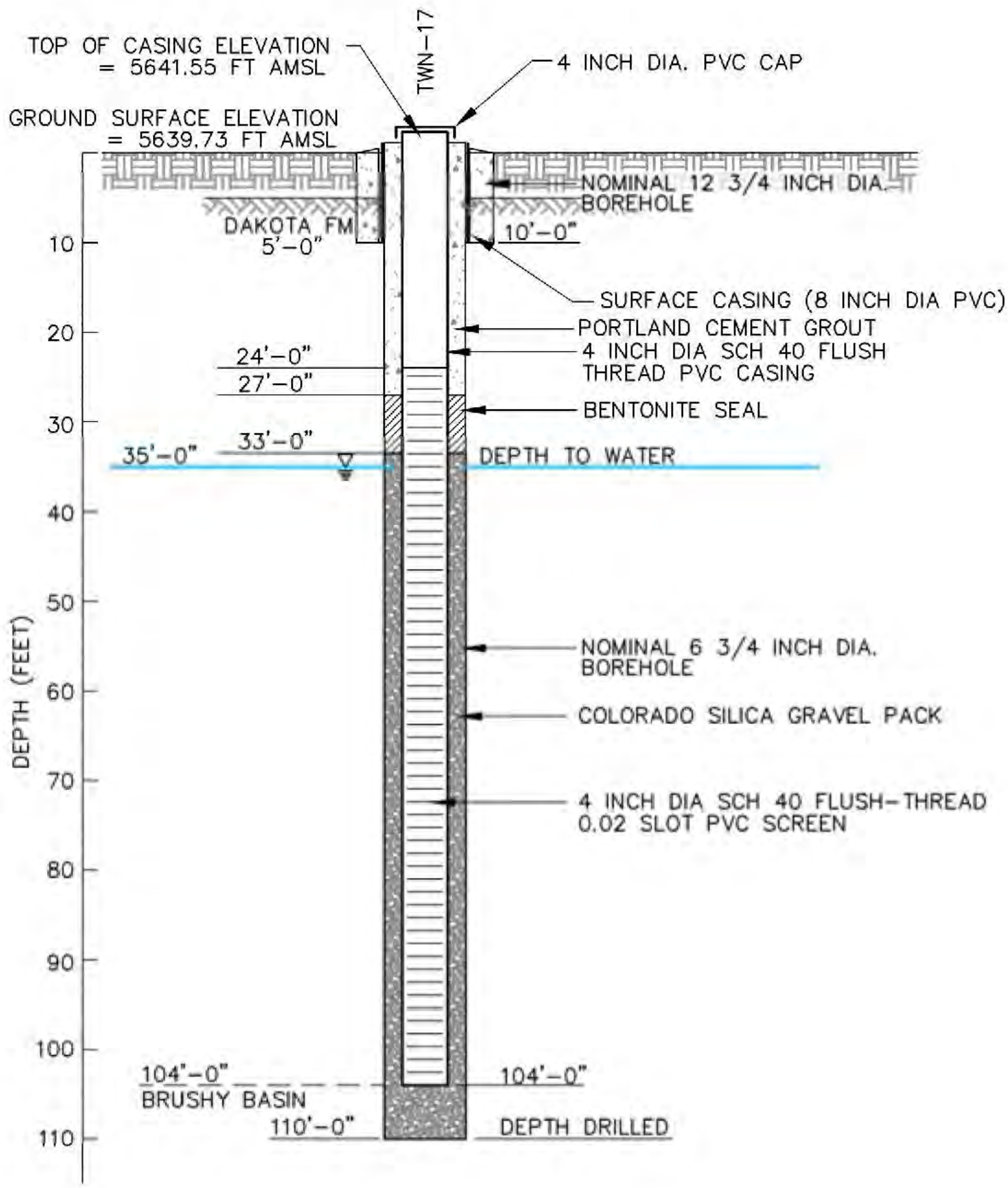


NOT TO SCALE

HYDRO GEO CHEM, INC.

TWN-16
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180237A	17

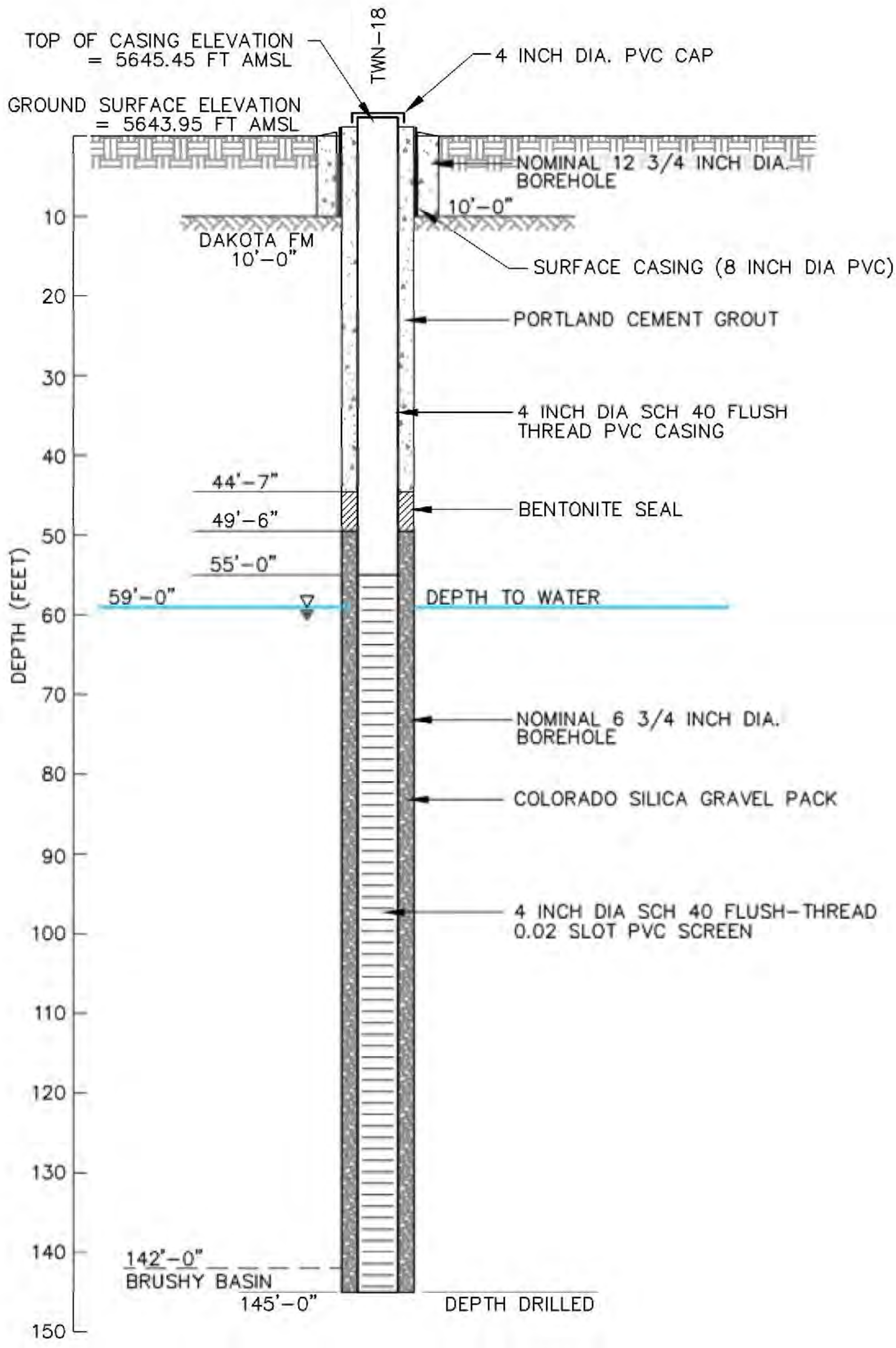


NOT TO SCALE

HYDRO GEO CHEM, INC.

TWN-17
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180238A	18

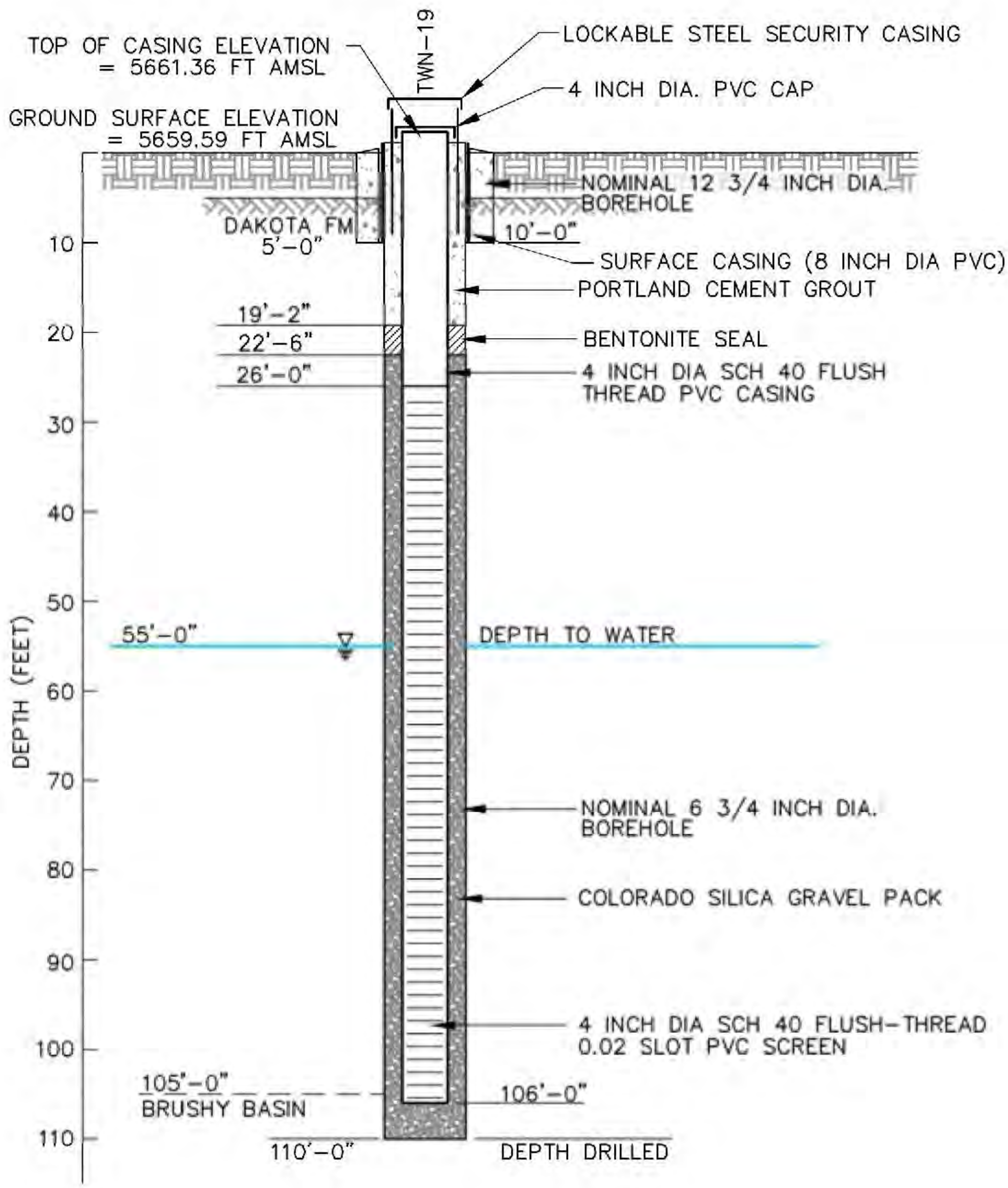


NOT TO SCALE

HYDRO GEO CHEM, INC.

TWN-18
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180239A	19



NOT TO SCALE

HYDRO GEO CHEM, INC.

TWN-19
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Author	Date	File Name	Figure
SS	03/04/10	AMC	03/04/10	7180240A	20

APPENDIX C

INTERA SOIL BORING LOGS

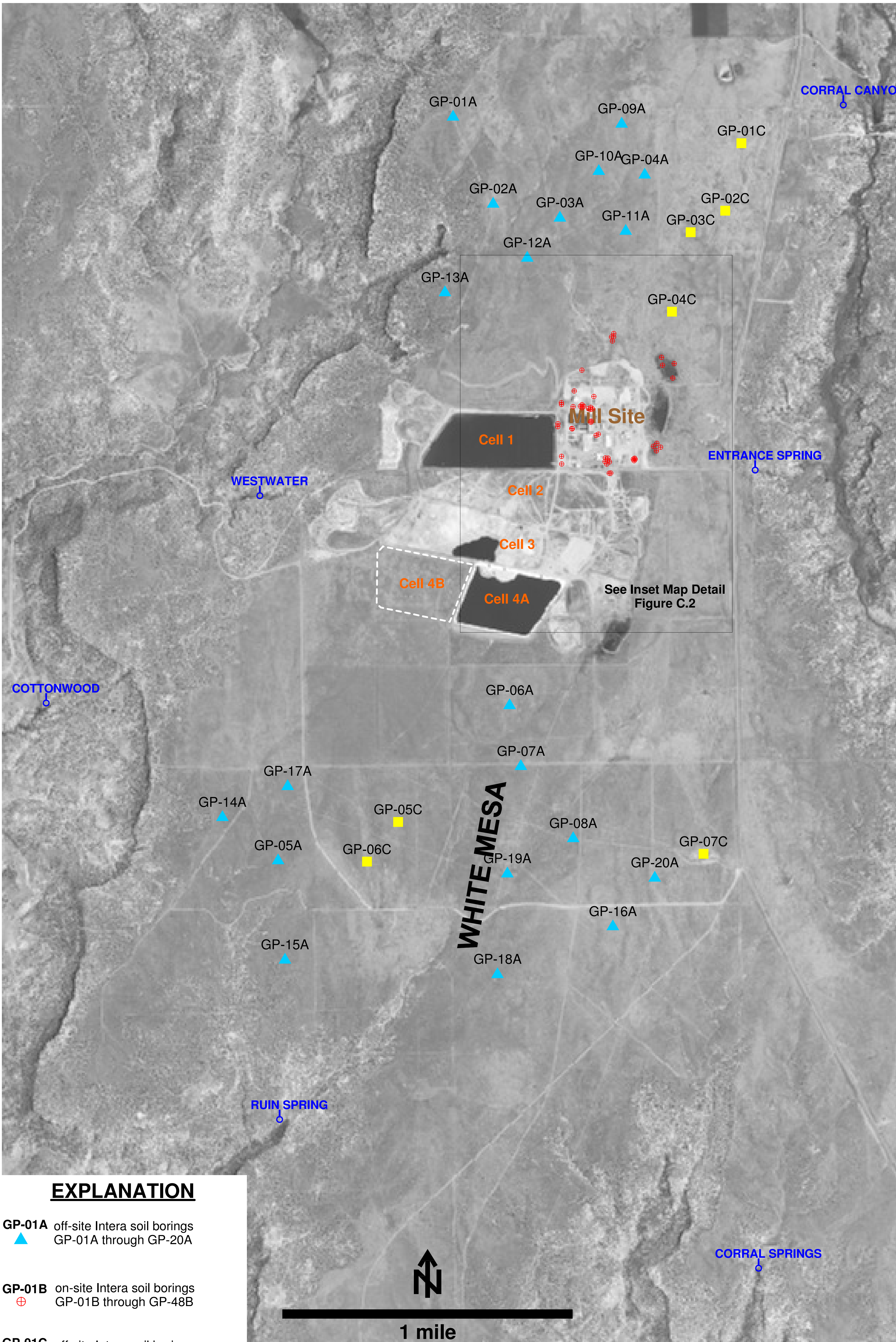
APPENDIX C
INTERA SOIL BORING LOGS SUMMARY

In May and June 2011, INTERA, Inc. installed 75 soil borings in the vicinity of the mill site. Borings GP-01A1 through GP-02A1 and GP-01C through GP-07C were installed to the north and south of the mill site and tailings cells; GP-01B through GP-48B were completed within and immediately outside the area of the mill site. Borings were drilled by Earth Worx using the Geoprobe push probe method. Soil samples for lithologic logging were collected using the continuous dual tube method. Locations of soil borings are provided on Figures C.1 and C.2; copies of the boring logs are provided in Appendix C.1.

Soil samples from the GP-A1 and GP-B series borings showed a consistent lithology. Depths of refusal ranged from 2.7 ft bgs to 9.7 ft bgs. Yellowish-red, silty, fine sand predominated from the ground surface to about four to six ft bgs, generally transitioning to pink, silty, fine sand or pink sandstone to the depth of refusal. Roots were occasionally present in the top several feet of the borings.

Soil samples from the GP-C series borings within or near the mill site showed more variable lithology. Depths to refusal were deeper overall than in the GP-A1 and GP-B series borings, and ranged from 1.7 to 24.5 ft bgs. Yellowish-red silty sand predominated in the upper portion of the GP-C borings, from approximately four to 10 ft bgs, and was typically underlain by interbedded reddish clay or clayey silt, and pinkish silt or silty sand to the depth of refusal. Gypsum precipitate was commonly seen in the lower portions of the GP-C series borings, and fine gravel was present in low proportions in multiple borings.

FIGURES



EXPLANATION

GP-01A off-site Intera soil borings GP-01A through GP-20A

GP-01B on-site Intera soil borings GP-01B through GP-48B

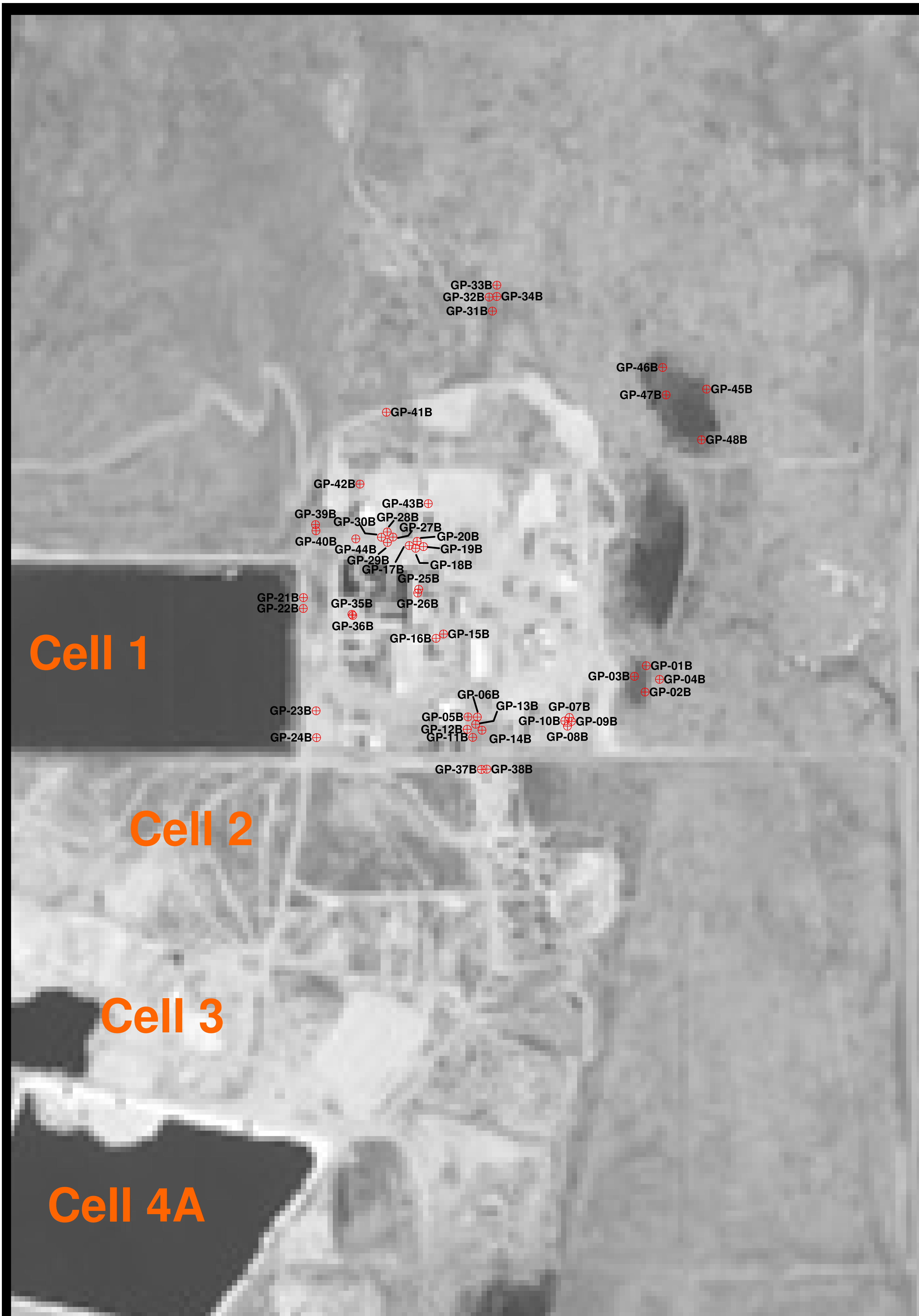
GP-01C off-site Intera soil borings GP-01C through GP-07C

RUIN SPRING seep or spring

HYDRO
GEO
CHEM, INC.

INTERA SOIL BORING LOCATIONS
WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
		H:/718000/hydrpt14/Intera_logs/interaloc.srf	C.1



EXPLANATION

GP-01B

⊕ on-site Intera soil borings GP-01B through GP-48B

HYDRO GEO CHEM, INC.

INTERA BORING LOCATIONS
GP-1B THROUGH GP-48B
(DETAIL MAP)
WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
		H:/718000/hydrpt14/ Intera_logs/intera_loc_det_rev.srf	C.2

APPENDIX C.1

INTERA SOIL BORING LOGS

Log of Soil Boring GP-01A1

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah			
Project #: DENMC.C002.000			
Date/Time Started	: 05/17/11	Driller	: L. Trujillo
Date/Time Completed	: 05/17/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 2.95	0-3.7' Silty SAND, reddish brown (5YR 4/4), very fine-grained sand, silt, poorly graded, very loose, dry, little white mottling, HCl strong	SM	
		0.5/ 0.65	3.7-4.5' Silty SAND, pink (5YR 6/4), very fine-grained sand, silt, poorly graded, medium dense, dry, HCl strong		
5			Total depth of boring 4.5' bgs (refusal)		
10					

Note(s):

Log of Soil Boring GP-02A1

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	Date/Time Started : 05/17/11; Date/Time Completed : 05/17/11; Drilling Method : Geoprobe; Sampling Method : Continuous Dual Tube; Drilling Co./Driller : Earth Worx
Project #: DENMC.C002.000	Driller : L. Trujillo; Depth to Water : NA; Logged by : J. Reed

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.2	0-4.7' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl weak to moderate, little white mottling w/ HCl strong	SM	
5		3.1/ 3.0	4.7-7.1' Silty SAND, pink (5YR 7/3), very fine-grained sand, silt, poorly graded, dense, dry, HCl strong, trace fine sand		
10			Total depth of boring 7.1' bgs (refusal)		

Note(s):

Log of Soil Boring GP-03A1

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/17/11	Driller	: L. Trujillo
Date/Time Completed	: 05/17/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis (1)

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.0	0-4.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand, silt, poorly graded, loose, dry, root at top, HCl strong	SM	
		2.8/ 3.1	4.0-6.8' Silty SAND, reddish yellow (6/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl strong, trace fine sand		
5					
			Total depth of boring 6.8' bgs (refusal)		
10					

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-04A1

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/17/11	Driller	: L. Trujillo
Date/Time Completed	: 05/17/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.6	0-3.7' Silty SAND, reddish brown (5YR 4/4), very fine-grained sand, silt, poorly graded, very loose, dry, little white mottling, HCl strong 3.7-4.0' Silty SAND, pink (5YR 6/4), very fine-grained sand, silt, poorly graded, medium dense, dry, HCl strong	SM	
5			Total depth of boring 4.0' bgs (refusal)		
10					

Note(s):

07-28-2011 S:\Projects\BoreLogs\Denison\GP-04A1.bor

Log of Soil Boring GP-05A1

Project Name: Denison Nitrate Investigation White Mesa Mill, Blanding, Utah	Date/Time Started : 05/17/11 Date/Time Completed : 05/17/11 Drilling Method : Geoprobe Sampling Method : Continuous Duel Tube Drilling Co./Driller : Earth Worx
Project #: DENMC.C002.000	Driller : L. Trujillo Depth to Water : NA Logged by : J. Reed

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 2.7	0-6.4' Silty SAND, yellow red (5YR 5/6), very fine-grained sand, silt, poorly graded, loose, roots at top, HCl moderate	SM	
5		3.6/ 3.6	6.4-7.6' Silty SAND, light brown gray (10YR 6/2), very fine-grained sand, silt, poorly graded, dense, dry, HCl strong, trace fine sand		
10			Total depth of boring 7.6' bgs (refusal)		

Note(s):

Log of Soil Boring GP-06A1

Project Name: Denison Nitrate Investigation White Mesa Mill, Blanding, Utah			
Project #: DENMC.C002.000			
Date/Time Started	: 05/17/11	Driller	: L. Trujillo
Date/Time Completed	: 05/17/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis (1)

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.1	0-5.9' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl moderate, trace roots at top, little white mottling w/ HCl strong	SM	
5		4.0/ 3.8	5.9-8.0' Silty SAND, very pale brown (10YR 8/4), very fine-grained sand, silt, poorly graded, dense, dry, HCl strong, trace fine sand		
10			Total depth of boring 8.0' bgs (refusal)		

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-07A1

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/17/11	Driller	: L. Trujillo
Date/Time Completed	: 05/17/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.0	0-4.9' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl strong, little white mottling, HCl strong 4 to 4.9' bgs	SM	
5		4.0/ 3.3	4.9-7.5' Silty SAND, pink (7.5YR 7/4), very fine-grained sand, silt, poorly graded, medium dense to dense, dry, HCl strong, trace loose fine sand 7 to 7.5'		
		1.7/ 1.8	7.5-9.7' Silty SAND, pink (7.5YR 7/3), very fine-grained sand, silt, poorly graded, loose to dense, dry, HCl strong, trace fine sand		
10			Total depth of boring 9.7' bgs (refusal)		

Note(s):

Log of Soil Boring GP-08A1

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	Date/Time Started : 05/17/11
	Date/Time Completed : 05/17/11
	Drilling Method : Geoprobe
	Sampling Method : Continuous Dual Tube
Project #: DENMC.C002.000	Drilling Co./Driller : Earth Worx
	Driller : L. Trujillo
	Depth to Water : NA
	Logged by : J. Reed

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.3	0-3.5' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose, dry, trace gravel, roots at top, HCl none	SM	
			3.5-4.0' Silty SAND, pink (7.5YR 8/4), very fine-grained sand, silt, poorly graded, dense, dry, HCl strong		
5			Total depth of boring 4.0' bgs (refusal)		
10					

Note(s):

07-28-2011 S:\Projects\BoreLogs\Denison\GP-08A1.bor

Log of Soil Boring GP-09A1

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/17/11	Driller	: L. Trujillo
Date/Time Completed	: 05/17/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 2.95	0-4.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand, silt, poorly graded, loose, dry, HCl none, trace roots		
5		4.0/ 3.75	4.0-8.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand trace fine-grained sand, silt, poorly graded, loose, HCl none, trace mica, trace white mottled w/ HCl strong	SM	
10			Total depth of boring 8.0' bgs (refusal)		

Note(s):
Duplicate sample collected. Sample interval was increased to 2 feet to accommodate additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-10A1

(Page 1 of 1)

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/18/11	Driller	: L. Trujillo
Date/Time Completed	: 05/18/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		2.66/ 1.25	0-2' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl none to weak	SM	
			2.0-2.7' Sand/Silty Sand, very pale brown (10YR 8/3), very fine-grained sand, trace silt, poorly graded, loose, dry, subangular to subrounded, HCl none, little very fine sand	SP/ SM	
			Total depth of boring 2.7' bgs (refusal)		
5					
10					

Note(s):

Log of Soil Boring GP-11A1

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/18/11	Driller	: L. Trujillo
Date/Time Completed	: 05/18/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.6	0-3.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl none	SM	
			3.0-5.0' Silty SAND, yellowish red (5YR 5/8 & very pale brown 10YR 8/2), fine-grained sand, silt, poorly graded, loose to medium dense, dry, some white mottling w/ HCl strong, mottled but little red or very pale brown, HCl weak to medium, trace fine sand		
		1.0/ 1.2			
5			Total depth of boring 5.0' bgs (refusal)		
10					

Note(s):
Duplicate sample collected. Sample interval was increased to 2 feet to accommodate additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-12A1

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/18/11	Driller	: L. Trujillo
Date/Time Completed	: 05/18/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.2	0-2' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl none	SM	
			2.0-4.0' Silty SAND, pink (5YR 7/4), very fine-grained sand, silt, poorly graded, medium dense loose to medium dense, trace fine sand, dry, some white mottling w/ HCl strong		
			Total depth of boring 4.0' bgs (refusal)		
5					
10					

Note(s):

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Log of Soil Boring GP-13A1

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	Date/Time Started : 05/19/11
Project #: DENMC.C002.000	Date/Time Completed : 05/19/11
	Drilling Method : Geoprobe
	Sampling Method : Continuous Dual Tube
	Drilling Co./Driller : Earth Worx
	Driller : L. Trujillo
	Depth to Water : NA
	Logged by : J. Reed

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.1	0-4.0' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, trace white mottling w/ HCl strong	SM	
		0.7/ 0.7	4.0-4.7' Silty SAND, pink (5YR 7/4), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl strong, trace fine sand		
5			Total depth of boring 4.7' bgs (refusal)		
10					

Note(s):

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Log of Soil Boring GP-14A1

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah			
Date/Time Started	: 05/19/11	Driller	: L. Trujillo
Date/Time Completed	: 05/19/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Project #: DENMC.C002.000

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 2.9	0-5.8' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, trace white mottling w/ HCl strong, HCl none to weak	SM	
5		2.9/ 1.9	5.8-6.9' Silty SAND, pink (5YR 7/4 & yellowish red 5YR 5/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, some what mottling w/ HCl strong, trace fine sand		
			Total depth of boring 6.9' bgs (refusal)		
10					

Note(s):

Log of Soil Boring GP-15A1

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	
Project #: DENMC.C002.000	

Date/Time Started	: 05/19/11	Driller	: L. Trujillo
Date/Time Completed	: 05/19/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.0	0-5.1' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, trace white mottling w/ HCl strong, HCl none to weak	SM	
5		3.6/ 4.0	5.1-7.6' Silty SAND, pink (5YR 7/4), very fine-grained sand, silt, poorly graded, medium dense, dry, trace fine sand, HCl strong, some white mottling w/ HCl strong		
			Total depth of boring 7.6' bgs (refusal)		
10					

Note(s):

Log of Soil Boring GP-16A1

INTERA

Project Name: Denison Nitrate Investigation White Mesa Mill, Blanding, Utah	Date/Time Started : 05/19/11	Driller	: L. Trujillo
	Date/Time Completed : 05/19/11	Depth to Water	: NA
	Drilling Method : Geoprobe	Logged by	: J. Reed
	Sampling Method : Continuous Dual Tube		
Project #: DENMC.C002.000	Drilling Co./Driller : Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0	Duplicate (0–0.5'); Soil sample (0.5–1.5')	4.0/ 3.7	0-3.1' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl none	SM	
	Soil sample (4–5'); Soil sample (6–7')	3.1/ 3.3	3.1-7.1' Silty SAND, pink (5YR 7/4), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl strong, trace fine sand		
5					
			Total depth of boring 7.1' bgs (refusal)		
10					

Note(s):
Duplicate sample collected. Sample interval was increased to 2 feet to accommodate additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-17A1

INTERA

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/18/11	Driller	: L. Trujillo
Date/Time Completed	: 05/18/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		3.2/ 2.9	0-2.5' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl weak 2.5-3.2' Silty SAND, pink (5YR 7/4), very fine-grainded sand, silt, loose to medium dense, dry, HCl strong, trace fine sand, little white mottling w/ HCl strong	SM	
			Total depth of boring 3.2' bgs (refusal)		
5					
10					

Notes:

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Log of Soil Boring GP-18A1

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/18/11	Driller	: L. Trujillo
Date/Time Completed	: 05/18/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.0	0-6.9' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl strong, trace white mottling w/ HCl strong, trace roots at top	SM	
5		3.3/ 3.1	6.9-7.3' Silty SAND, pink (5YR 7/4), very fine-grainded sand, silt, poorly graded, loose to medium dense, dry, HCl strong, trace fine sand		
10			Total depth of boring 7.3' bgs (refusal)		

Notes:

Log of Soil Boring GP-19A1

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah			
Date/Time Started	: 05/18/11	Driller	: L. Trujillo
Date/Time Completed	: 05/18/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Project #: DENMC.C002.000

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Intervl	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.9	0-6.0' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl none to weak, little white mottling w/ HCl strong	SM	
5		4.0/ 4.0	6.0-8.0' Silty SAND, pink (5YR 7/4), very fine-grainded sand, silt, poorly graded, loose to medium dense, dry, HCl strong, trace fine sand, sand & fine gravel 7.9-8.0' bgs		
10			Total depth of boring 8.0' bgs (refusal)		

Note(s):
Duplicate sample collected. Sample interval was increased to 2 feet to accommodate additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-20A1

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/18/11	Driller	: L. Trujillo
Date/Time Completed	: 05/18/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.0	0-3.1' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl none	SM	
			3.1-5.1' Silty SAND, pink (5YR 7/4), very fine-grainded sand, silt, loose to medium dense, dry, HCl weak to strong, little white mottling w/ HCl strong, trace fine sand		
5		1.1/ 1.3			
			Total depth of boring 5.1' bgs (refusal)		
10					

Notes:

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Log of Soil Boring GP-01B

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah			
Date/Time Started	: 06/12/11	Driller	: L. Trujillo
Date/Time Completed	: 06/12/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Project #: DENMC.C002.000

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.15	0-3.1' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~70%), poorly graded, loose to dense, dry, HCl strong, mottling common	SM	
		0.4/ 0.6	3.1-4.4' Silty Gravelly SAND, pinkish gray (5YR 7/2), very fine- to coarse-grained sand (~60%), gravel to 0.1" diameter (~30%), well graded, angular to subrounded, very loose, non-plastic, dry, no HCl	SW/ SM	
5			Total depth of boring 4.4' bgs (refusal)		
10					

Note(s):

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Log of Soil Boring GP-02B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/12/11	Driller	: L. Trujillo
Date/Time Completed	: 06/12/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS
0–3.0	Soil sample 3.0–4.0	4.0/ 1.5	0-3.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~65%), poorly graded, subangular to subrounded, loose, dry, HCl strong, roots abundant top 0.5'	SM
3.0–7.0	Duplicate 6.0–7.0	4.0/ 3.8	3.0-7.0' Lean CLAY, light reddish brown (5YR 6/3), very fine-grained sand (~25%), subangular to subrounded, soft, medium plastic, moist, HCl moderate	CL
7.0–11.8	Soil sample 7.0–8.0; 10.5–11.5	3.8/ 3.5	7.0-11.8' Clayey SAND, light reddish brown (5YR 6/3), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose to dense, medium plastic, moist, HCl strong	SC

Depth scale: 0, 5, 10, 15

Total depth of boring 11.8' bgs (refusal)

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

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INTERA

Log of Soil Boring GP-03B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started : 06/12/11
Date/Time Completed : 06/12/11
Drilling Method : Geoprobe
Sampling Method : Continuous Dual Tube
Drilling Co./Driller : Earth Worx

Driller : L. Trujillo
Depth to Water : NA
Logged by : E. Muller

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.2	0-4.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~80%), poorly graded, subangular to subrounded, loose, dry, HCl strong, mottling common	SM	
5		4.0/ 4.0	4.0-8.6' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose, moist, HCl strong, mottling common	SM	
		1.6/ 2.2	8.6-9.6' Lean CLAY, pink (5YR 7/4), very fine-grained sand (~25%), subangular to subrounded, soft, moderately plastic, moist, HCl strong	CL	
10			Total depth of boring 9.6' bgs (refusal)		
15					

Note(s):

Log of Soil Boring GP-04B

Project Name: Denison Nitrate Investigation White Mesa Mill, Blanding, Utah	Date/Time Started : 06/12/11
	Date/Time Completed : 06/12/11
	Drilling Method : Geoprobe
	Sampling Method : Continuous Dual Tube
Project #: DENMC.C002.000	Drilling Co./Driller : Earth Worx
	Driller : L. Trujillo
	Depth to Water : NA
	Logged by : E. Muller

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.3	0-4.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~70%), poorly graded, subangular to subrounded, loose, dry, HCl weak, mottling common, roots in top 0.3'	SM	
		0.8/ 1.1	4.0-4.6' SILT, red (2.5YR 5/6), very fine-grained sand (~25%), loose, non-plastic, non-cohesive, dry, HCl strong	ML	
5			Total depth of boring 4.8' bgs (refusal)		
10					

Note(s):

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Log of Soil Boring GP-05B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/08/11	Driller	: L. Trujillo
Date/Time Completed	: 06/08/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.0	0-6.5' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~70%), poorly graded, subangular to subrounded, loose, dry, HCl strong, white mottling common, roots in top 1.3'	SM	
5		4.0/ 3.4			
			6.5-13.3' Clayey SILT, yellowish brown (10YR 5/4), loose to dense, non- to slightly plastic, dry to moist, HCl slight, gypsum stringers and precipitate common	ML	
10		4.0/ 3.9			
		1.3/ 1.3			
15			Total depth of boring 13.3' bgs (refusal)		

Note(s):

Log of Soil Boring GP-06B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/07/11	Driller	: L. Trujillo
Date/Time Completed	: 06/07/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.0	0-1.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~80%), poorly graded, angular to subrounded, very loose, dry, no HCl 1-4' HCl strong and 5YR 4/4	SM	
4–5	Soil sample submitted	4.0/ 4.0	4.0-8.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~80%), poorly graded, angular to subrounded, very loose, dry, HCl	SM	
8		4.0/ 4.0	8.0-12' Clayey SILT, yellowish brown (10YR 5/4), poorly graded, loose, non-plastic, dry to moist, HCl slight	ML	
9.5–10.5	Soil sample submitted			ML	
12		1.8/ 1.8	12-13.8' Clayey SILT, yellowish brown (10YR 5/4), poorly graded, loose, non-plastic, dry, HCl slight, laminated	ML	
12.5–13.5	Soil sample submitted				
15			Total depth of boring 13.8' bgs (refusal)		

Note(s):

Log of Soil Boring GP-07B

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	
Project #: DENMC.C002.000	

Date/Time Started	: 06/09/11	Driller	: L. Trujillo
Date/Time Completed	: 06/09/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis (diagonal hatching)
- Duplicate soil sample submitted for laboratory analysis (horizontal lines)

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0	3.0-4.0 (soil sample)	4.0/ 3.5	0-4.0' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~70%), poorly graded, subangular to subrounded, loose, dry, HCl strong, white mottling common	SM	
5	6.5-7.5 (soil sample)	4.0/ 3.5	4.0-8.0' Silty SAND, reddish brown (5YR 5/4), very fine-grainded sand (~80%), poorly graded, subangular to subrounded, loose, dry, HCl strong, white mottling common	SM	
	8.5-9.5 (duplicate); 9.5-10.5 (soil sample)	2.8/ 4.0	8.0-10.2' Silty SAND, reddish brown (5YR 5/4), very fine-grainded sand (~60%), poorly graded, subangular to subrounded, slightly dense, dry, HCl strong, white mottling common	SM	
10			10.2-10.8' SILT, pink (5YR 7/4), very dense to hard, non-plastic, dry, HCl strong	ML	
15			Total depth of boring 10.8' bgs (refusal)		

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-08B

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	Date/Time Started: 06/09/11	Driller: L. Trujillo
	Date/Time Completed: 06/09/11	Depth to Water: NA
	Drilling Method: Geoprobe	Logged by: E. Muller
	Sampling Method: Continuous Dual Tube	
Project #: DENMC.C002.000	Drilling Co./Driller: Earth Worx	

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0			Road base		
	3-4 (soil sample)	4.0/ 3.6	0.8-4.0' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~80%), poorly graded, subangular to subrounded, dense, dry, HCl strong, white mottling throughout	SM	
5	7-8 (soil sample)	4.0/ 3.9	4.0-8.0' SILT, pink (5YR 7/4), trace very fine-grained sand, loose, non-plastic, dry, HCl strong	ML	
10		4.0/ 4.0	8.0-11.3' Silty SAND, pink (5YR 7/4), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose to dense, dry, HCl strong	SM	
	11-12 (soil sample)		11.3-12' SILT, pink (5YR 7/4), very dense, hard, non-plastic, dry, HCl strong	ML	
15			Total depth of boring 12' bgs (refusal)		

Note(s):

Log of Soil Boring GP-09B

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Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/09/11	Driller	: L. Trujillo
Date/Time Completed	: 06/09/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- (hatched) Soil sample submitted for laboratory analysis
- (open box) Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Pen./Rec. (feet)	DESCRIPTION	USCS
0-4.0	4.0/ 2.2	0-4.0' Silty SAND, reddish brown (5YR 5/4), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose, dry, HCl strong, white mottling common	SM
4.0-8.0	4.0/ 3.75	4.0-8.0' Silty SAND, reddish brown (5YR 5/4), very fine-grained sand (~80%), poorly graded, subangular to subrounded, loose, dry, HCl strong, white mottling common	SM
8.0-10.8	3.4/ 3.4	8.0-10.8' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~70%), poorly graded, subangular to subrounded, slightly dense, dry to moist, HCl strong, white mottling common	SM
10.8-11.4		10.8-11.4' SILT, pink (5YR 7/4), very dense, hard, non-plastic, dry, HCl strong	ML

Total depth of boring 11.4' bgs (refusal)

Note(s):

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Log of Soil Boring GP-10B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/09/11	Driller	: L. Trujillo
Date/Time Completed	: 06/09/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis (hatched box)
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0–4	Soil sample 3.0–4.0	4.0/ 3.6	0-4.0' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose, dry, HCl strong, white mottling common	SM	
4–8	Soil sample 7.0–8.0	4.0/ 4.0	4.0-8.0' Silty SAND, reddish brown (5YR 5/4), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose, dry, HCl strong, white mottling common	SM	
8–11.5	Soil sample 11.0–12.0	4.0/ 4.0	8.0-11.5' Silty SAND, reddish brown (5YR 5/4), very fine-grained sand (~60%), poorly graded, loose to dense, dry, HCl strong, white mottling common	SM	
11.5–12			11.5- 12' SILT, pink (5YR 7/4), very dense, hard, dry, HCl strong	ML	

Total depth of boring 12' bgs (refusal)

Depth scale: 0, 5, 10, 15

Note(s):

Log of Soil Boring GP-11B

(Page 1 of 1)

INTERA

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/07/11
Date/Time Completed	: 06/07/11
Drilling Method	: Geoprobe
Sampling Method	: Continuous Dual Tube
Drilling Co./Driller	: Earth Worx
Driller	: L. Trujillo
Depth to Water	: NA
Logged by	: E. Muller

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.2	0-2.0' Silty SAND, reddish brown (5YR 4/4), very fine-grained sand (~60%), poorly graded, subangular to subrounded, very loose, dry, HCl slight, roots	SM	
			2.0-4.0' Silty SAND, light reddish brown (5YR 6/3), very fine-grained sand (~60%), poorly graded, subangular to subrounded, very loose, dry, HCl strong		
5		4.0/ 3.2	4.0-7.0' Silty SAND, light reddish brown (5YR 6/3), very fine-grained sand (~60%), poorly graded, subangular to subrounded, very loose, dry, HCl strong		
10		4.0/ 3.2	7.0-12.1' Clayey SILT, pinkish gray (7.5YR 6/2), loose to dense, non-plastic, dry, HCl strong, white mottling common, laminated	ML	
		0.1/0.1			
15			Total depth of boring 12.1' bgs (refusal)		

Note(s):

Log of Soil Boring GP-12B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/07/11	Driller	: L. Trujillo
Date/Time Completed	: 06/07/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis (diagonal hatch)
- Duplicate soil sample submitted for laboratory analysis (horizontal lines)

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0–4	Soil sample 3.5–4.5	4.0/ 3.5	0-1.5' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand, poorly graded, subangular to subrounded, very loose, dry, no HCl 0-1.5' bgs, HCl slight 1.5-8.0' Silty SAND, reddish brown (5YR 5/4), very fine-grained sand, poorly graded, subangular to subrounded, very loose, dry, HCl slight, laminated	SM	
4–8	Soil sample 7.5–8.5	4.0/ 3.1			
8–12	Duplicate 10–11; Soil sample 11–12	4.0/ 3.4	8.0-12.4' Clayey SILT, light olive brown (2.5YR 4/3), poorly graded, loose, non-plastic, dry, HCl, laminated, gypsum precipitate throughout 10.5-12' 5-10mm gypsum stringers	ML	
12–12.4		0.4/0.4			

Total depth of boring 12.4' bgs (refusal)

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-13B

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah			
Date/Time Started	: 06/07/11	Driller	: L. Trujillo
Date/Time Completed	: 06/07/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Project #: DENMC.C002.000

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.6	0-1.5' Silty SAND, yellowish red brown (5YR 4/6), very fine-grained sand, poorly graded, subangular to subrounded, very loose, dry, HCl slight 1.5-6.2' Silty SAND, light reddish brown (5YR 6/3), very fine-grained sand, poorly graded, subangular to subrounded, very loose, dry, HCl slight	SM	
5	Soil sample submitted (4-5')	4.0/ 4.0	6.2-8.0' Clayey SILT, reddish brown (5YR 5/4), trace very fine-grained sand, loose to dense, non-plastic, dry to moist, HCl strong, white mottling throughout	ML	
10	Soil sample submitted (8.5-9.5')	4.0/ 4.0	8.0-12' Clayey SILT, dark grayish brown (10YR 4/2), dense, slightly plastic, dry, HCl weak, thin bedding	ML	
	Soil sample submitted (12.5-13.5')	1.8/ 1.8	12-13.8' Clayey SILT, light yellowish brown (10YR 6/4), loose, non-plastic, dry, HCl slight, thin bedding	ML	
15			Total depth of boring 13.8' bgs (refusal)		

Note(s):

Log of Soil Boring GP-14B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/07/11	Driller	: L. Trujillo
Date/Time Completed	: 06/07/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.0	0-4.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand, poorly graded, subangular to subrounded, very loose, dry, no HCl	SM	
4-5	Soil sample submitted for laboratory analysis (4.0-5.0)	4.0/ 3.0	quartz fragments 4.0-4.7' bgs 4.7-8.0' Silty SAND, reddish yellow (2.5YR 6/6), very fine-grained sand, poorly graded, loose to dense, dry, HCl moderate, white mottling throughout	SM	
8	Soil sample submitted for laboratory analysis (8.5-9.5)	4.0/ 3.5	8.0-12' Clayey SILT, brown (7.5YR 5/2), poorly graded, loose to dense, non-plastic, dry, HCl slight	ML	
12	Soil sample submitted for laboratory analysis (13.0-14.0)	2.0/ 2.0	12-14' Clayey SILT, yellowish brown (10YR 5/6), poorly graded, loose to dense, non-plastic, dry, HCl slight	ML	
14-15			Total depth of boring 14' bgs (refusal)		

Note(s):

Log of Soil Boring GP-15B

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah			
Date/Time Started	: 06/08/11	Driller	: L. Trujillo
Date/Time Completed	: 06/08/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Project #: DENMC.C002.000

Sample Interval Description
- Soil sample submitted for laboratory analysis (hatched)
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0–4		4.0/ 3.4	0-3.5' Silty SAND, yellowish red (5YR 4/6), very fine- to medium-grained sand (~80%), well graded, angular to subrounded, loose, dry to moist, HCl moderate, minor white mottling	SM	
			3.5-4.0' Clayey SILT, light reddish brown (5YR 6/4), poorly graded, dense, slightly plastic, moist, HCl moderate	ML/ CL	
4–8	Soil sample (4.5–5.5)	4.0/ 3.4	4.0-10' Silty SAND, yellowish red (5YR 4/6), very fine-grainded sand (~75%), poorly graded, subangular to subrounded, loose, dry to moist, HCl strong, white mottling throughout	SM	
8–12	Soil sample (10–11)	4.0/ 2.8	10-12' CLAY, yellowish red (5YR 4/6), dense, low to medium plastic, cohesive, moist, HCl slight	CL	
12–16	Soil sample (15–16)	4.0/ 4.0	12-16' CLAY, pale brown (10YR 6/3), very dense, low plastic, slightly cohesive, dry, HCL moderate, minor FeO staining	CL	

Total depth of boring 16' bgs (refusal)

Note(s):

Log of Soil Boring GP-16B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/08/11	Driller	: L. Trujillo
Date/Time Completed	: 06/08/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.0	0-5.5' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~75%), poorly graded, subangular to subrounded, loose, dry to moist, no HCl	SM	
5	Soil sample (4.5-5.5)	4.0/ 3.2	5.5-8.0' Silty SAND, reddish yellow (5YR 6/6), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose, dry, HCl strong, white mottling throughout	SM	
		4.0/ 3.1	8.0-11.3' CLAY, reddish yellow (5YR 6/6), hard, medium plastic, cohesive, dry to moist w/ increasing moisture towards base of interval, HCl strong	CL	
10	Soil sample (10-11)				
		4.0/ 4.0	11.3-16' CLAY, pale brown (10YR 6/3), very hard, slightly plastic, slightly cohesive, moist, HCl strong	ML	
15	Soil sample (15-16)				
20			Total depth of boring 16' bgs (refusal)		

Note(s):

Log of Soil Boring GP-17B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/09/11	Driller	: L. Trujillo
Date/Time Completed	: 06/09/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.6	0-1.4' FILL		
			1.4-12' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~75%), poorly graded, subangular to subrounded, loose, dry, HCl moderate, white mottling common	SM	
5	Soil sample (5.5-6.5)	4.0/ 3.85			
10		4.0/ 3.65			
	Soil sample (11.5-12.5)		12-15.6' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose, moist, HCl strong, white mottling common		
15		4.0/ 3.4	15.6-16' SILT, very pale brown (10YR 7/4), hard, non-plastic, non-cohesive, dry, HCl moderate	ML	
		2.6/ 2.6	16-18' Lean CLAY, yellowish red (5YR 5/6), very fine-grained sand (~30%), subrounded, soft, slightly plastic, slightly cohesive, moist, HCl slight	ML/ CL	
	Soil sample (17.5-18.5)		18-18.6' SILT, very pale brown (10YR 7/4), hard, non-plastic, non-cohesive, dry, HCl moderate	ML	
20			Total Depth of Boring 18.6' bgs (refusal)		

Note(s):

Log of Soil Boring GP-18B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/09/11	Driller	: L. Trujillo
Date/Time Completed	: 06/09/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 4.0	0-1.5' FILL		
			1.5-12' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~75%), poorly graded, subangular to subrounded, loose, dry, HCl strong, white mottling common, caliche rich 10-10.5' bgs	SM	
5		4.0/ 3.8			
10		4.0/ 3.8			
		4.0/ 3.25	12-16' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~75%), poorly graded, subangular to subrounded, loose, slightly moist with moisture increasing w/ depth, HCl strong, occasional white mottling		
15		2.5/ 2.85	16-17.9' Sandy Silty CLAY, yellowish red (5YR 5/6), very fine-grained sand (~30%), soft, slightly plastic, slightly cohesive, moist, HCl slight	ML/ CL	
			17.9-18.5' SILT, very pale brown (10YR 7/4), hard, non-plastic, non-cohesive, dry, HCl strong, shale	ML	
20			Total depth of boring 18.5' bgs (refusal)		

Note(s):

Log of Soil Boring GP-19B

INTERA

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/09/11	Driller	: L. Trujillo
Date/Time Completed	: 06/09/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0–2.5		4.0/ 3.85	0-2.5' FILL		
2.5–12	Soil sample 5–6 ft; 11–12 ft	4.0/ 3.85; 4.0/ 3.95	2.5-12' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~75%), poorly graded, subangular to subrounded, loose, dry, HCl moderate, occasional white mottling	SM	
12–17.1	Soil sample 16.5–17.5 ft	4.0/ 3.8	12-17.1' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose to dense, slightly moist to moist increasing w/ depth, HCl strong, occasional white mottling	SM	
17.1–17.9			17.1-17.9' SILT, very pale brown (10YR 7/4), very dense, hard, non-plastic, dry, HCl strong, weathered shale	ML	

Total depth of boring 17.9' bgs (refusal)

Note(s):

Log of Soil Boring GP-20B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/09/11	Driller	: L. Trujillo
Date/Time Completed	: 06/09/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 4.0	0-1.0' FILL		
			1.0-12' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~70%), poorly graded, subangular to subrounded, loose, dry, HCl moderate, occasional white mottling	SM	
5	Duplicate (4-5'); Soil sample (5-6')	4.0/ 3.9			
10	Soil sample (11-12')	4.0/ 3.5			
		4.0/ 3.2	12-16' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose, moist, HCl moderate, occasional white mottling		
15	Soil sample (16-17')	1.4/ 1.4	16-16.7' Sandy Lean CLAY, very fine-grained sand (~15%), yellowish red (5YR 5/6), soft, medium plastic, medium cohesive, very moist, HCl slight	CL	
			16.7-17.4' SILT, very pale brown (10YR 7/4), hard, non-plastic, dry, HCl strong, shale	ML	
20			Total depth of boring 17.4' bgs (refusal)		

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-21B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/12/11	Driller	: L. Trujillo
Date/Time Completed	: 06/12/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 2.3	0-4.5' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~70%), poorly graded, subangular to subrounded, loose, moist, HCl weak, gravel from 3.8-4.0'	SM	
5		2.7/ 2.9	4.5-5.5' Silty SAND, pink (5YR 7/3), very fine-grained sand (~60%), poorly graded, subrounded, loose, slightly cohesive, wet, HCl moderate	SM	
			5.5-6.7' Sandy SILT, light yellowish brown (10YR 6/4), very fine-grained sand (~15%), poorly graded, subrounded, loose, dry, thin bedding, HCl strong	ML	

Total depth of boring 6.7' bgs (refusal)

10

15

Note(s):

Log of Soil Boring GP-22B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/12/11	Driller	: L. Trujillo
Date/Time Completed	: 06/12/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.2	0-4.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~75%), poorly graded, subrounded, loose, dry to slightly moist, HCl no to weak	SM	
5		4.0/ 2.9	4.0-7.6' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~60%), poorly graded, subrounded, loose, moist to very moist, HCl weak	SM	
		0.9/ 1.9	7.6-8.0' SILT, pink (5YR 8/3), very fine-grained sand (~25%), poorly graded, subrounded, dense, slightly cohesive, moist, HCl strong 8.0-8.9' SILT, brownish yellow (10YR 6/6), very fine-grained sand (~25%), poorly graded, subrounded, loose, slightly moist, HCl weak, thin bedding	ML	
10			Total depth of boring 8.9' bgs (refusal)		
15					

Note(s):

Log of Soil Boring GP-23B

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	Date/Time Started: 06/11/11
Project #: DENMC.C002.000	Date/Time Completed: 06/11/11
	Drilling Method: Geoprobe
	Sampling Method: Continuous Dual Tube
	Drilling Co./Driller: Earth Worx
	Driller: L. Trujillo
	Depth to Water: NA
	Logged by: E. Muller

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Pen./Rec. (feet)	DESCRIPTION	USCS
0-2.0	4.0/3.2 (0-4.0)	0-2.0' Silty SAND, reddish gray (5YR 5/2), very fine- to coarse-grained sand, well graded, angular to subrounded, loose, non-plastic, dry, HCl moderate	SW/SM
2.0-4.0		2.0-4.0' Lean CLAY w/ Sand, brownish yellow (10YR 6/6), fine- to coarse-grained sand (~20%), well graded, angular to subrounded, hard, slightly plastic, moist, HCl slight, burned (ash?) layer from 2.0-2.2' bgs	CL
4.0-15.3	4.0/2.5 (4.0-8.0); 4.0/2.0 (8.0-12.0); 3.3/2.3 (12.0-15.3)	4.0-15.3' Sandy Lean CLAY, reddish brown (5YR 5/4), fine- to coarse-grained sand (~30%), up to 0.05' diameter gravel (<10%), well graded, angular to subrounded, soft, low to moderate plastic, moist, HCl weak	CL

Sample intervals: soil samples submitted for laboratory analysis at approximately 4.5-5.5', 9.5-10.5' and 14.0-15.0'; duplicate soil sample at approximately 8.5-9.5'.

Total depth of boring 15.3' bgs (refusal)

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-24B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/11/11	Driller	: L. Trujillo
Date/Time Completed	: 06/11/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0–4		4.0/ 3.7	0-8.0' Clayey Gravelly SAND, dark yellowish brown, (10YR 4/4), very fine- to coarse-grained sand (~75%), up to 0.04' diameter gravel (~15%), soft, slightly plastic, moist, HCl weak	SW /SC	
4–8		4.0/ 2.7			
8–12		4.0/ 2.5	8.0-11.3' Sandy Gravelly SILT, brown (10YR 5/3), fine- to coarse-grained sand (~30%), up to 0.02' diameter gravel (~10%), soft, slightly plastic, moist, HCl weak	ML	
			11.3-12.5' Silty SAND, brownish yellow (10YR 6/6), very fine- to fine-grained sand (~70%), well graded, subangular to subrounded, dense, dry, no HCl, gypsum precipitate throughout	SM	
12–12.8		0.8/ 0.8	12.5-12.8' Silty SAND, yellowish red (5YR 4/6), very fine- to fine-grained sand (~80%), poorly graded, subangular to subrounded, loose, wet, HCl weak		

Total depth of boring 12.8' bgs (refusal)

Depth scale: 0, 5, 10, 15, 20

Note(s):

Log of Soil Boring GP-25B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/08/11	Driller	: L. Trujillo
Date/Time Completed	: 06/08/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis (hatched)
- Duplicate soil sample submitted for laboratory analysis (horizontal lines)

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.1	0-0.75' Road base gravel		
5	Soil sample (~5.5–6.5)	4.0/ 3.6	0.75-11.7' Silty SAND, reddish yellow (5YR 6/6), very fine-grained sand (~65%), poorly graded, subangular to subrounded, loose to dense, dry to 10.9' bgs, moist to 11.7' bgs, HCl strong, occasional white mottling	SM	
10	Duplicate sample (~12–13)	4.0/ 3.8	11.7-13.3' CLAY, reddish yellow (5YR 6/6), dense, plastic to very plastic, cohesive, slightly moist, HCl strong	CL/ CH	
15	Soil sample (~13–14); Soil sample (~18–19)	4.0/ 4.0 3.4/ 3.4	13.3-19.4' CLAY, pale brown (10YR 6/3), dense, slightly plastic, slightly cohesive, dry, HCl slight, weathered shale, platy shale fragments increasing w/ depth, weathered shale w/ shale fragments	ML	
20			Total depth of boring 19.4' bgs (refusal)		

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

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Log of Soil Boring GP-26B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/09/11	Driller	: L. Trujillo
Date/Time Completed	: 06/09/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.3	0-0.3' Road base gravel		
			0.3-4.0' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, subangular to subrounded, dense, moist, HCl strong, white mottling common	SM	
5	4.5-5.5 (soil sample)	4.0/ 3.3	4.0-10.1' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~80%), poorly graded, subangular to subrounded, dense, dry to moist, HCl moderate, white mottling common	SM	
10	10-11 (soil sample)	4.0/ 3.6	10.1-13' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~70%), poorly graded, subangular to subrounded, dense, moist, HCl moderate	SM	
15	15-16 (soil sample)	4.0/ 4.0	13-16' SILT, yellowish brown (10YR 5/4), very dense, hard, dry, HCl strong	ML	
20			Total depth of boring 16' bgs (refusal)		

Note(s):

Log of Soil Boring GP-27B

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	Date/Time Started: 06/10/11	Driller: L. Trujillo	
	Date/Time Completed: 06/10/11	Depth to Water: NA	
	Drilling Method: Geoprobe	Logged by: E. Muller	
	Sampling Method: Continuous Dual Tube		
Project #: DENMC.C002.000	Drilling Co./Driller: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis (hatched)
- Duplicate soil sample submitted for laboratory analysis (horizontal lines)

Depth in Feet	Pen./Rec. (feet)	DESCRIPTION	USCS
0-4	4.0/ 3.2	0-4.0' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~80%), poorly graded, subangular to subrounded, loose, dry, HCl moderate, mottling common	SM
4-8	4.0/ 3.3	4.0-11.8' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~70%), poorly graded, subangular to subrounded, loose, moist, HCl weak, mottling rare	SM
8-12	4.0/ 3.6		
12-14.6	2.6/ 2.6	11.8-13' Clayey SAND, yellowish red (5YR 4/6), very fine-grained sand, subrounded, loose, slightly plastic, moist, HCl strong, mottling throughout	SC
		13-14.6' Sandy SILT, yellowish brown (10YR 5/6), very fine-grained sand (~25%), subrounded, loose, non-plastic, non-cohesive, dry, HCl strong	ML

Total depth of boring 14.6' bgs (refusal)

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

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Log of Soil Boring GP-28B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/10/11	Driller	: L. Trujillo
Date/Time Completed	: 06/10/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.3	0-7.4' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose, moist, HCl weak to strong	SM	
5		4.0/ 3.0			
			7.4-7.7' Lean CLAY w/ Sand, very dark gray (5YR 3/1), very fine-grained sand (~15%), soft, plastic, moist, HCl weak	CL	
10		4.3/ 3.4	7.7-12' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~80%), poorly graded, subangular to subrounded, loose, moist, HCl weak, occasional mottling	SM	
			12-12.3' Clayey SAND, very pale brown (10YR 7/3), very fine-grained sand w/ plastic fines, poorly graded, subangular to subrounded, loose, slightly plastic, moist, HCl strong	SC	
15			Total depth of boring 12.3' bgs (refusal)		

Note(s):

Log of Soil Boring GP-29B

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	Date/Time Started : 06/10/11
	Date/Time Completed : 06/10/11
	Drilling Method : Geoprobe
	Sampling Method : Continuous Dual Tube
Project #: DENMC.C002.000	Drilling Co./Driller : Earth Worx
	Driller : L. Trujillo
	Depth to Water : NA
	Logged by : E. Muller

Sample Interval Description
- Soil sample submitted for laboratory analysis (hatched)
- Duplicate soil sample submitted for laboratory analysis (horizontal lines)

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0–1.3		4.0/ 2.95	0-1.3' Road base		
1.3–3.0			1.3-3.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~80%), poorly graded, subangular to subrounded, loose, dry, HCl moderate, white mottling throughout	SM	
3.0–4.0			3.0-4.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~80%), poorly graded, subangular to subrounded, loose, moist, gravel and wood fragments common, HCl moderate,	SM	
4.0–12	Soil sample 4.0–5.0; duplicate 7.5–8.5; soil sample 8.5–9.5	4.0/ 3.0; 4.0/ 3.25	4.0-12' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~70%), poorly graded, subangular to subrounded, loose, dry to moist, HCl weak, occasional mottling	SM	
12–13.2		2.4/ 2.6	12-13.2' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose, moist, HCl moderate	SM	
13.2–14.4	Soil sample 13.0–14.0		13.2-14.4' Silty SAND, yellowish brown (10YR 5/4), very fine-grained sand (~60%), poorly graded, subangular to subrounded, dense, moist, HCl moderate	SM	

Total depth of boring 14.4' bgs (refusal)

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-30B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/10/11	Driller	: L. Trujillo
Date/Time Completed	: 06/10/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.3	0-7.1' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~70%), poorly graded, subangular to subrounded, loose, dry to moist, HCl weak, occasional mottling	SM	
5		4.0/ 3.15			
			7.1-7.2' Clayey SAND w/ low plastic fines, dark reddish brown (5YR 3/4), very fine-grained sand, poorly graded, subrounded, soft, slightly plastic, moist, HCl moderate	SC	
			7.2-12' Silty SAND, Yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, subrounded, loose, moist, HCl none to weak	SM	
10		4.0/ 3.3			
			12-13.1' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, subrounded, loose, wet, HCl moderate		
			Total depth of boring 13.1' bgs (refusal)		
15					

Note(s):

Log of Soil Boring GP-31B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/08/11	Driller	: L. Trujillo
Date/Time Completed	: 06/08/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.1	0-4.7' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~65%), poorly graded, subangular to subrounded, very loose, dry, HCl moderate, white mottling throughout	SM	
5		1.6/ 1.6	4.7-5.6' SAND w/ minor Silt, pinkish gray (7.5YR 6/2), very fine- to fine-grained sand, poorly to well graded, subangular to subrounded, very loose, moist, HCl strong	SP/ SM	
10			Total depth of boring 5.6' bgs (refusal)		

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-32B

Project Name: Denison Nitrate Investigation White Mesa Mill, Blanding, Utah	Date/Time Started : 06/08/11 Date/Time Completed : 06/08/11 Drilling Method : Geoprobe Sampling Method : Continuous Dual Tube Drilling Co./Driller : Earth Worx
Project #: DENMC.C002.000	Driller : L. Trujillo Depth to Water : NA Logged by : E. Muller

Sample Interval Description

- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 2.9	0-4.0' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, subangular to subrounded, very loose, dry to moist increasing w/ depth, HCl moderate	SM	
5			Total depth of boring 4.0' bgs (refusal)		
10					

Note(s):

Log of Soil Boring GP-33B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/08/11	Driller	: L. Trujillo
Date/Time Completed	: 06/08/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0–1.2	Soil sample submitted for laboratory analysis (hatched, ~0.2–1.2)	1.7/ 1.7	0-1.2' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~75%), poorly graded, subangular to subrounded, very loose, dry, HCl moderate, minor white mottling	SM	
1.2–1.7			1.2-1.7' SAND w/ minor Silt, pinkish gray (5YR 6/2), very fine- to fine-grained sand, poorly to well graded, subangular to subrounded, very loose, dry, HCl strong	SP/ SM	

Total depth of boring 1.7' bgs (refusal)

Depth scale: 0, 1, 2, 3, 4, 5

Note(s):

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Log of Soil Boring GP-34B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/08/11	Driller	: L. Trujillo
Date/Time Completed	: 06/08/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		3.8/ 2.7	0-3.0' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~65%), poorly graded, subangular to subrounded, loose, dry to moist, HCl slight, minor roots 0-0.8' bgs	SM	
			3.0-3.8' SAND w/ minor silt, pinkish gray (5YR 6/2), very fine- to fine-grained sand, poorly to well graded, subangular to subrounded, very loose, moist, HCl strong	SP/ SM	
			Total depth of boring 3.8' bgs (refusal)		
5					
10					

Note(s):

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Log of Soil Boring GP-35B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/11/11	Driller	: L. Trujillo
Date/Time Completed	: 06/11/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.5	0-4.0' SAND w/ gravel FILL, dark reddish brown (5YR 3/3), fine- to coarse-grained sand, gravel to 0.06' diameter, well graded, angular to subrounded, loose, dry, HCl moderate	SW	
5	Soil sample submitted for laboratory analysis (~5.5-6.5')	4.0/ 1.8	4.0-11' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~75%), poorly graded, subrounded, loose, moist, HCl moderate, mottling common	SM	
10		4.0/ 2.7	11-12' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~75%), poorly graded, subrounded, dense, moist, HCl weak	SM	
	Soil sample submitted for laboratory analysis (~12-13')	4.0/ 3.7	12-17.4' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~75%), poorly graded, subrounded, loose, moist to wet near bottom of interval. HCl weak	SM	
15	Soil sample submitted for laboratory analysis (~17.5-18.5')	2.9/ 2.8	17.4-18.9' Clayey SILT, yellowish brown (10YR 5/4), dense, slightly plastic, moist, HCl strong	ML/ CL	
20			Total depth of boring 18.9' bgs (refusal)		

Note(s):

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Log of Soil Boring GP-36B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/11/11	Driller	: L. Trujillo
Date/Time Completed	: 06/11/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.5	0-2.5' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, loose, dry, HCl moderate, mottling common	SM	
		4.0/ 2.6	2.5-11' Clayey Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, subrounded, loose, soft, slightly plastic, moist, HCl moderate	SM/ SC	
10		4.0/ 2.8	11- 13' Clayey Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, subrounded, dense, slightly plastic, moist, no HCl		
		4.0/ 3.4	13-18.3' Silty SAND, reddish yellow (5YR 6/8), very fine-grained sand (~70%), poorly graded, subrounded, loose, dry to moist increasing with depth, HCl strong, mottling common	SM	
		9.3/ 3.1	18.3-19.3' SILT, light gray (10YR 7/2), very fine-grained sand (~30%), subrounded, dense, non-plastic, dry, HCl strong, FeO staining	ML	
20			Total depth of boring 19.3' bgs (refusal)		

Note(s):

Log of Soil Boring GP-37B

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	
Project #: DENMC.C002.000	

Date/Time Started	: 06/11/11	Driller	: L. Trujillo
Date/Time Completed	: 06/11/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0–4		4.0/ 3.3	0-4.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~60%), poorly graded, subrounded, loose, dry, HCl strong, mottling throughout	SM	
4–8	Soil sample (4.5–5.5)	4.0/ 3.2	4.0-9.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~70%), poorly graded, subrounded, loose, moist, HCl slight, occasional mottling	SM	
8–12	Soil sample (10–11)	4.0/ 4.0	9.0'-13.2' Clayey SAND, yellowish red (5YR 5/6), very fine-grained sand (~60%), poorly graded, subrounded, soft, slightly plastic, moist, HCl strong, ~30% motttling	SC	
12–16	Soil sample (15–16)	4.0/ 4.0	13.2-16' Clayey SILT, yellowish brown (10YR 5/6), soft to hard, slightly plastic, moist, HCl strong, ~5% mottling	ML/ CL	

Total depth of boring 16' bgs (refusal)

Note(s):

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Log of Soil Boring GP-38B

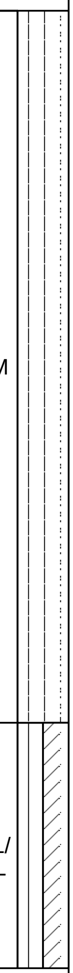
Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/11/11	Driller	: L. Trujillo
Date/Time Completed	: 06/11/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Pen./Rec. (feet)	DESCRIPTION	USCS
0–4	4.0/ 3.3	0-5.0' Silty SAND, yellowish red (5YR 5/8), very fine-grained sand (~70%), poorly graded, subrounded, loose, dry, HCL strong, mottling common	SM
4–8	4.0/ 3.3	5.0-11.9' Silty SAND, yellowish red (5YR 5/8), very fine-grained sand (~60%), poorly graded, subrounded, dense, moist, HCl weak	SM
8–12	4.0/ 3.1		
12–16	4.0/ 4.0	11.9-16' Clayey SILT, yellowish brown (10YR 5/6), soft to hard, slightly plastic, moist, massive-transitions to platy structure near bottom of interval, HCl slight	ML/ CL



Total depth of boring 16' bgs (refusal)

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-39B

Project Name: Denison Nitrate Investigation White Mesa Mill, Blanding, Utah	Date/Time Started : 06/12/11	Driller : L. Trujillo	
	Date/Time Completed : 06/12/11	Depth to Water : NA	
	Drilling Method : Geoprobe	Logged by : E. Muller	
	Sampling Method : Continuous Dual Tube		
Project #: DENMC.C002.000	Drilling Co./Driller : Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.6	0-6.6' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~70%), poorly graded, subrounded, loose, dry to moist, HCL none 0-4' bgs & strong 4-6.6' bgs, mottling common 4-6.6' bgs	SM	
5		4.0/ 4.0			
			6.6-11' Lean CLAY, reddish brown (5YR 5/3), very fine-grained sand (~15%), poorly graded, subrounded soft, slightly plastic to plastic, moist, HCl strong	CL	
10		4.0/ 4.0			
			11-12.8' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, subrounded, loose, moist w/ moisture increasing with depth, HCl weak	SM	
		2.2/ 3.4	12.8-14.2' Sandy SILT, gray (10YR 5/1), very fine-grained sand (~30%), poorly graded, subrounded, dense, dry, HCl weak, thin bedding to platy, FeO common 12.8-13.6' bgs	ML	
15			Total depth of boring 14.2' bgs (refusal)		
20					

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-40B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/12/11	Driller	: L. Trujillo
Date/Time Completed	: 06/12/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.3	0-4.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~70%), poorly graded, subrounded, loose, dry to moist, HCL moderate	SM	
5		4.0/ 4.0	4.0-8.0' Sandy Silty Lean CLAY, yellowish red (5YR 5/6), very fine-grained sand (~20%), poorly graded, subrounded, soft, slightly plastic, moist, HCl moderate, occasional mottling	ML/ CL	
10		4.0/ 3.9	8.0-13' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~60%), poorly graded, subrounded, loose, moist, HCl moderate, occasional mottling	SM	
		1.6/ 1.8	13-13.6' Sandy SILT, yellowish brown (10YR 5/4), very fine-grained sand (~30%), poorly graded, subrounded, soft, slightly plastic, moist, HCl moderate	ML	
15			Total depth of boring 13.6' bgs (refusal)		
20					

Note(s):

Log of Soil Boring GP-41B

(Page 1 of 1)

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	Date/Time Started : 06/11/11
	Date/Time Completed : 06/11/11
	Drilling Method : Geoprobe
	Sampling Method : Continuous Dual Tube
Project #: DENMC.C002.000	Drilling Co./Driller : Earth Worx
	Driller : L. Trujillo
	Depth to Water : NA
	Logged by : E. Muller

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0–4		4.0/ 2.4	0-6.5' SAND, pale yellow (5Y 8/2), very fine- to fine-grained sand (~85%), poorly graded, subangular to subrounded, dense, dry, HCl none	SP	
4–8		4.0/ 2.8			
8–12		4.0/ 3.0	6.5-19' Silty SAND, light brown (7.5YR 6/3) to pinkish gray (7.5YR 7/2), very fine-grained sand (~60%), poorly graded, subangular to subrounded, loose, dry, HCl none, thin bedded, occasional sandstone fragments, occasional FeO stains	SM	
12–16		4.0/ 2.8			
16–20		4.0/ 2.7	19-24.5' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, subrounded, loose, dry, HCl strong, mottling common		
20–24		4.0/ 3.8			
24–24.5		0.5/0.9			

Total depth of boring 24.5' bgs (refusal)

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

07-28-2011 S:\Projects\BoreLogs\Denison\GP-41B.bor

Log of Soil Boring GP-42B

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	Date/Time Started: 06/11/11	Driller: L. Trujillo	
	Date/Time Completed: 06/11/11	Depth to Water: NA	
	Drilling Method: Geoprobe	Logged by: E. Muller	
	Sampling Method: Continuous Dual Tube		
Project #: DENMC.C002.000	Drilling Co./Driller: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis (hatched)
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0–4	Soil sample 2–3	4.0/3.4	0-5.5' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~65%), poorly graded, subangular to subrounded, loose, dry to moist, HCl strong, mottling common	SM	
4–8	Soil sample 5–6	4.0/3.8	5.5-8.0' Clayey Silty SAND, reddish brown (5YR 5/4), very fine-grained sand, poorly graded, subrounded, dense, slightly plastic, moist, HCl strong, mottling common	SM/SC	
8–8.5	Soil sample 7.5–8.5	0.5/1.1	8.0-8.5' Silty CLAY, dark reddish brown (5YR 3/2), soft, slightly plastic to plastic, non-cohesive, dry, HCl strong, weathered shale, thin bedding	ML/CL	

Total depth of boring 8.5' bgs (refusal)

Note(s):

Log of Soil Boring GP-43B

(Page 1 of 1)

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/11/11	Driller	: L. Trujillo
Date/Time Completed	: 06/11/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Pen./Rec. (feet)	DESCRIPTION	USCS
0	4.0/ 3.5	0-1.8' Fill	
		1.8-4.0' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~65%), poorly graded, subrounded, loose, dry, HCl moderate	SM
5	4.0/ 4.0	4.0-5.8' Well Graded GRAVEL, very pale brown (10YR 2/3), fine- to medium-grained sand (~10%), gravel (~40%), well graded, subangular to subrounded, very loose, non-plastic, dry, HCl moderate	GW/ GM
		5.8-8.4' Clayey SAND, yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, subrounded, dense, plastic, moist, HCl strong	SC
	1.7/ 1.9	8.4-9.7' SILT, light yellowish brown (10YR 6/4), soft, non-plastic, non-cohesive, moist, HCl strong	ML
10		Total depth of boring 9.7' bgs (refusal)	
15			

Note(s):

Log of Soil Boring GP-44B

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	
Date/Time Started	: 06/10/11
Date/Time Completed	: 06/10/11
Drilling Method	: Geoprobe
Sampling Method	: Continuous Dual Tube
Drilling Co./Driller	: Earth Worx
Driller	: L. Trujillo
Depth to Water	: NA
Logged by	: E. Muller

Project #: DENMC.C002.000

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 2.3	0-4.0' Silty SAND, pale brown (10YR 6/3), very fine- to medium-grained sand (~80%), well graded, subrounded, loose, dry, HCl moderate, fine crystals precipitate throughout	SW/ SM	
5		4.0/ 2.8	4.0-6.0' Clayey Sitly SAND, very pale brown (10YR 7/4), very fine-grained sand (~60%), poorly graded, subrounded, loose, slightly plastic, dry, HCL none, small rocks, wood scattered throughout 6.0-8.0' Clayey Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~60%), poorly graded, subrounded, slightly plastic, moist, HCl weak	SM/ SC	
10		4.0/ 3.7	8.0-12' Lean CLAY, dark reddish brown (5YR 3/2), silt, soft, slightly plastic, moist, HCl weak	CL	
		4.0/ 3.5	12-14.3' Sandy Lean CLAY, dark reddish brown (5YR 3/2), very fine-grained sand (~20%), poorly graded, subrounded, very soft, plastic to very plastic, very cohesive, moist, HCl weak	CL/ CH	
15			14.3-16' Lean CLAY, gray to blueish gray (2 6/1), hard, plastic, non-cohesive, moist, HCl none, laminate bedding, weathered shale	CL	
		2.4/ 3.1	16-18' Lean CLAY, blueish gray to gray (2 6/1), loose, plastic, moist, HCl none, thin bedding, FeO staining throughout, weathered shale	CL	
			18-18.4' SILT, blueish gray to gray (2 5/1), hard, laminate bedding, shale fragments	ML	
20			Total depth of boring 18.4' bgs (refusal)		

Note(s):

Log of Soil Boring GP-45B

INTERA

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah	Date/Time Started : 06/07/11
	Date/Time Completed : 06/07/11
	Drilling Method : Geoprobe
	Sampling Method : Continuous Dual Tube
Project #: DENMC.C002.000	Drilling Co./Driller : Earth Worx
	Driller : L. Trujillo
	Depth to Water : NA
	Logged by : E. Muller

Sample Interval Description
- Soil sample submitted for laboratory analysis (diagonal hatch)
- Duplicate soil sample submitted for laboratory analysis (horizontal lines)

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.0	0-4.0' Silty SAND, dark reddish brown (5YR 3/4), fine- to very fine-grained sand, poorly graded, subangular to subrounded, very loose, moist to wet, HCl none, roots 0-2' bgs	SM	
		0.6/ 0.6	4.0-4.6' SAND w/ minor silt, pinkish gray (5YR 6/2), very fine- to fine-grained sand, poorly graded, subangular to subrounded, very loose, moist, HCl none	SP/ SM	
5			Total depth of boring 4.6' bgs (refusal)		
10					

Note(s):
1. Duplicate sample collected. Sample interval was increased to 2 feet to accommodate for additional sample volume required by the analytical laboratory.

Log of Soil Boring GP-46B

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 06/07/11	Driller	: L. Trujillo
Date/Time Completed	: 06/07/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 2.8	0-3.7' Silty SAND, dark reddish brown (5YR 3/4), very fine-grained sand (~70%), poorly graded, subangular to subrounded, very loose, moist to wet, HCl slight	SM	
		0.3/0.6	3.7-4.3' SAND w/ minor silt, yellowish red (5YR 5/6), very fine- to fine-grained sand, poorly graded, subangular to subrounded, very loose, moist, HCl none	SP/ SM	
5			Total depth of boring 4.3' bgs (refusal)		
10					

Note(s):

Log of Soil Boring GP-47B

Project Name: Denison Nitrate Investigation White Mesa Mill, Blanding, Utah	Date/Time Started : 06/08/11 Date/Time Completed : 06/08/11 Drilling Method : Geoprobe Sampling Method : Continuous Dual Tube Drilling Co./Driller : Earth Worx
Project #: DENMC.C002.000	Driller : L. Trujillo Depth to Water : NA Logged by : E. Muller

Sample Interval Description
- Soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 2.6	0-4.7' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand (~80%), poorly graded, subangular to subrounded, very loose to loose, moist to wet, HCl none, roots 0-2.5' bgs	SM	
		0.7/0.7			
5			Total depth of boring 4.7' bgs (refusal)		
10					

Note(s):

Log of Soil Boring GP-48B

Project Name: Denison Nitrate Investigation, White Mesa Mill, Blanding, Utah			
Date/Time Started	: 06/08/11	Driller	: L. Trujillo
Date/Time Completed	: 06/08/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: E. Muller
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Project #: DENMC.C002.000

Sample Interval Description
- Soil sample submitted for laboratory analysis (hatched)
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0			0-2.0' Silty SAND, yellowish red (5YR 5/6), very fine-grained sand (~70%), poorly graded, subangular to subrounded, very loose, dry, HCl none, roots 0-1.4' bgs		
1	(1.0-2.0 soil sample)	2.3/		SM	
2			2.0-2.3' SAND w/ minor Silt, light gray (10YR 7/2), very fine- to fine-grained sand, poorly graded, subangular to subrounded, very loose, dry, HCl strong	SP/SM	
3			Total depth of boring 2.3' bgs (refusal)		
4					
5					

Note(s):

Log of Soil Boring GP-01C

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/19/11	Driller	: L. Trujillo
Date/Time Completed	: 05/19/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample
- Field test sample collected; not submitted to lab (1)
- Field test sample submitted for laboratory analysis
- Duplicate soil sample not submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		3.5/ 2.8	0-3.1' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl none, trace white mottled HCl strong	SM	
			3.1-3.5' Sandstone, pink (5YR 7/3), very fine- to fine-grained sand, dense, dry, HCl medium to strong		
			Total depth of boring 3.5' bgs (refusal)		
5					
10					

Note(s):
1. Field test soil sample not submitted to laboratory due to no detectable results during test kit analysis.

Log of Soil Boring GP-02C

Project Name: Denison Nitrate Investigation White Mesa Mill, Blanding, Utah	Date/Time Started : 05/19/11 Date/Time Completed : 05/19/11 Drilling Method : Geoprobe Sampling Method : Continuous Dual Tube Drilling Co./Driller : Earth Worx
Project #: DENMC.C002.000	Driller : L. Trujillo Depth to Water : NA Logged by : J. Reed

Sample Interval Description
- Field test soil sample collected; not submitted to lab (1)
- Field test soil sample submitted for laboratory analysis
- Duplicate soil sample not submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		2.7/ 2.7	0-2.3' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl strong 2.3-2.7' Sandstone, brownish yellow (10YR 6/6), very fine- to fine-grained sand, poorly graded, loose to dense, dry, subangular to subrounded, HCl none	SM	
			Total depth of boring 2.7' bgs (refusal)		
5					
10					

Note(s):
1. Field test soil sample not submitted to laboratory due to no detectable results during test kit analysis.

07-28-2011 S:\Projects\BoreLogs\Denison\GP-02C.bor

Log of Soil Boring GP-03C

Project Name: Denison Nitrate Investigation White Mesa Mill, Blanding, Utah	Date/Time Started : 05/19/11 Date/Time Completed : 05/19/11 Drilling Method : Geoprobe Sampling Method : Continuous Dual Tube Drilling Co./Driller : Earth Worx
Project #: DENMC.C002.000	Driller : L. Trujillo Depth to Water : NA Logged by : J. Reed

Sample Interval Description
- Field test soil sample collected; not submitted to lab (1)
- Field test soil sample submitted for laboratory analysis
- Duplicate soil sample submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 2.8	0-4.0' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl none	SM	
			4.0-5.4' Silty SAND, pink (5YR 7/4), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, trace fine sand, HCl medium to strong, white mottling w/ HCl strong		
5		2.6/ 2.7	5.4-6.6' Sandstone, light brown gray (10YR 6/2), very fine- to fine-grained sand, loose to dense, dry, HCl none to weak, subangular to subrounded		
			Total depth of boring 6.6' bgs (refusal)		
10					

Note(s):
1. Field test soil sample not submitted to laboratory due to no detectable results during test kit analysis.

Log of Soil Boring GP-04C

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/19/11	Driller	: L. Trujillo
Date/Time Completed	: 05/19/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Field test soil sample collected; not submitted to lab (1)
- Field test soil sample submitted for laboratory analysis
- Duplicate soil sample not submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0–5		4.0/ 3.3; 1.5/ 1.7	0-5.1' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl none, trace white mottling w/ HCl strong, roots at top	SM	
10			Total depth of boring 5.1' bgs (refusal)		

Note(s):
1. Field test soil sample not submitted to laboratory due to no detectable results during test kit analysis.

07-28-2011 S:\Projects\BoreLogs\Denison\GP-04C.bor

Log of Soil Boring GP-05C

INTERA

Project Name: Denison Nitrate Investigation White Mesa Mill, Blanding, Utah		
Date/Time Started	: 05/19/11	Driller : L. Trujillo
Date/Time Completed	: 05/19/11	Depth to Water : NA
Drilling Method	: Geoprobe	Logged by : J. Reed
Sampling Method	: Continuous Dual Tube	
Drilling Co./Driller	: Earth Worx	

Project #: DENMC.C002.000

Sample Interval Description
- Field test soil sample collected; not submitted to lab (1)
- Field test soil sample submitted for laboratory analysis
- Duplicate soil sample not submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.6	0-4.0' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose, dry, HCl none, trace white mottling w/ HCl strong	SM	
			Total depth of boring 4.0' bgs (refusal)		
5					
10					

Note(s):
1. Field test soil sample not submitted to laboratory due to no detectable results during test kit analysis.

07-28-2011 S:\Projects\BoreLogs\Denison\GP-05C.bor

Log of Soil Boring GP-06C

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/19/11	Driller	: L. Trujillo
Date/Time Completed	: 05/19/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

Sample Interval Description
- Field test soil sample collected; not submitted to lab (1)
- Field test soil sample submitted for laboratory analysis
- Duplicate soil sample not submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.4	0-4.4' Silty SAND, yellowish red (5YR 4/6), very fine-grained sand, silt, poorly graded, loose to medium dense, dry, HCl none to strong, some white mottling w/ HCl strong 3.2-4.4' bgs	SM	
5		1.6/ 1.7	4.4-4.9' Silty SAND, pink (5YR 7/4), very fine-grained sand, silt, poorly graded, loose to medium dense, HCl strong, trace fine sand 4.9-5.6' Rock fragments, white, HCl none, very fine grained		
			Total depth of boring 5.6' bgs (refusal)		
10					

Note(s):
1. Field test soil sample not submitted to laboratory due to no detectable results during test kit analysis.

Log of Soil Boring GP-07C

Project Name:
Denison Nitrate Investigation
White Mesa Mill, Blanding, Utah

Project #: DENMC.C002.000

Date/Time Started	: 05/18/11	Driller	: L. Trujillo
Date/Time Completed	: 05/18/11	Depth to Water	: NA
Drilling Method	: Geoprobe	Logged by	: J. Reed
Sampling Method	: Continuous Dual Tube		
Drilling Co./Driller	: Earth Worx		

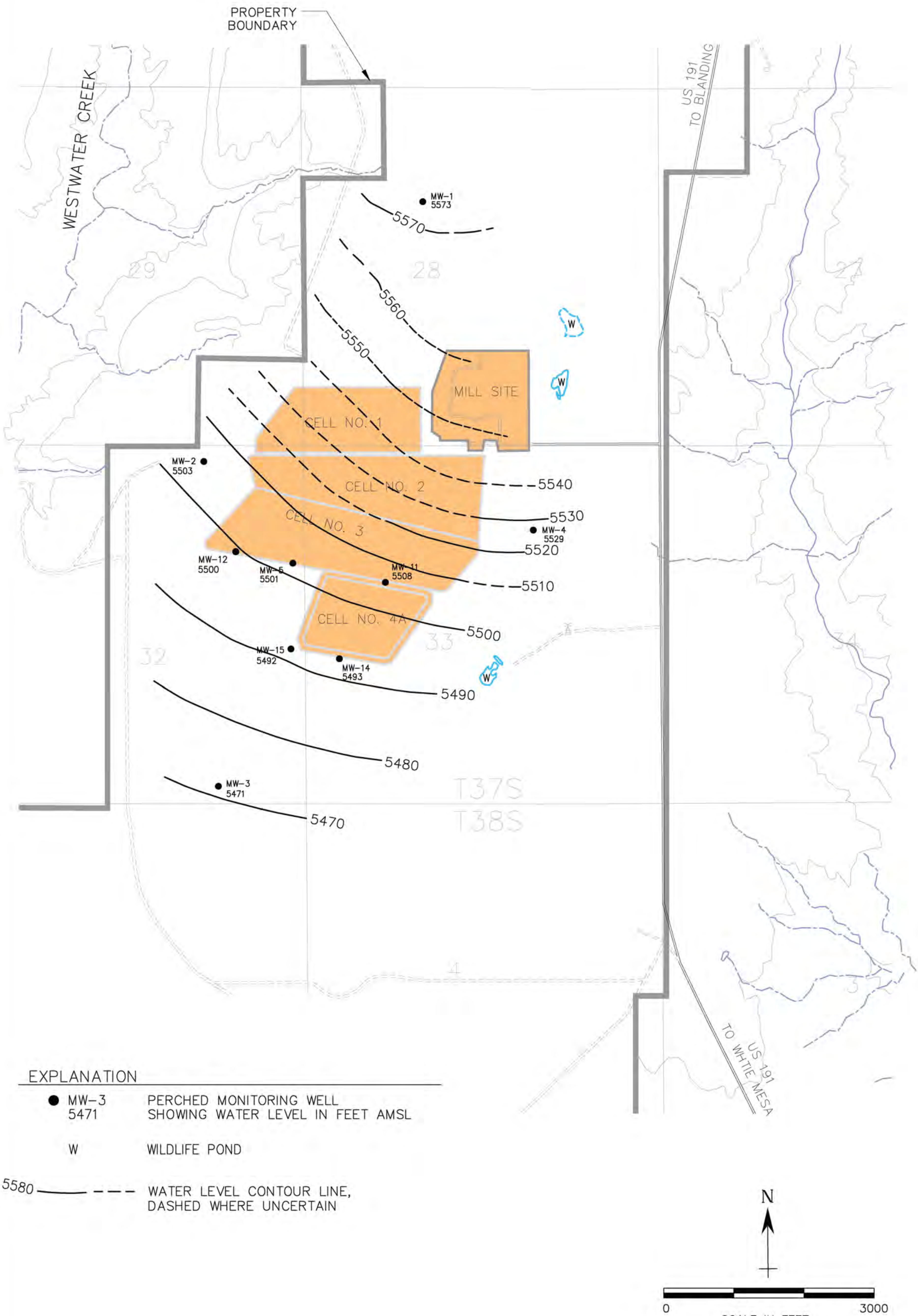
Sample Interval Description
- Field test soil sample collected; not submitted to lab (1)
- Field test soil sample submitted for laboratory analysis
- Duplicate soil sample not submitted for laboratory analysis

Depth in Feet	Sample Interval	Pen./Rec. (feet)	DESCRIPTION	USCS	GRAPHIC
0		4.0/ 3.2	0-1.5' Sandy Clayey SILT, reddish brown (5YR 4/4), very fine-grained sand, medium stiff, dry to moist, cohesive, HCl none	ML	
			1.5-1.7' CLAY, dark red brown (5YR 3/4), stiff, moist, medium plastic	CL	
			1.7-4.9' Sandy SILT/Silty SAND, reddish brown (5YR 4/4), very fine-grained sand, silt, medium stiff/medium dense, slightly moist to moist, trace clay (cohesive), trace fine sand, HCl none to weak, trace white mottling at 2.5' bgs, little more sand or more silt	ML/ SM	
5		2.1/ 2.1	4.9-6.1' Silty SAND/SAND, brownish yellow (10YR 6/4), very fine- to fine-grained sand, silt (varying amounts), medium dense, slightly moist, trace medium sand, slightly cohesive, HCl none, little iron stained	SM/ SP	
			Total depth of boring 6.1' bgs (refusal)		
10					

Note(s):
1. Field test soil sample not submitted to laboratory due to no detectable results during test kit analysis.

APPENDIX D

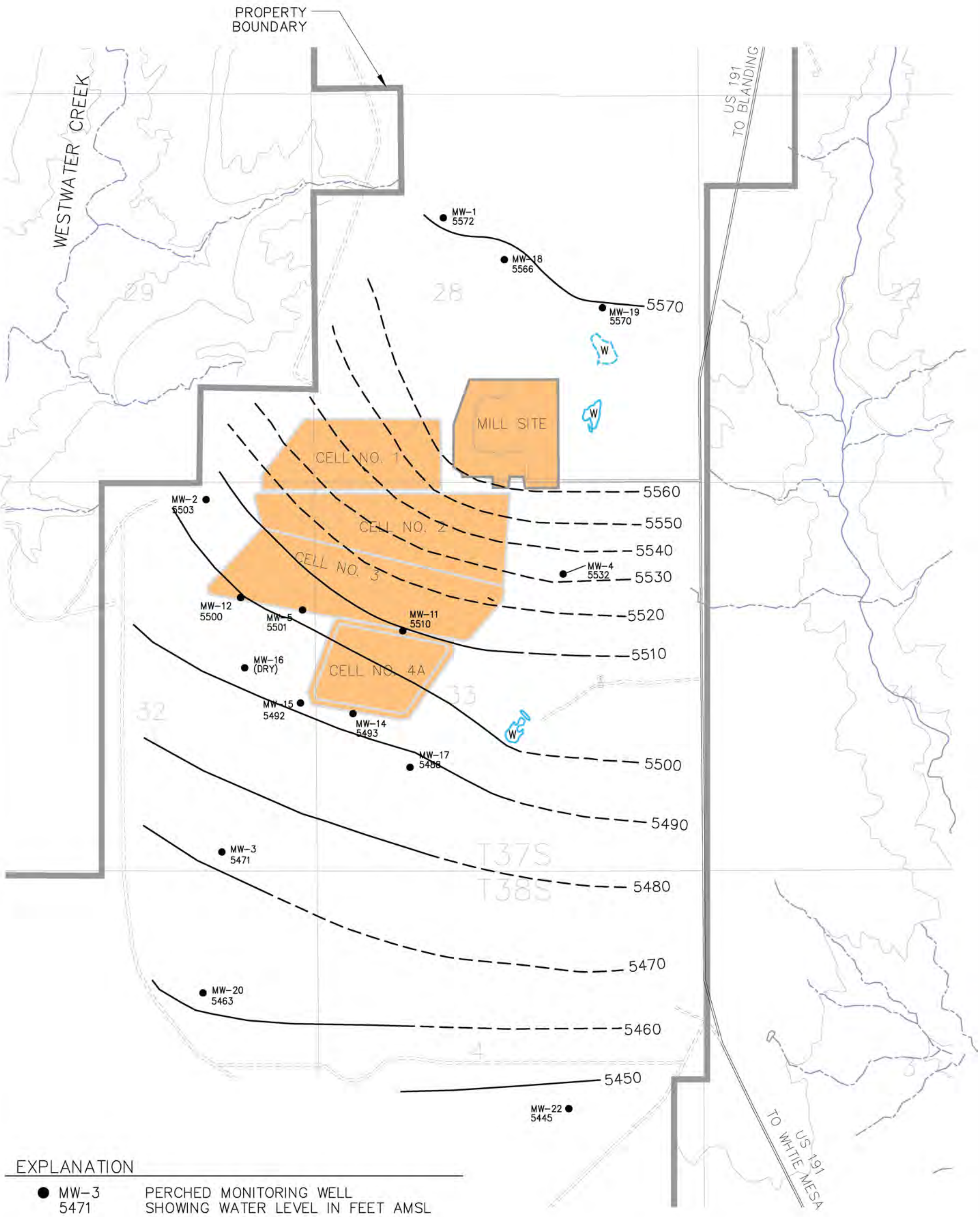
HISTORIC WATER LEVEL MAPS
(SEEP AND SPRING ELEVATIONS NOT CONSIDERED IN CONTOURING)



HYDRO GEO CHEM, INC.

PERCHED WATER LEVELS
AUGUST 1990

Approved:	Date:	Author:	Date:	File Name:	Figure:
SS	06/22/07			71800086	D.1



EXPLANATION

● MW-3 5471	PERCHED MONITORING WELL SHOWING WATER LEVEL IN FEET AMSL
W	WILDLIFE POND
5580 ——— — —	WATER LEVEL CONTOUR LINE, DASHED WHERE UNCERTAIN

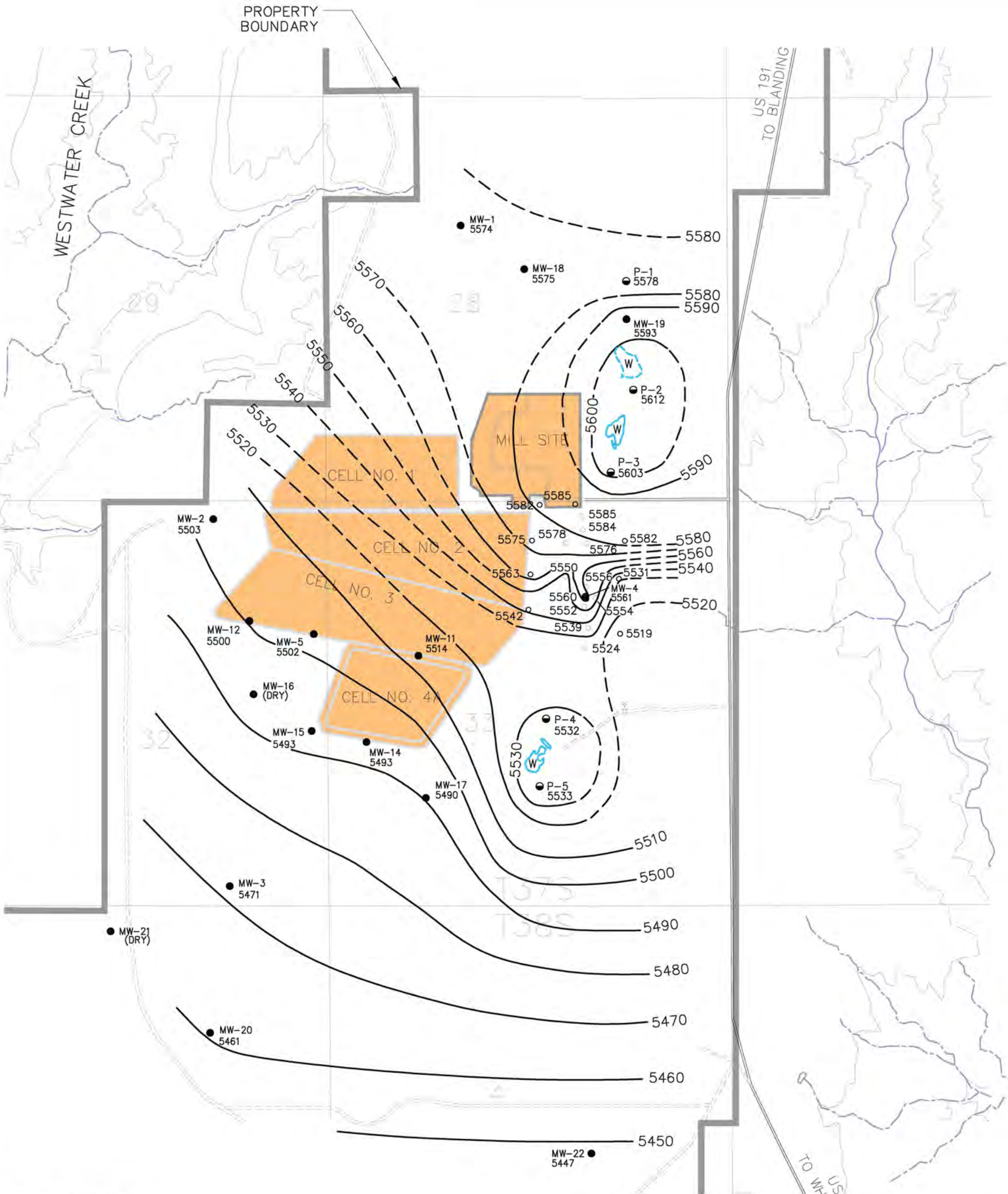
N

0 — 3000
SCALE IN FEET

HYDRO GEO CHEM, INC.

PERCHED WATER LEVELS
AUGUST 1994

Approved	Date	Revised	Date	Reference:	FIG:
SS	06/2/07			71800070	D.2



EXPLANATION

● MW-11 5514 — PERCHED MONITORING WELL SHOWING WATER LEVEL IN FEET AMSL

5524 — TEMPORARY PERCHED MONITORING WELL SHOWING WATER LEVEL IN FEET AMSL

P-5 5533 — PIEZOMETER SHOWING WATER LEVEL IN FEET AMSL

5580 — WATER LEVEL CONTOUR LINE, DASHED WHERE UNCERTAIN

W — WILDLIFE POND

NOTE: WATER LEVELS FOR PIEZOMETERS ARE FROM AUGUST, 2002

N

0 — 3000
SCALE IN FEET

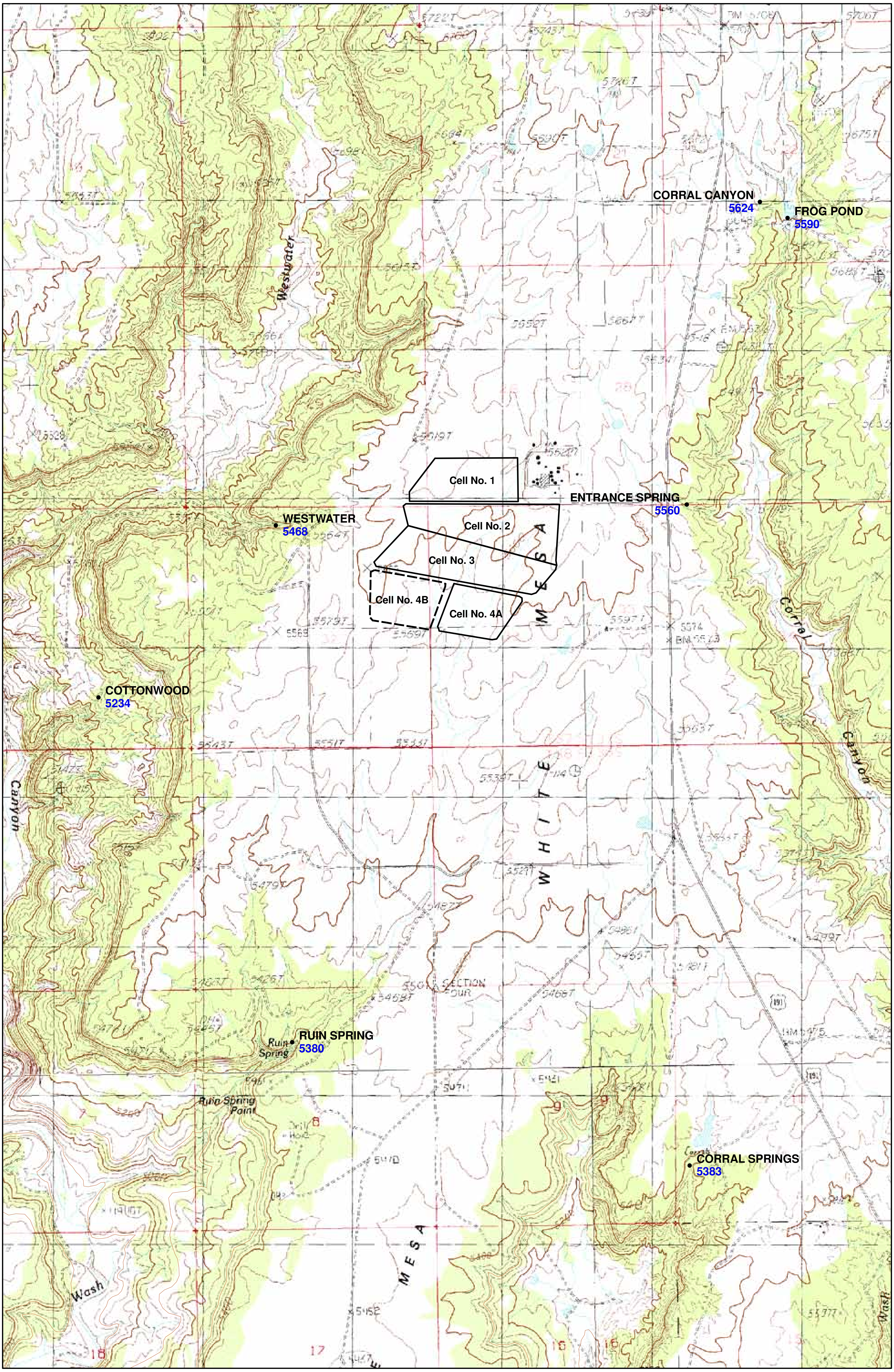
HYDRO GEO CHEM, INC.

PERCHED WATER LEVELS
SEPTEMBER 2002

Approved	Date	Revised	Date	Reference:	FIG:
SS	06/22/07			71800088	D.3

APPENDIX E

TOPOGRAPHIC AND GEOLOGIC MAPS



0.5 0.25 0 0.5 1 Mile

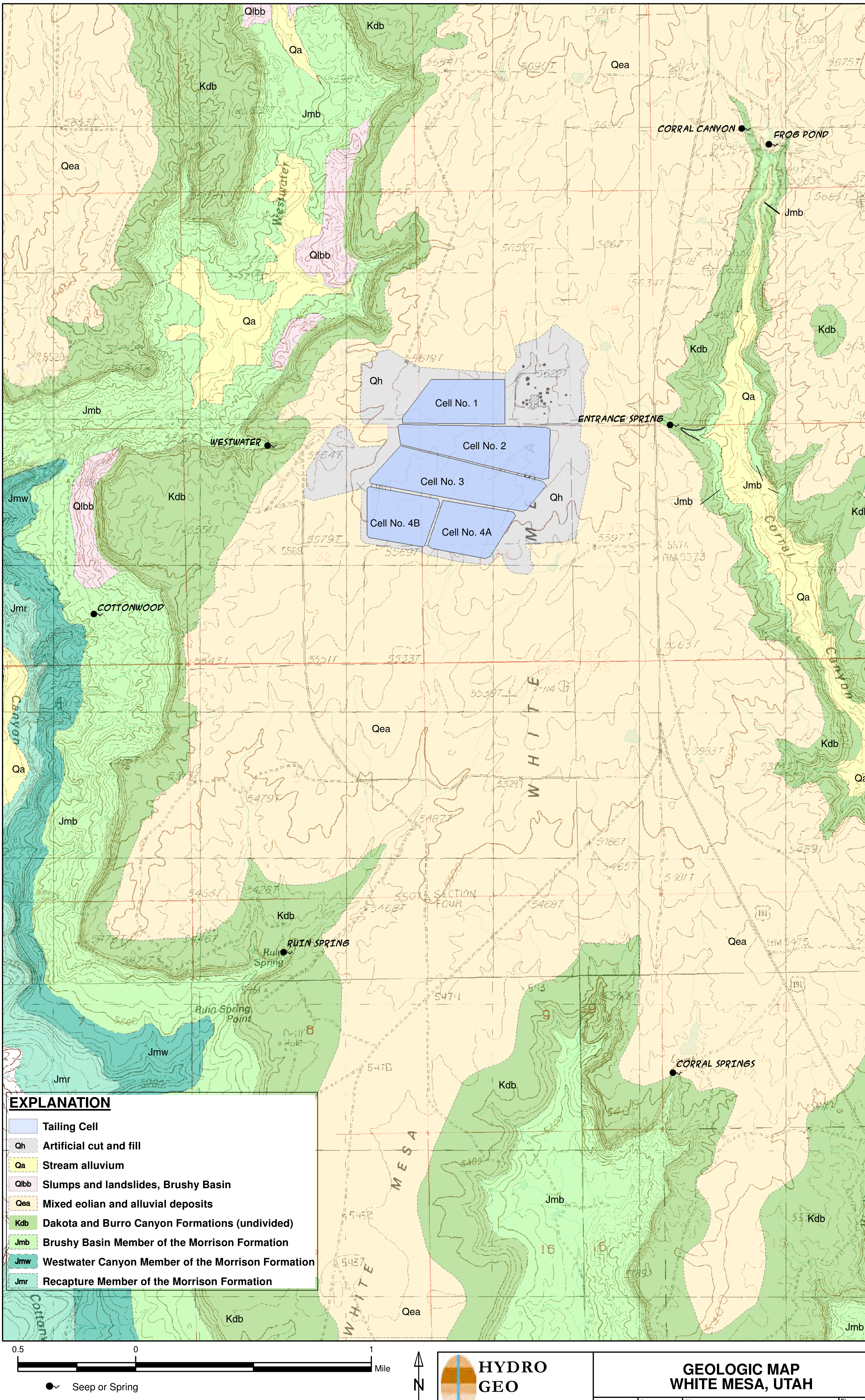
● WESTWATER 5468 Seep or Spring
Elevation (feet) above mean sea level

NORTH

HYDRO GEO CHEM, INC.

SEEPS AND SPRINGS ON USGS TOPOGRAPHIC BASE WHITE MESA

Approved	Date	Author	Date	File Name	Figure
SJS	09/17/10	DRS	07/16/10	7180002G	E.1



HYDRO GEO CHEM, INC.

GEOLOGIC MAP
WHITE MESA, UTAH

Approved	Date	File	Figure
SJS	12/28/11	K:\718000\GIS\Geology	E.2

Geological Map of the Blanding Area, San Juan County, Utah (modified from Haynes et al., 1962; Dames & Moore, 1978 and Kirby, 2008)
Base Map Prepared from Portions of the Blanding South, Black Mesa Butte, Big Bench and No Mans Land U.S.G.S. 7.5' Quadrangles.

APPENDIX C

ANNUAL WIND ROSE DIAGRAMS (2013-2017)

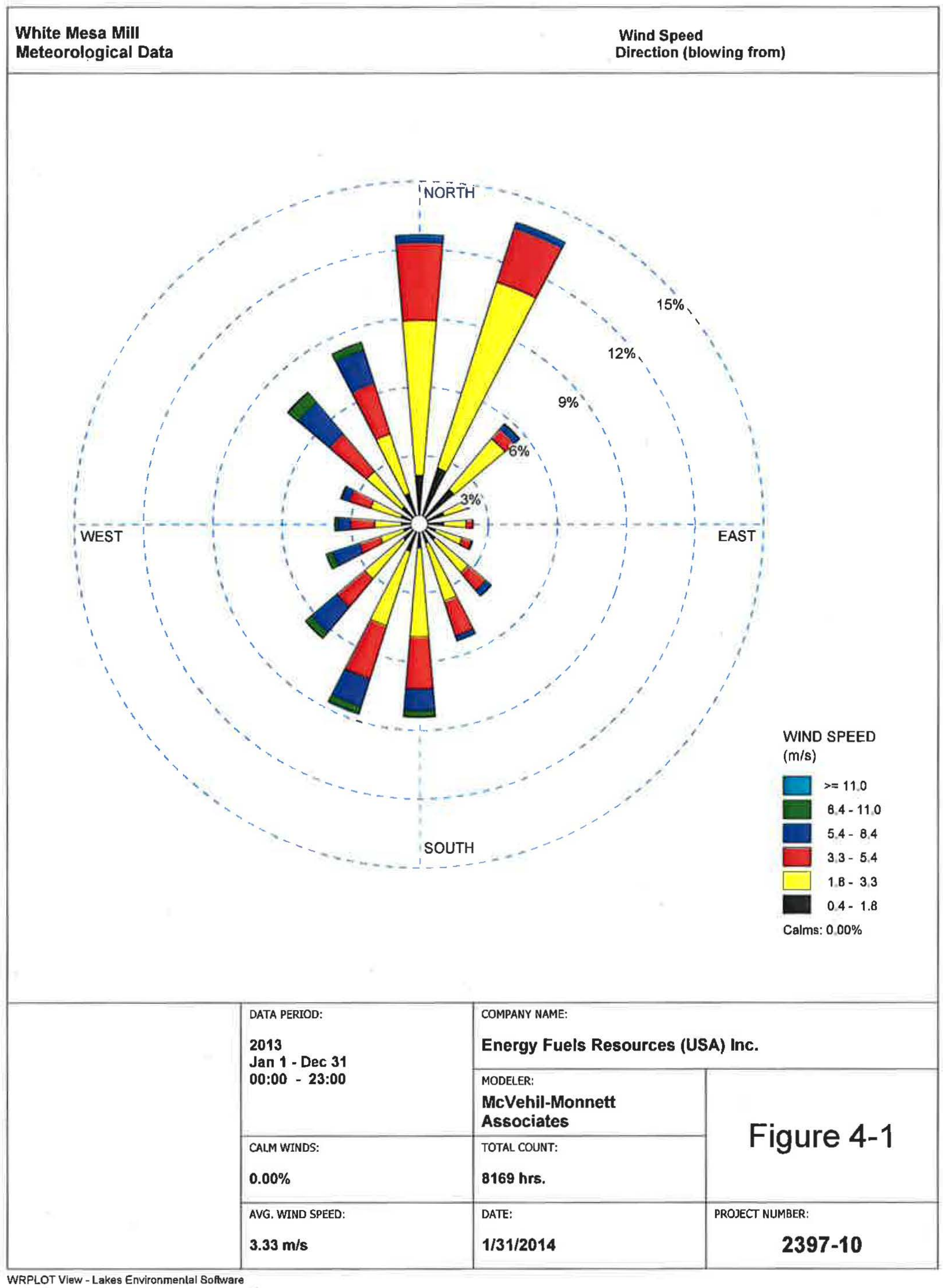


Figure 4-1 January – December 2013 Wind Rose

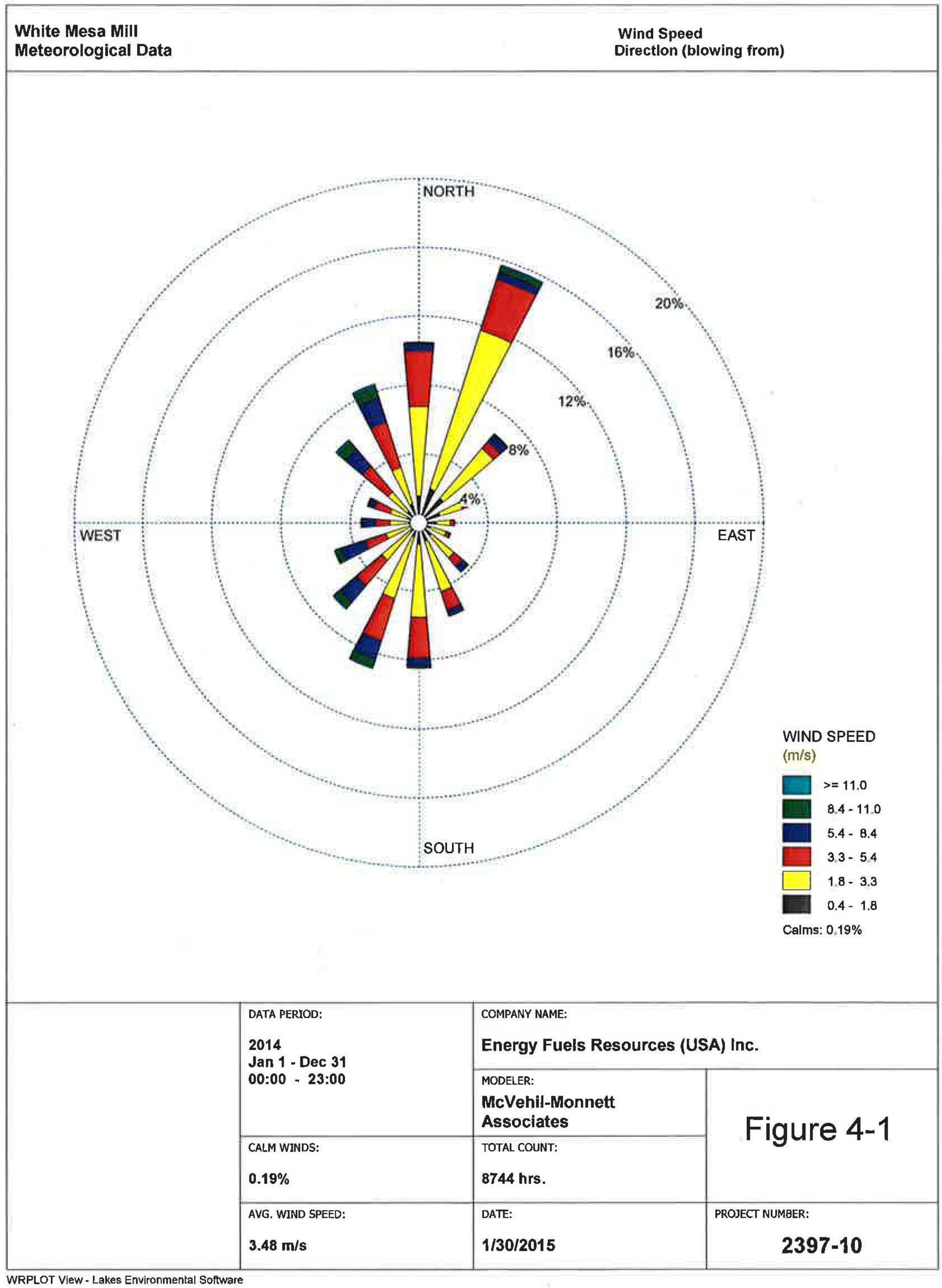


Figure 4-1 January – December 2014 Wind Rose

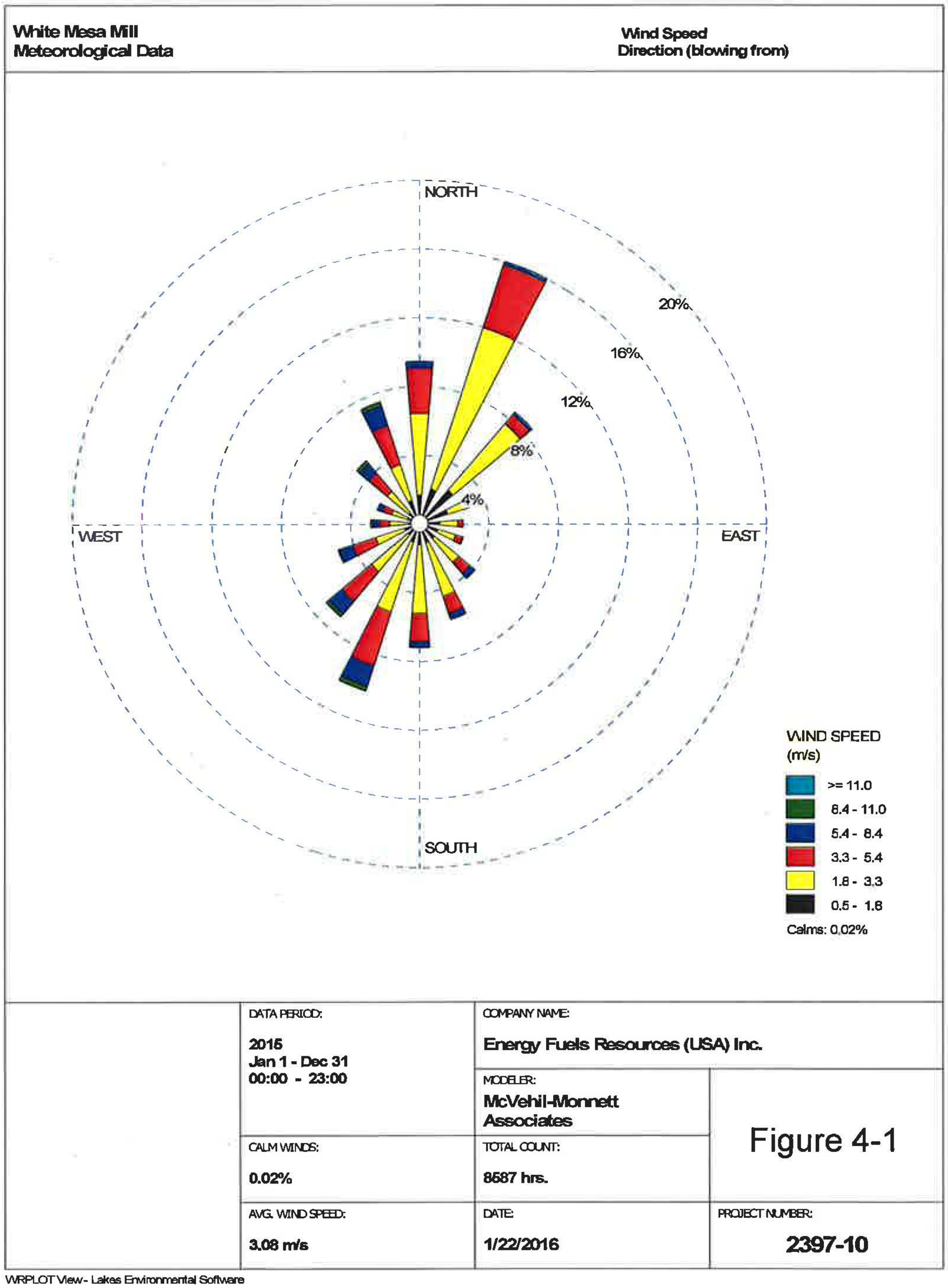


Figure 4-1 January – December 2015 Wind Rose

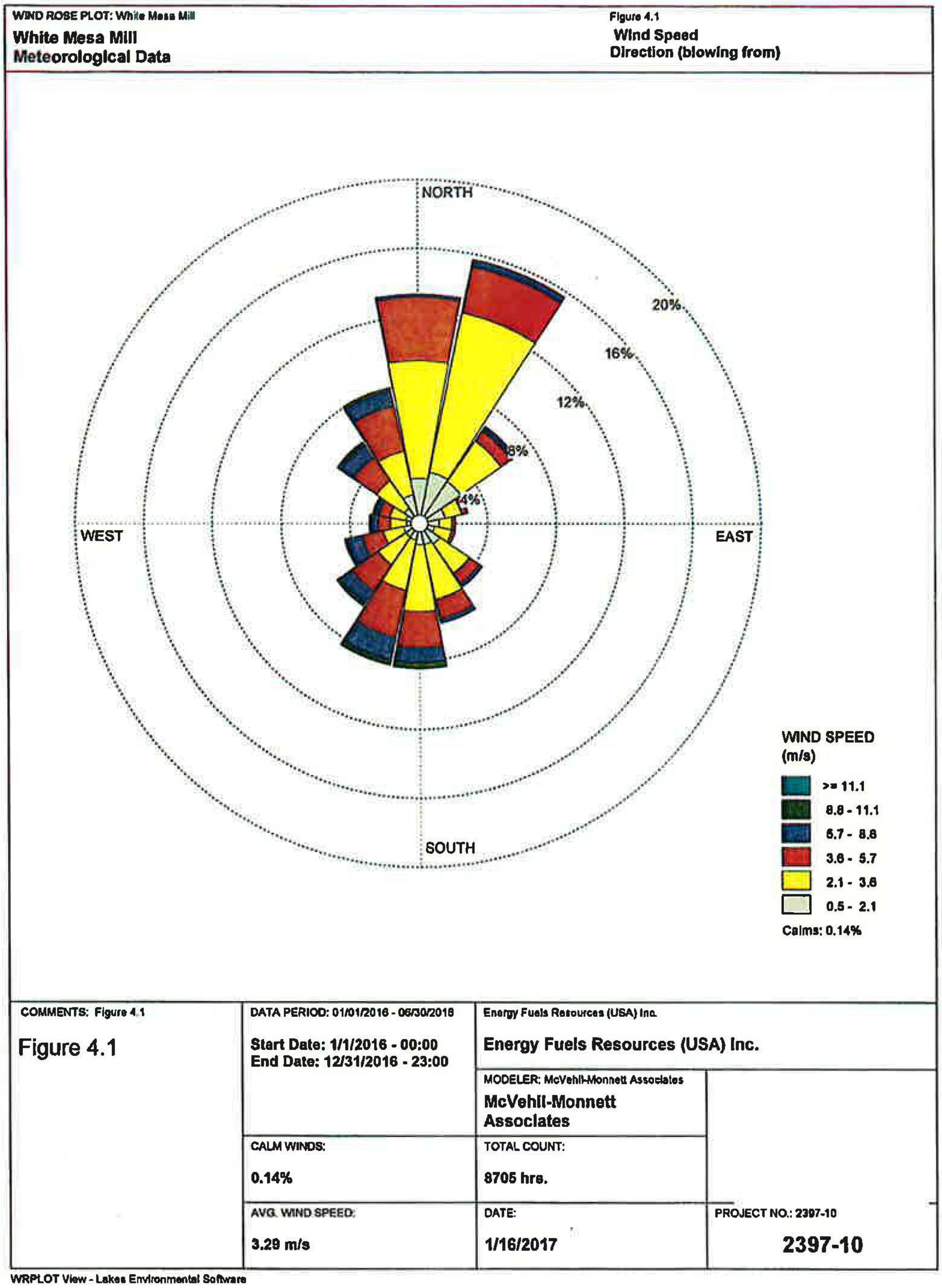


Figure 4-1 January – December 2016 Wind Rose

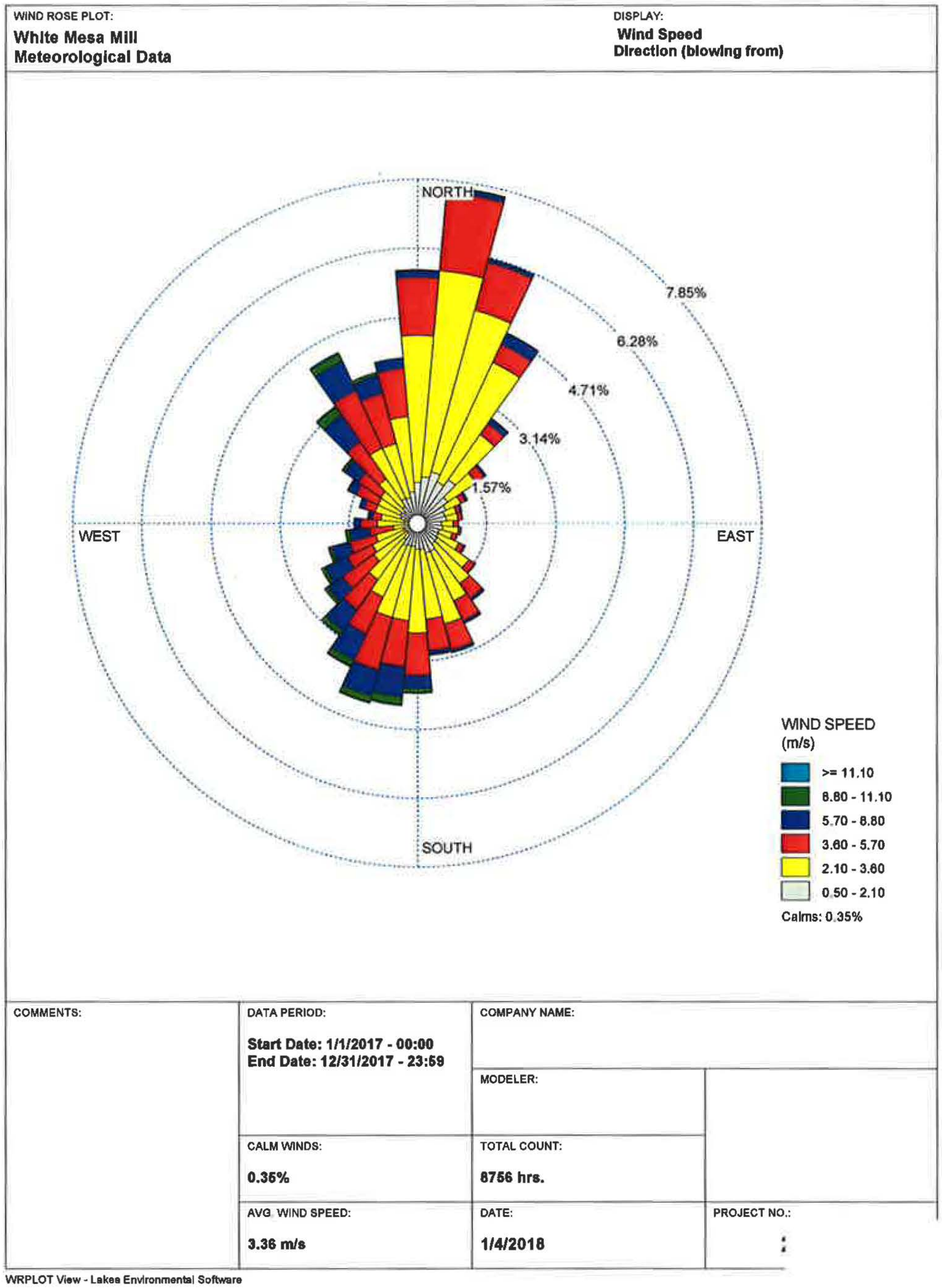


Figure 4-1 January – December 2017 Wind Rose

APPENDIX D

CELLS 5A & 5B DESIGN REPORT

[SEE SEPARATE BINDER]

Prepared for

Energy Fuels Resources (USA), Inc.
6425 S. Highway 191
P.O. Box 809
Blanding, UT 84511

CELLS 5A & 5B DESIGN REPORT

WHITE MESA MILL
BLANDING, UTAH

Prepared by

Geosyntec consultants

engineers | scientists | innovators

16644 West Bernardo Drive, Suite 301
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Project Number SC0634A

July 2018

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1. INTRODUCTION

This report presents the results of design analyses performed in support of the Cells 5A and 5B construction at the White Mesa Mill Facility in Blanding, Utah (site). The San Diego office of Geosyntec Consultants, Inc. (Geosyntec) prepared this report for Energy Fuels Resources (USA), Inc. (EF). This report was prepared by Mr. Jay Griffin and reviewed by Ms. Rebecca Oliver, both of Geosyntec. Mr. Gregory Corcoran, P.E. of Geosyntec was in responsible charge and provided senior peer review of the work presented herein in accordance with the internal peer review policy of the firm.

1.1 Objective

The objective of this report is to present the components of Cells 5A and 5B, including two alternative liner systems: Option A – Triple Liner and Option B- Double Liner with Geosynthetic Clay Liner (GCL). EF will decide which Option to construct and notify Utah Division of Waste Management and Radiation Control (UDWMRC) at least 30 days prior to starting construction of the selected Option liner system. This report demonstrates that the proposed Cell 5A and 5B designs and both liner system options comply with the applicable regulatory standards for the State of Utah, the United States Nuclear Regulatory Commission, and the Federal Environmental Protection Agency (USEPA). In particular, the designs are in accordance with the Utah Administrative Code (UAC) R317-6, and the Best Available Technology requirements mandated by Part I.D. of existing site Ground Water Discharge Permit No. UGW370004.

This report contains the design and permitting information for both Options including Construction Drawings (Appendix A-1 and A-2 for Options A and B, respectively), Construction Quality Assurance (CQA) Plan (Appendix B), Technical Specifications (Appendix C), Design Calculations (Appendix D), and supporting boring logs and geotechnical laboratory results (Appendix E).

1.2 Background

Current site operations utilize Cells 1, and 4B for process liquids evaporation and Cells 3 and 4A for disposal of tailings and by-products from the processing operations at the site. Cells 4A and 4B are adjacent to the proposed 5A and 5B cells. Cells 5A and 5B will initially be used for evaporation of process liquids and as needed thereafter for final storage of solids contained in the tailings and by-products from processing operations at the site. Cell 5A will be constructed first and Cell 5B will be constructed in the future.

1.3 Report Organization

The remainder of this design report is organized into the following sections:

- Section 2, *Background and Site Conditions*, presents general information on the site and background information on the existing conditions at Cells 5A and 5B.
- Section 3, *Design*, presents the design for Cells 5A and 5B.
- Section 4, *Summary and Conclusions*, presents the summary, conclusions, and limitations of this technical design report.

As described previously, the Cell 5A and 5B permit documents include Construction Drawings (Appendix A), a Construction Quality Assurance (CQA) Plan (Appendix B), Technical Specifications (Appendix C), engineering design calculations (Appendix D), and seismic refraction data, trench logs, and geotechnical laboratory data (Appendix E).

2. BACKGROUND AND SITE CONDITIONS

2.1 Site Location

The location of the site is shown on Sheet 1 of the Construction Drawings (Appendix A-1 and A-2). The site is located approximately 6 miles south of Blanding, Utah on Highway 191. Per the Universal Transverse Mercator (UTM) Coordinate System, the site is located at 4,159,100 meters Northing and 634,400 meters Easting.

The Mill is located on a parcel of fee land, State of Utah lease property and associated mill site claims, covering approximately 5,415 acres. The site mill operations are limited to approximately 50 acres located directly east of Cell 1. The existing tailings disposal Cells (Cells 1 through 4B) are approximately 454 acres. Cells 5A and 5B are located south of existing cells 4A and 4B. The site plan is shown on Sheet 2 of the Construction Drawings (Appendix A-1 and A-2).

2.2 Climatology

The climate of southeastern Utah is classified as dry to arid. Although varying somewhat with elevation and terrain, the climate in the vicinity of the site can be considered as semi-arid with normal precipitation of about 13.4 in (WRCC, 2005). Most precipitation is in the form of rain, with snowfall accounting for about 30 percent of the annual precipitation total. There are two separate rainfall seasons in the region, the first in late summer and early autumn (August to October) and the second during the winter months (December to March).

The average temperature in Blanding ranges from approximately 30 degrees Fahrenheit (ºF) in January to approximately 76ºF in July. Average minimum temperatures are approximately 18ºF in January and average maximum temperatures are approximately 91ºF in July (City-Data.com, 2007).

The mean annual relative humidity is about 44 percent and is normally highest in January and lowest in July. The average annual Class I pan evaporation rate is 86 inches (WRCC, 2007), with the largest evaporation occurring in July. Values of pan coefficients range from 60 percent to 81 percent. The annual lake evaporation rate for the site is 47.6 inches and the net evaporation rate is 34.2 inches per year.

2.3 Topography

The existing topography within the Cells 5A and 5B area consists of a gently sloping grade (approximately 2 percent) from the northwestern portion of Cell 5A to the southwestern portion of Cell 5B and from the northeastern portion of Cell 5B to the southwestern portion of Cell 5B. Existing Cell 4A and 4B slopes within the proposed Cell 5A and 5B area are inclined at a slope of approximately 3 horizontal : 1 vertical (3H:1V).

2.4 Existing Soil Conditions

2.4.1 Surface Conditions

Currently, the proposed 5A and 5B Cells are undeveloped and covered by native low grass and shrub vegetation. The site is bordered to the north by the existing Cells 4A and 4B and to the south, east, and west by undeveloped lands.

The existing ground surface within the area of the proposed Cell 5A slopes gently from northwest to south-southeast from respective elevations of approximately 5600 feet to 5554 feet, above Mean Sea Level (MSL). The existing ground surface within the proposed Cell 5B area gently slopes from northeast to southwest from respective elevation of approximately 5590 feet to 5550 feet above MSL.

2.4.2 Soil Berms

Soil berms exist on the northern perimeters of the proposed Cells 5A and 5B. These berms were constructed previously of engineered fill with approximately 3H:1V side slopes.

2.4.3 Subsurface Conditions

Geosyntec performed a geotechnical investigation within the proposed limits of Cells 5A and 5B (Figure 1). The geotechnical investigation consisted of a site reconnaissance, seismic refraction surveys lines, test pit excavation and observation, soil sampling, and geotechnical laboratory analysis of soil samples collected.

Soils encountered during soil sampling and test pit excavation and observation were consistent with formations in Southern Utah. Within the limits of the explorations, the site is underlain by surficial windblown loess and eolian deposits and variably weathered deposits of the Dakota Sandstone.

Loess and eolian deposits were encountered at the ground surface across the site extending to approximate depths of 1 to 7 feet. The deposit is generally thickest along the western portion of the site and thins to the east and southeast, with locally thicker deposits in between. The loess and eolian deposits are generally homogeneous across the site consisting of firm to stiff, yellowish red sandy clay (Unified Soil Classification System Classification CL). Test pit logs and geotechnical laboratory results are presented in Appendix E.

The Dakota Sandstone underlies the surficial deposits at depth across the entire site area. The deposit generally exhibits a weathering rind approximately 0 to 7.5 feet thick consisting of dense to very dense, pale yellow to pink, silty fine sandstone with irregular zones of caliche accumulation. The unweathered Dakota Sandstone is encountered at approximately 1 to 11 feet below the ground surface. The deposit generally consists of very dense, very pale brown to white, fine grained sandstone with little silt.

2.5 Surface Water

Surface water at the facility is diverted around the Cells, including the proposed Cells 5A and 5B. Surface water run-on into Cells 5A and 5B is primarily limited to direct precipitation.

The site has implemented a Storm Water Best Management Practices Plan in accordance with the facility permit. Site construction activities will be performed in accordance with the site Storm Water Best Management Practices Plan.

2.6 Groundwater

Groundwater is located at a depth of approximately 50 to 80 feet at the site. Groundwater monitoring wells DR-12 and DR-13 will be abandoned during construction of this project. Groundwater monitoring wells MW-14, MW-15, MW-17, MW-33, MW-34, MW-37, and DR-11 will be protected in place and raised as necessary.

2.7 Tailings

Cells 5A and 5B will accept process liquids, tailings, and by-products associated with onsite processing operations for both conventional ores and alternate feed materials. The liquids are typically highly acidic with a pH generally between 1 and 2. Tailings are generally comprised of ore that is ground to a maximum grain size of approximately 28 Mesh (US #30 Sieve) (0.023 inches (0.6 millimeters)), resulting in a fine sand and silt material.

3. DESIGN

The liner system is designed to provide a Cell for disposal of by-products from the onsite processing operations while protecting the groundwater beneath the site. The liner system is designed to meet the Best Available Technology requirements of the UAC R317-6, which require that the facility be designed to achieve the maximum reduction of a pollutant achievable by available processes and methods taking into account energy, public health, environmental and economic impacts, and other costs. Two liner systems have been proposed for the cells, from top to bottom:

Option A – Triple Liner

- Slimes drain system;
- Primary geomembrane liner;
- Leak detection system;
- Secondary geomembrane liner;
- Leak detection system; and
- Tertiary geomembrane liner.

Option B – Double Liner with Geosynthetic Clay Liner

- Slimes drain system;
- Primary geomembrane liner;
- Leak detection system;
- Secondary geomembrane liner; and
- Geosynthetic Clay Liner (GCL).

These components and related design considerations are discussed below.

3.1 Cell Capacity and Geometry

Cell 5A has been designed to accommodate storage of up to 1,330 acre-feet (2.15 million cubic yards) of tailings with solids storage to within 1.5-feet of the top of the geomembrane liner, and Cell 5B has been designed to accommodate storage of up to 1,360 acre-feet (2.20 million cubic yards) of tailings with solids storage to within 1.5-feet of the top of the geomembrane liner. The lowest elevation in Cell 5A is the sump located in the southeast corner at an elevation of approximately 5,541 feet above MSL, and the lowest elevation in Cell 5B is the sump located in the southwest corner at an elevation of approximately 5,539 feet above MSL.

Interior side slopes of Cell 5A and 5B will be constructed with 2H:1V inclinations with the exception of the northwest and southeast corners of Cell 5A and the northeast and southwest corners of Cell 5B, which will be constructed with 3H:1V slope inclinations. This will require re-grading of the southern berms of Cells 4A and 4B, which currently have exterior side slopes of 3H:1V. The eastern berm of Cell 5A will be constructed with a 2H:1V interior slope and 3H:1V exterior slope. During construction of Cell 5B, the slope will be reduced to 2H:1V. The proposed southern berms of Cell 5A and 5B will have 2H:1V interior slopes and 3H:1V exterior slopes. The eastern berm of Cell 5B will be constructed with 2H:1V interior slopes and 5H:1V exterior slopes. An approximately 25-foot wide berm, containing an unpaved access road, is proposed to surround Cells 5A and 5B. Cell layout is shown on Construction Drawing (Appendix A).

3.2 Slope Stability

Static and pseudostatic slope stability analysis was conducted for the final earthen berms and interim waste/tailings slopes associated with the operation of Cells 5A and 5B. Final slope stability and operational conditions are required to maintain a minimum factor of safety of approximately 1.5 for final berm slope conditions and 1.3 for interim slope conditions based on the proposed design of the cell and its liner system.

Three cross-sections from Cells 5A and 5B were analyzed which represent worst-case conditions in the cells. Each cross-section was modeled for four different loading conditions. These four conditions were static analysis, pseudo-static analysis for seismic loading conditions, interim construction loading, and evaluation of the yield acceleration. Numerous potential failure surfaces were analyzed for each model to evaluate various slip surface geometries and to identify the critical slip surface for each cross-section and condition.

Slope stability analysis of all three cross-sections for the four different loading conditions resulted in factors of safety above 1.5 for final conditions and above 1.3 for interim conditions. A detailed description of the slope stability calculations is presented in Appendix D.

3.3 Earthwork

Earthwork will consist of excavation, blasting, ripping, trenching, hauling, placing, moisture conditioning, backfilling, compacting, and grading. The requirements for earthwork for Cells 5A and 5B construction is provided in Appendix C, Section 02200 of the Technical Specifications.

3.3.1 Excavation

Prior to excavating soils and rock for Cells 5A and 5B, vegetation will be cleared and grubbed and surficial unsuitable materials will be removed. Excavation will proceed with the removal of topsoil and then in-situ soils for placement as fill for the construction of Cells 5A and 5B south berms. Excess soils will be stockpiled to the west of Cell 5A or to the east of Cell 5B in designated stockpile areas (Appendix A).

Rock will be ripped, blasted, or mechanically removed and stockpiled west of Cell 5A or east of Cell 5B, in a separate stockpile from the excess soil stockpile. Rock will be excavated a minimum of 6-inches below final grade and fill will be placed, moisture conditioned, compacted, and graded to provide a surface on which the geosynthetic liner system components will be installed.

Leak detection system and anchor trenches will be excavated as shown on the Construction Drawings (Appendix A).

3.3.2 Fill Placement

Along the southern perimeter of the proposed Cells 5A and 5B, berms will be constructed of fill with 2H:1V inside slopes and 3H:1V outer slopes. During construction of Cell 5A, a berm with 2H:1V inside slopes and interim, 3H:1V outer slopes will be constructed between Cell 5A and future Cell 5B. During construction of Cell 5B, the interior slope of the berm between Cell 5A and Cell 5B will be reduced from 3H:1V to 2H:1V. Along the eastern perimeter of Cell 5A, a berm with 2H:1V inside slopes and 5H:1V outside slopes will be constructed. Berms will be constructed with a top width of 25-feet.

Settlement analyses have been performed to evaluate the potential settlement of the berm and potential associated strain that could develop in the liner system components (Appendix D). The results of the conservative analyses indicate a maximum strain in the liner due to potential differential settlement of 0.002 percent, which is much less than the liner components can tolerate and is therefore acceptable.

Construction materials used for fill will consist of onsite soils placed in lifts resulting in a compacted thickness no greater than 8-inches and compacted to 90 percent of maximum dry density per American Society for Testing and Materials (ASTM) standard D1557 (Modified Proctor) at a moisture content of ±3 percent of optimum. Fill soil used in construction of the berm will consist of onsite soils with maximum particle size of 6-inches.

3.3.3 Subgrade Preparation

Subgrade preparation includes placement, moisture conditioning, compaction, and grading of subgrade soil. The subgrade will consist of a minimum of 6-inches of soil material with a maximum particle size of 3-inches compacted above the rock. Subgrade fill will be placed in loose lifts of no more than 8-inches and compacted to 90 percent of the maximum density at a moisture content of ±3 percent of optimum moisture content, as determined by ASTM D1557. The surface of the subgrade will have protrusions no greater than 0.7-inches. Section 02220 of the Technical Specifications, in Appendix C, provides the requirements for subgrade for Cells 5A and 5B construction.

3.3.4 Anchor Trench

The liner system will be anchored at the top of the slope with an anchor trench. The anchor trench was sized to resist anticipated maximum wind uplift forces, see Anchor Trench Capacity Calculations provided in Appendix D. The anchor trench will be a minimum of 1.5 feet deep and 2 feet wide and filled with compacted soil, as shown on the Construction Drawings (Appendix A). During construction, the contractor will be allowed to construct deeper anchor trenches to allow partial backfilling between subsequent liner component installation to facilitate temporary anchoring of each geosynthetic layer as it is installed. Anchor trench backfill will be placed in lifts of no more than 12-inches and compacted to 90 percent of the maximum density at a moisture content of ±3 percent of optimum moisture content, as determined by ASTM D1557.

3.4 Liner System

Two liner systems are proposed for Cells 5A and 5B: Option A – Triple Liner and Option B – Double Liner with GCL. Option A includes both a primary and secondary leak detection system while Option B includes a primary leak detection system. The liner system for the base of the cells will consist of (from top to bottom):

Option A – Triple Liner

- Slimes Drain System;
- 60-mil smooth high density polyethylene (HDPE) geomembrane (Primary Liner);
- 300-mil geonet;
- 60-mil smooth HDPE geomembrane (Secondary Liner);
- 60-mil HDPE Drain Liner™ geomembrane (Tertiary Liner)[1]; and
- Prepared Subgrade.

Option B – Double Liner with GCL

- Slimes Drain System;
- 60-mil smooth high density polyethylene (HDPE) geomembrane (Primary Liner);
- 300-mil geonet;
- 60-mil smooth HDPE geomembrane (Secondary Liner);
- GCL; and
- Prepared Subgrade.

(Composite Secondary Liner) — applies to: 60-mil smooth HDPE geomembrane (Secondary Liner); GCL; and Prepared Subgrade.

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[1] The 60-mil HDPE Drain Liner™ geomembrane consists of a geomembrane with continuously molded 130-mil HDPE studs (in addition to the 60-mil geomembrane thickness) on one side to create an integrated transmissive layer between the Drain Liner™ and overlying geomembrane.

The liner system for the side slopes of the cells will consist of (from top to bottom):

Option A – Triple Liner	Option B – Double Liner with GCL	
• 60-mil smooth HDPE geomembrane (Primary Liner);	• 60-mil smooth HDPE geomembrane (Primary Liner);	
• 60-mil HDPE Drain Liner™ geomembrane (Secondary Liner);	• 60-mil HDPE Drain Liner™ geomembrane (Secondary Liner);	(Composite Secondary Liner)
• 60-mil HDPE Drain Liner™ geomembrane (Tertiary Liner); and	• GCL; and	
• Prepared Subgrade	• Prepared Subgrade	

Construction materials were selected for chemical resistance, including resistance to acidic and chemical processing solids and liquids from both conventional ores and alternate feed materials, as well as resistance to ultraviolet (UV) degradation. HDPE geomembrane and geonet was selected due to its high resistance to chemical and UV degradation and ability to retain durability in an acidic environment. The chemical resistance lists for the most common HDPE geomembrane manufacturers, AGRU and GSE (now SolmaxGSE) are included in Appendix F (electronic only).

Stability analyses were conducted to evaluate the various slip surface geometries and to identify the critical slip surfaces for three cross-sections with various conditions. The analysis determined the minimum factor of safety of 1.3 for interim conditions and 1.5 for final conditions will be met during and after filling operations. The complete calculation is located in Appendix D.

3.4.1 Slimes Drain System

A slimes drain system will be placed on top of the primary geomembrane liner in the bottom of the cell to facilitate dewatering of the tailings prior to final reclamation of the cell. The slimes drain system will consist of perforated 4-inch diameter schedule 40 polyvinyl chloride (PVC) pipe, concrete sand filled sand bags, drainage aggregate, cushion geotextile, filter geotextile, and strip composite that will provide a means to drain the tailings disposed within Cells 5A and 5B. The slimes drain system is shown on the Construction Drawings (Appendix A).

The slimes drain system is designed to remove the liquids within Cells 5A and 5B in a reasonable time. Based on the calculations presented in Appendix D, the slimes drain is expected to drain the tailings in approximately 5.6 years. A sump pump capable of pumping 147 gallons per minute (gpm) will be required upon start-up of the slimes drain system. The pumping rate is anticipated to decrease with time as the head within Cells 5A and 5B decreases.

The perforated PVC pipe is designed to resist crushing and wall buckling due to the anticipated loading associated with the maximum height of overlying tailings. The design analyses for the pipe are presented in Appendix D, while Appendix C, Section 02616 provides material specifications for the pipe and strip composite and Section 02225 provides material specifications for the drainage aggregate. The strip composite will be comprised of a 1-inch thick by 12-inch wide high density polyethylene, or equivalent acid resistant material, wrapped in a nonwoven polypropylene geotextile. The drainage aggregate will consist of a crushed rock that has a carbonate content loss of no more than 10 percent by weight.

A continuous row of sand bags filled with a concrete sand meeting Utah Department of Transportation (UDOT) standard specifications for Portland Cement Concrete will overlie the strip composite laterals to act as an additional filter layer above the geotextile component of the strip composite. The proposed UDOT concrete sand will be placed in sand bags consisting of woven geotextile capable of allowing liquids to pass. When placed overlying the strip composite, the sand bags will have an approximate length of 18 inches, width of 12 inches, and a height of 3 inches. This results in a sand bag that is approximately 30 to 35 pounds and will provide sufficient coverage over the width and ends of the strip composite to act as an additional filter layer. The UDOT concrete sand will consist of sand that has a carbonate content loss of no more than 10 percent by weight. Alternatively, a woven geotextile may be placed above the strip composite with concrete sand installed above. Following placement of a minimum of 3 inches of sand above the strip composite, the geotextile will be folded over and seamed creating a continuous sand layer above the strip composites.

The cushion geotextile that is to be installed beneath the drainage aggregate surrounding the PVC pipe is designed to protect the underlying primary high density polyethylene (HDPE) geomembrane from puncture due to the drainage aggregate and the anticipated loading associated with the maximum height of overlying tailings and final cover (9-feet of soil). The design analyses for the cushion geotextile are presented in Appendix D, while Appendix C, Section 02771 provides material specifications. Overlying the drainage aggregate and cushion geotextile will be a woven geotextile, as shown on the Construction Drawings (Appendix A), that will serve to separate the tailings and the drainage aggregate.

The Slimes Drain sump will include a side slope riser pipe to allow installation of a submersible pump for manual collection of liquids in the sump. The sump and riser pipes are shown on the Construction Drawings (Appendix A).

3.4.2 Primary Liner Systems

The primary liner will consist of smooth 60-mil HDPE geomembrane. The geomembrane will have a white surface that will limit geomembrane movement and the creation of wrinkles due to temperature variations. The limit of the liner systems (both primary and secondary) and details are shown on the Construction Drawings (Appendix A).

Tension due to wind up lift was analyzed for the 60-mil HDPE geomembrane. Based on the analysis, the geomembrane anchor trench has been sized to accommodate the loading associated with a wind speed of 25 miles per hour and a slope length of approximately 103 feet. The design analyses for the HDPE liner uplift are presented in Appendix D.

The HDPE geomembrane will be constructed in accordance with the current standard of practice for geomembrane liner installation, as outlined in the site Technical Specifications (Appendix C, Section 02770) and the site CQA Plan (Appendix B). Seams will be welded to provide a continuous geomembrane liner. Testing during construction will include both non-destructive and destructive testing, as outlined in the Technical Specifications and CQA Plan. Upon completion of construction, the geomembrane manufacturer will provide a 20-year warranty for the geomembrane.

3.4.3 Primary Leak Detection System (Option A and Option B)

The primary leak detection system (LDS) will underlie the primary liner and is designed to collect potential leakage through the liner and convey the liquid to the sump for manual detection through monitoring of sump levels. The bottom LDS consists of a 300-mil thick geonet above a 60-mil HDPE geomembrane and a network of gravel trenches throughout the bottom of Cells 5A and 5B. The trenches will contain a 4-inch diameter perforated schedule 40 PVC pipe, drainage aggregate, and a cushion geotextile, which will drain to sumps located in the southeast corner of Cell 5A and the southwest corner of Cell 5B. The trenches will aid in rapidly conveying leakage to the LDS sump. On the side slopes, the primary leak detection system consists of a 130-mil Drain Liner™ geomembrane. The LDS is shown on the Construction Drawings (Appendix A).

3.4.3.1 Action Leakage Rate

The Action Leakage Rate (ALR) was calculated for the LDS in accordance with Part 254.302 of the USEPA Code of Federal Regulations. The ALR was evaluated for various scenarios within Cells 5A and 5B. The most conservative approaches were selected and evaluated in the calculation packages included in Appendix D. The ALR was calculated to be 526 gallons per day per acre in the primary LDS. The flow in the primary LDS side slope Drain Liner™ was evaluated against the flow through a defect in the primary geomembrane. The flow in the Drain Liner™ was found to be 4.08×10^{-6} m^3/sec, or 1.6 times greater than the flow through a defect; therefore, the Drain Liner™ will be adequate for leak detection on the side slopes.

The total travel time for liquids entering the geonet LDS layer to travel from the leak to the LDS piping system was estimated to be approximately one day for the primary LDS. Assuming a worst case scenario under which all the primary geomembrane defects are located at the high end of the leakage collection layer slope, the liquid head on the secondary liner does not exceed 13.4 mils (0.0134 in). This value is well below the required maximum limit of 12 inches and the collection layer thickness of 300 mils. The geonet and Drain Liner™ provide sufficient flow rates to accommodate the ALR on the cell bottoms and side slopes, respectively. The complete ALR calculation is located in Appendix D and Sections 02770 and 02773 of Appendix C provides material specifications for the geonet.

3.4.3.2 Perforated Pipe

The perforated PVC pipe is designed to resist crushing and wall buckling due to the anticipated loading associated with the maximum height of overlying tailings. Pipe strength analysis indicated the 4-inch PVC pipe with a maximum allowable deflection of 7.5 percent will have the ability to resist the anticipated maximum load associated with a tailing deposit height of 43 feet and additional cover soil height of 9 feet. The design analysis for the pipe is presented in Appendix D, while Appendix C, Section 02616 provides material specifications for the pipe and Section 02225 provides material specifications for the drainage aggregate.

3.4.3.3 Puncture Protection

The cushion geotextile is designed to protect the underlying secondary HDPE and overlying primary HDPE geomembrane from puncture due to the drainage aggregate and the anticipated loading associated with the maximum height of overlying tailings. Puncture analysis indicated a 16 ounce per square yard (oz./yd^2) cushion geotextile and 1-inch maximum particle size would provide puncture protection for the 60-mil HDPE smooth geomembrane. The design analyses for the cushion geotextile are presented in Appendix D, while Appendix C, Section 02771 provides material specifications.

3.4.3.4 Sump

The LDS sump will include a side slope riser pipe and submersible pump to allow for manual collection of liquids in the LDS sump. The LDS sump and riser pipes are shown on the Construction Drawings (Appendix A).

3.4.4 Secondary Leak Detection System (Option A Only)

The primary purpose of the secondary liner is to provide a flow barrier so that potential leakage through the primary liner will collect on top of the secondary liner then flow through the LDS to the LDS sump for manual collection. The secondary liner also provides an added hydraulic barrier against leakage to the subsurface soils and groundwater. The secondary liner consists of a 60-mil HDPE Drain Liner™ for both the base liner the side slopes.

The secondary LDS will underlie the secondary geomembrane and primary LDS and is designed to collect potential leakage through the secondary liner and convey the liquid to the sump for manual detection through monitoring of sump levels. On the side slopes and bottom of the cells the secondary LDS consists of a 130-mil Drain Liner™ geomembrane. On the bottom of the cells, a network of gravel trenches. Similar to the primary LDS, the trenches will contain a 4-inch diameter perforated schedule 40 PVC pipe, drainage aggregate, and a cushion geotextile, which will drain to sumps located in the southeast corner of Cell 5A and the southwest corner of Cell 5B. The trenches will aid in rapidly conveying leakage to the LDS sump. The LDS is shown on the Construction Drawings (Appendix A-1).

3.4.4.1 Action Leakage Rate

The Action Leakage Rate (ALR) was calculated for the LDS in accordance with Part 254.302 of the USEPA Code of Federal Regulations. The ALR was evaluated for various scenarios within Cells 5A and 5B. The most conservative approaches were selected and evaluated in the calculation packages included in Appendix D. The ALR was calculated to be 15 gallons per day per acre and the total travel time for liquids entering the Drain Liner™ LDS layer to travel from the leak to the LDS piping system was estimated to be approximately 5.1 hours. Assuming a worst case scenario under which all the primary geomembrane defects are located at the high end of the leakage collection layer slope, the liquid head on the secondary liner does not exceed 0.1 mils (0.0001-inches), well below the required maximum limit of 12 inches (1-foot) and the collection layer thickness of 130-mil. The Drain Liner™ provides sufficient flow rate to accommodate the ALR. The complete ALR calculation is located in Appendix D and Section 02770 of Appendix C provides material specifications for the Drain Liner™.

3.4.4.2 Puncture Protection

The tertiary geomembrane resistance to puncture was evaluated for direct contact between the subgrade and tertiary geomembrane. Puncture analysis indicated a maximum subgrade protrusion height of 0.7 inch would not puncture the Drain Liner™ geomembrane. The design analysis is presented in Appendix D.

3.4.4.3 Sump

The secondary LDS sump will include a side slope riser pipe and submersible pump to allow for manual collection of liquids in the secondary LDS sump. The secondary LDS sump and riser pipes are shown on the Construction Drawings (Appendix A-1).

3.4.5 Secondary Composite Liner System (Option B Only)

The primary purpose of the secondary liner is to provide a flow barrier so that potential leakage through the primary liner will collect on top of the secondary liner then flow through the LDS to the LDS sump for manual collection. The secondary liner also provides an added hydraulic barrier against leakage to the subsurface soils and groundwater. The secondary liner consists of a composite liner that includes a 60-mil HDPE geomembrane overlying a GCL.

3.4.5.1 Secondary Geomembrane Liner

The geomembrane component of the secondary liner system will consist of a smooth 60-mil HDPE geomembrane for the base liner and 60-mil HDPE Drain Liner™ for the side slope liner and will meet the same criteria as the primary liner geomembrane (Section 3.4.2). The limit of the liner system (both primary and secondary) and details are shown on the Construction Drawings (Appendix A-2).

3.4.5.2 Secondary GCL Liner

The GCL component of the secondary liner system consists of bentonite sandwiched between two geotextile layers that are subsequently needle-punched together to form a single composite hydraulic barrier material. The GCL is approximately 0.2-inches thick with a hydraulic conductivity on the order of 1×10^{-9} cm per second (cm/s) (Daniel and Scranton, 1996). The GCL will be hydrated to account for the high acidity of the tailings.

Since 1986, GCLs have been increasingly used as an alternative to compacted clay liners (CCLs) on containment projects due to their low cost, ease of construction/placement, and resistance to freeze-thaw and wet-dry cycles. In general, the USEPA and the containment industry accept that GCLs are hydraulically equivalent to a minimum of 2 feet of compacted clay liner consisting of 1×10^{-7} cm/s soil materials.

For the Cell 4A design, and in accordance with Permit no. UGW370004, Geosyntec demonstrated that a secondary composite liner system consisting of a 60-mil HDPE geomembrane overlying a GCL has equivalent or better fluid migration characteristics when compared with a secondary composite liner system consisting of a 60-mil HDPE geomembrane overlying a CCL having a saturated hydraulic conductivity less than 1×10^{-7} cm/s (Geosyntec, 2006). This analysis accounted for the loading conditions and anticipated liquid head on the secondary liner system, the amount of flow through the secondary liner system with CCL was evaluated to be 8.51 times greater than flow through the secondary liner system with GCL for a liquid head of 0.16 inches, which is more than the calculated Cell 5A and 5B liquid head (0.0134 inches). Therefore, in terms of limiting fluid flow through the composite secondary liner system, the secondary liner system containing a GCL performs better than the secondary liner system containing a CCL.

The following site specific conditions must be considered prior to use of a GCL in place of CCL (Koerner and Daniel, 1993):

- Puncture Resistance: While CCLs naturally provide greater puncture resistance than GCLs due to their inherent thickness, proper subgrade preparation and design of the geotextile components of the GCL can result in protection from puncture. The geotextile components of the GCL for Cell 4B are designed to protect the overlying secondary HDPE geomembrane from puncture due to protrusions from the subgrade and the anticipated loading associated with the maximum height of overlying tailings. The puncture protection analysis of the GCL indicated that a 3 oz/yd^2 geotextile and 6 oz/yd^2 geotextile above and below (respectively) the GCL and a maximum subgrade protrusion height of ½-inch will provide puncture protection for the secondary HDPE geomembrane. The design analyses considers a 60-mil geomembrane placed directly on the subgrade which is more conservative than the GCL placed directly on the subgrade and beneath the 60-mil geomembrane. The puncture calculations for the geomembrane on subgrade are presented in Appendix D, while Appendix C, Section 02772 provides material specifications.
- Hydraulic Conductivity: Due to the acidic nature of the fluid to be stored in the cell, Geosyntec conducted hydraulic conductivity testing on hydrated specimens of GCL for the Cell 4A project (Geosyntec 2007). Based on the results, the GCL will be hydrated to a moisture content of 50% during construction.
- Chemical Adsorption Capacity: Due to the thickness of a CCL, the chemical adsorption capacity of a CCL is greater than that of a GCL. However,

adsorption capacity is only relevant in the short term and not considered a parameter for steady-state analyses.

- Stability: The internal strength of a GCL can be significantly lower than that of a CCL, especially at high confinement stresses. This reduced strength can have significant effects on stability, especially at disposal facilities with high waste slopes and the potential for seismic activity. Strength of the GCL and its effects on stability are not a concern at Cells 5A and 5B due to the low confining stresses expected and geometry of the cell. Waste deposits will not be placed above the elevation of the perimeter road. Since no above grade slopes will be present, there are no long term destabilizing forces on the liner system.
- Construction Issues: For the Cells 5A and 5B liner system, GCLs may be considered superior to the CCLs with respect to construction issues. Construction of GCLs is typically much quicker and is more easily placed than a CCL, which requires moisture conditioning and compaction for placement. Further, CQA testing for a GCL is much simpler and less affected by interpretation of field staff than that for a CCL, which requires careful control of material type, moisture conditions, clod size, maximum particle size, lift thickness, etc.
- Physical/Mechanical Issues: Physical and mechanical issues include items such as the effect of freeze/thaw and wetting/drying cycles. CCLs may undergo significant increases in hydraulic conductivity as a result of freeze/thaw. Existing laboratory data suggests that GCLs do not undergo increases in hydraulic conductivity as a result of freeze/thaw. CCLs are also known to form desiccation cracks upon drying which can result in significant increases in hydraulic conductivity. This increase drastically jeopardizes the effectiveness of the CCL as a barrier layer. Available laboratory data on GCLs indicates that upon re-hydration after desiccation, GCLs swell and the cracks developed during drying cycles are 'self-healed'. Due to the arid environment at the site, GCL performance in the Cells 5A and 5B liner system with respect to physical and mechanical issues is expected to be superior to that of a CCL.

Based on review of the above site-specific considerations, a GCL is considered superior to a CCL for use in the secondary composite liner system.

3.5 Splash Pad

Approximately eighteen splash pads will be constructed in Cells 5A and 5B, nine splash pads in each, to allow filling of the cells without damaging the liner system. The splash pads consist of an additional textured geomembrane placed along the side slope of the Cell extending a minimum of 5 feet from the toe of the slope. The geomembrane will protect the underlying liner system from contact with the inlet pipes. A cross section of a typical splash pad is shown on the Construction Drawings (Appendix A). The locations of the splash pads will be finalized in the field during construction, based on site operational needs.

3.6 Emergency Spillway

Emergency spillways will be constructed between Cells 4B and 5A and Cells 5A and 5B. The spillway locations and details are shown on the Construction Drawings (Appendix A).

The spillway between Cells 4B and 5A will be located on the berm separating the two cells in the southeastern portion of Cell 4B and the northeastern portion of Cell 5A and will be constructed during the Cell 5A construction. The spillway will be approximately 5.5 feet deep, sloped at 2% toward Cell 5A, and include 10H:1V approach pads that will allow traffic moving along the top of the berm to pass through the spillway (when dry). The spillway will consist of a 6-inch thick reinforced concrete pad, designed to withstand loadings from truck traffic, see Concrete Calculations provided in Appendix D. The spillway is designed to handle the Probable Maximum Precipitation (PMP) for a 6 hour storm event for the site, see Spillway Calculations provided in Appendix D.

The spillway between Cells 5A and 5B will be located on the berm separating the two cells in the southeastern portion of Cell 5A and the southwestern portion of Cell 5B and will be constructed during the Cell 5B construction. The spillway will be approximately 5.8 feet deep, sloped at 2% toward Cell 5B, and include 10H:1V approach pads that will allow traffic moving along the top of the berm to pass through the spillway (when dry). The spillway will consist of a 6-inch thick reinforced concrete pad, designed to withstand loadings from truck traffic, see Concrete Calculations provided in Appendix D. The spillway is designed to handle the Probable Maximum Precipitation (PMP) for a 6 hour storm event for the site, see Spillway Calculations provided in Appendix D.

4. SUMMARY AND CONCLUSIONS

This report presents the engineering design evaluations for Cells 5A and 5B at the White Mesa Mill Facility. The calculations presented in this Design Report establish the dimensions and properties of the liner system components (Appendix D). The design plans and details are presented in the Construction Drawings (Appendix A), recommended construction quality testing and observation requirements are provided in the CQA Plan (Appendix B), and material requirements are provided in the project Technical Specifications (Appendix C).

4.1 Limitations

The professional opinions and recommendations expressed in this report are made in accordance with generally accepted standards of geotechnical engineering practice. This warranty is in lieu of any other warranty either express or implied. We are responsible for the conclusions and recommendations contained in this report based on the data relating only to the specific project and location discussed herein. We are not responsible for use of the information contained in this report for purposes other than those expressly stated in this report. In the event that there are changes in the design or location of this project that do not conform to the project as described herein, we will not be responsible for these changes unless given the opportunity to review them and concur with them in writing. We are not responsible for any conclusions or recommendations made by others based upon the data or conclusions contained herein unless given the opportunity to review them and concur with them in writing.

Gregory T. Corcoran, P.E.
Utah Registration No. 6020077-2202

REGISTERED PROFESSIONAL ENGINEER
No. 6020077-2202
GREGORY T. CORCORAN
STATE OF UTAH

5. REFERENCES

City-Data.com, 2007. Blanding, Utah. Available at: www.city-data.com/city/Blanding-Utah.html.

Daniel, D.E., and Scranton, H.G. (1996), "Report of 1995 Workshop of Geosynthetic Clay Liners," EPA/600/R-96/149, June, 93 pgs.

Geosyntec (2006), "Cell 4A Lining System Design Report for the White Mesa Mill, Blanding, Utah," Prepared for International Uranium (USA) Corporation, January, 2006.

Geosyntec (2007), "Cell 4B Design Report for the White Mesa Mill, Blanding, Utah," Prepared for Denison Mines (USA) Corporation, as revised in Round 1, Round 2, and Round 3 Interrogatories.

Western Regional Climate Center (WRCC), 2005. Based on data from 12/8/1904 to 3/31/2005 at Blanding, Utah weather station (420738).

WRCC, 2007. Monthly Average Pan Evaporation Rate for Mexican Hat, Utah. Available at: www.wrcc.dri.edu/htmlfiles/westevap.final.html#utah

FIGURES

LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- PROPOSED GRADING MAJOR CONTOUR (10')
- PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- TP12-01 AS-BUILT TRENCH LOCATION
- AS-BUILT SEISMIC LINES

PRELIMINARY DESIGN DRAWINGS
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: CELL 5A AND 5B PROPOSED GRADING

PROJECT: CELL 5A AND 5B PRELIMINARY CELL DESIGN

SITE: WHITE MESA MILL
BLANDING, UTAH

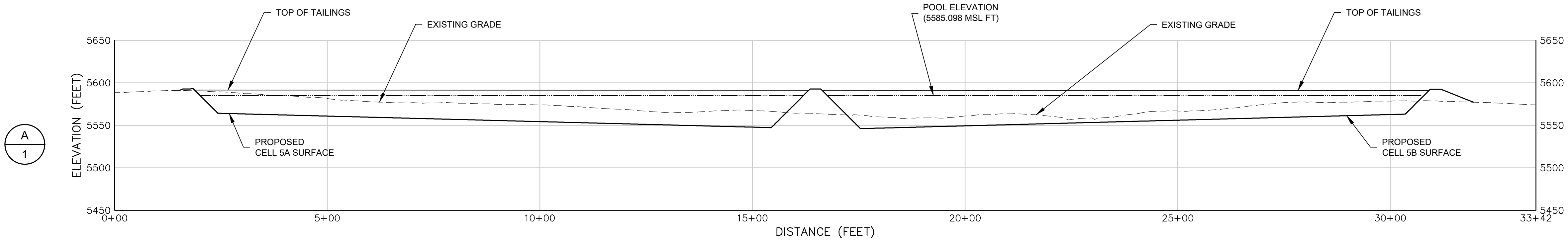
THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

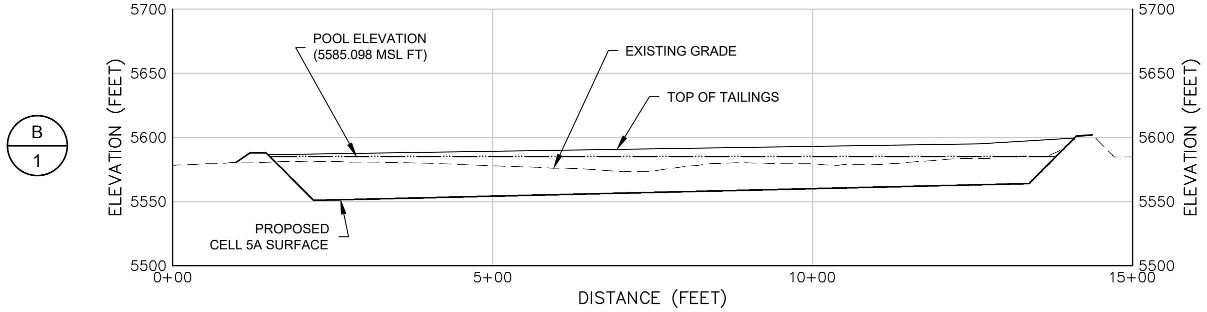
SIGNATURE

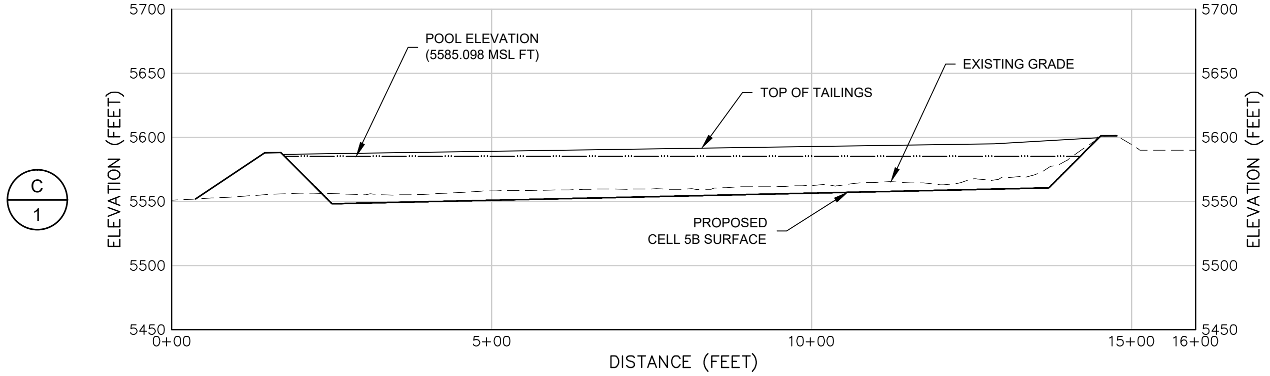
DATE

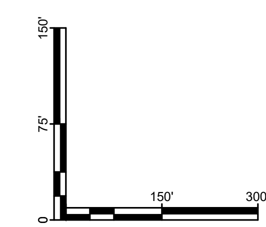
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0349
CHECKED BY:	GTC	FILE:	
REVIEWED BY:	GTC	FIGURE NO.:	
APPROVED BY:	GTC	1 OF 2	

P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Working\10-2-12 CELL 5A & 5B REVISED GRADING.dwg









LEGEND

- JUNE 2011 EXISTING GROUND SURFACE
- PROPOSED GRADING SURFACE
- POOL SURFACE
- TOP OF TAILINGS SURFACE

PRELIMINARY DESIGN DRAWINGS
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUTE 200
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PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: CELL 5A AND 5B PROPOSED GRADING - PROFILES

PROJECT: CELL 5A AND 5B PRELIMINARY CELL DESIGN

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

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DRAWN BY:	MMC	PROJECT NO.:	SC0349
CHECKED BY:	GTC	FILE:	
REVIEWED BY:	GTC	FIGURE NO.:	
APPROVED BY:	GTC	2 OF 2	

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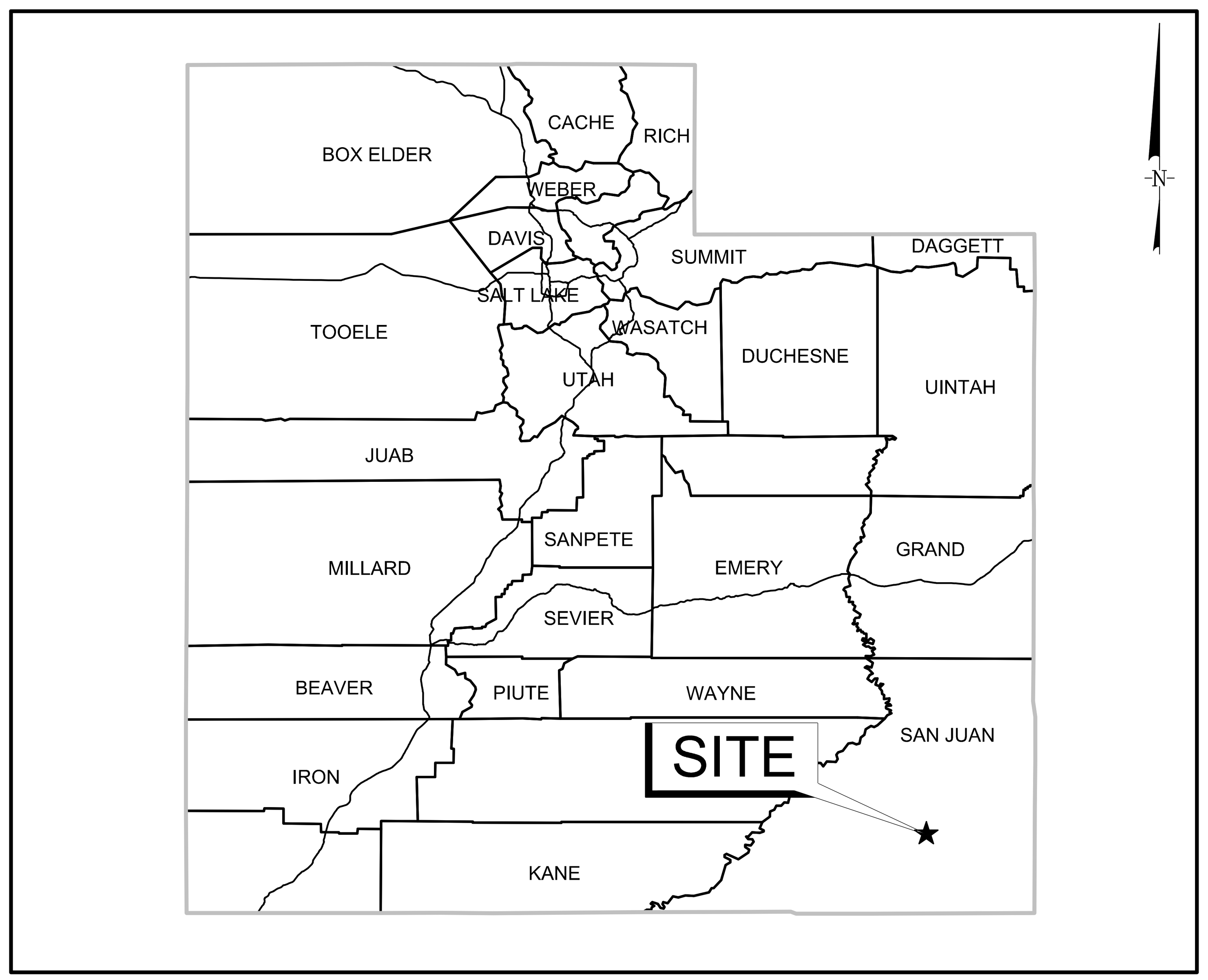
APPENDIX A-1

Construction Drawings

Option A – Triple Liner

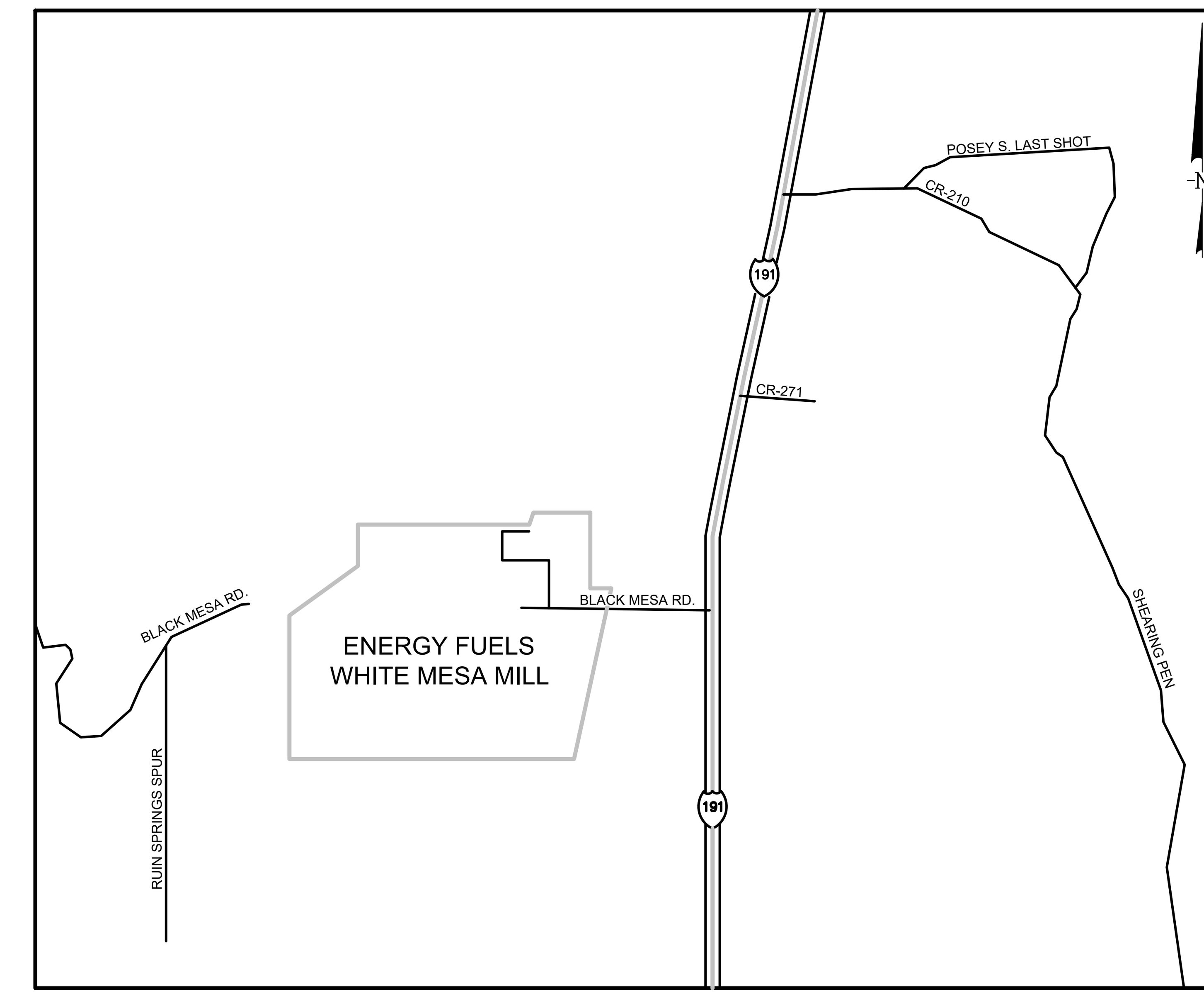
PERMIT LEVEL DESIGN DRAWINGS
CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER
ENERGY FUELS WHITE MESA MILL
BLANDING, UTAH
JUNE 2018



VICINITY MAP
NOT TO SCALE

LIST OF DRAWINGS

DRAWING	DESCRIPTION
01	TITLE SHEET
02	SITE PLAN
03A	CELL 5A PROPOSED GRADING
03B	CELL 5B PROPOSED GRADING
04A	PIPE LAYOUT PLAN AND DETAILS - CELL 5A
04B	PIPE LAYOUT PLAN AND DETAILS - CELL 5B
05	LINER SYSTEM DETAILS I
06	LINER SYSTEM DETAILS II
07	DETAILS & SECTIONS III
08	DETAILS & SECTIONS IV
09	DETAILS & SECTIONS V
10	DETAILS & SECTIONS VI



LOCATION MAP
NOT TO SCALE

4 / 6 — DETAIL NUMBER; SHEET ON WHICH ABOVE DETAIL IS PRESENTED

DETAIL NUMBER — 4
SHEET ON WHICH ABOVE DETAIL WAS FIRST REFERENCED — 3

DETAIL
TITLE OF DETAIL
SCALE: 1"=2'

EXAMPLE: DETAIL NUMBER 4 PRESENTED ON SHEET NO. 6 WAS REFERENCED FOR THE FIRST TIME ON SHEET NO. 3.

DETAIL IDENTIFICATION LEGEND

(ABOVE SYSTEM ALSO APPLIES TO SECTION IDENTIFICATIONS, HOWEVER, LETTERS ARE USED INSTEAD OF NUMBERS.)

PREPARED FOR:

Energy Fuels Resources (USA) Inc.

ENERGY FUELS RESOURCES (USA) INC.
6425 S. HIGHWAY 191
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BLANDING, UTAH 84511
(306) 628-7798

PREPARED BY:

Geosyntec consultants

GEOSYNTEC CONSULTANTS
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(858) 674-6559

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUITE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: TITLE SHEET

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

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SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
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CHECKED BY:	RFO	FILE:	SC0634-01
REVIEWED BY:	GTC	DRAWING NO.:	01 OF 10
APPROVED BY:	GTC		

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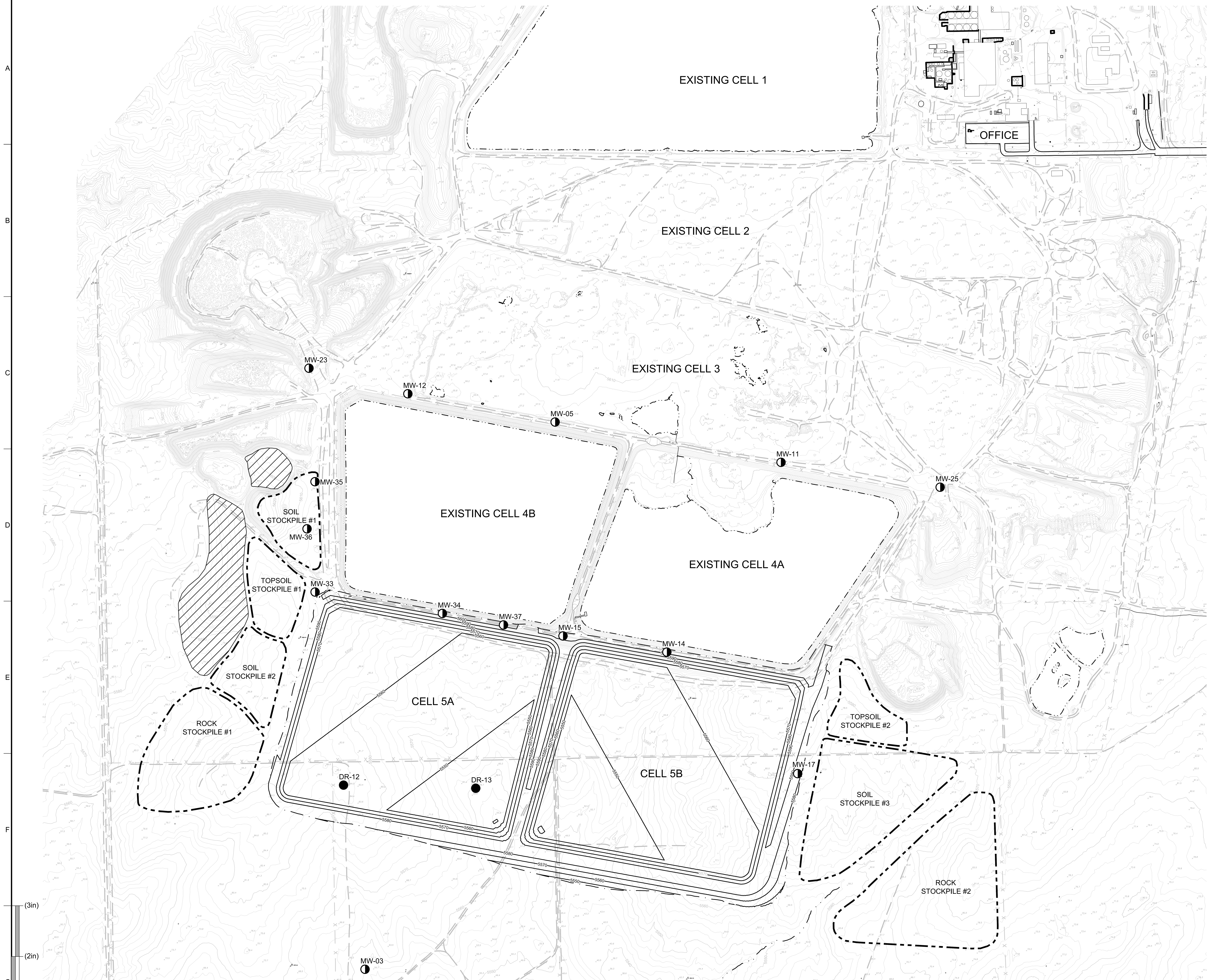
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



LEGEND

5570	JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
	EXISTING DIRT ROAD
x x	EXISTING FENCE
	SURFACE WATER BOUNDARY
	SURFACE WATER DRAINAGE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
	PROPOSED GRADING LIMIT
	PROPOSED STOCKPILE BOUNDARIES
	KNOWN ARCHEOLOGICAL AREAS (SEE NOTE 6)
DR-13 MW-12	EXISTING GROUNDWATER MONITORING WELLS

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. EXISTING WELLS, PIPING, AND OTHER SITE FEATURES SHALL BE PROTECTED IN PLACE, EXCEPT AS NOTED OTHERWISE.
3. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL, AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
4. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
5. CONSTRUCTION WATER TO BE PROVIDED BY OWNER AT NORTHEAST CORNER OF CELL 4A.
6. CONTRACTOR TO AVOID KNOWN ARCHEOLOGICAL AREAS. OWNER TO CLEAR ARCHEOLOGICAL AREAS WITHIN LIMITS OF WORK PRIOR TO BEGINNING EXCAVATION.

N

0 300' 600'

SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
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SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: SITE PLAN

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

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06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

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REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	02 OF 10	

PERMIT LEVEL DESIGN
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SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

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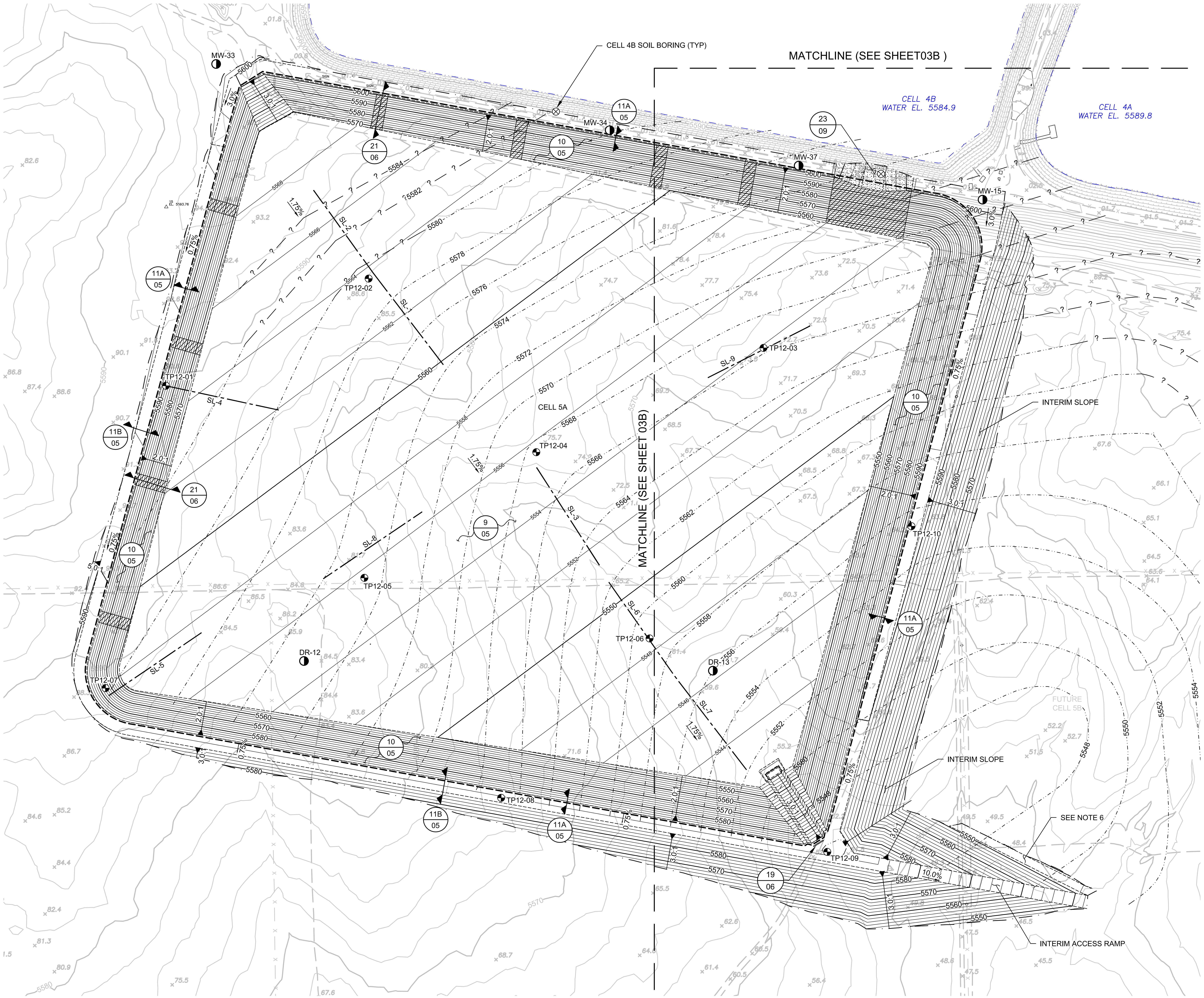

LEGEND

5570	JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
	EXISTING DIRT ROAD
x x	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	PROPOSED GRADE BREAK
	LIMIT OF LINER SYSTEM
5570	APPROXIMATE TOP OF ROCK CONTOUR (1') (SEE NOTES 4 AND 5)
	SPLASH PAD 21/06
TP12-03	EXPLORATORY TRENCH LOCATION
	SEISMIC LINE LOCATIONS (SEE NOTE 4)
⊗	CELL 4B SOIL BORINGS (SEE NOTE 4)
MW-33	EXISTING GROUNDWATER MONITOR WELL

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
4. SEISMIC LINE DATA AND CELL 4B BORINGS ARE PROVIDED IN SECTION 02200 OF THE TECHNICAL SPECIFICATIONS.
5. ROCK SURFACE IS APPROXIMATE AND BASED ON TRENCHES PERFORMED AT THE SITE. WHERE QUESTION MARKS ARE SHOWN, SURFACE IS ESTIMATED AND NOT BASED ON TRENCHES.
6. LOCALLY GRADE AREA NORTH OF BERM TO DRAIN AROUND BERM.

N

0 100' 200'
SCALE IN FEET

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: CELL 5A PROPOSED GRADING

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

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06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
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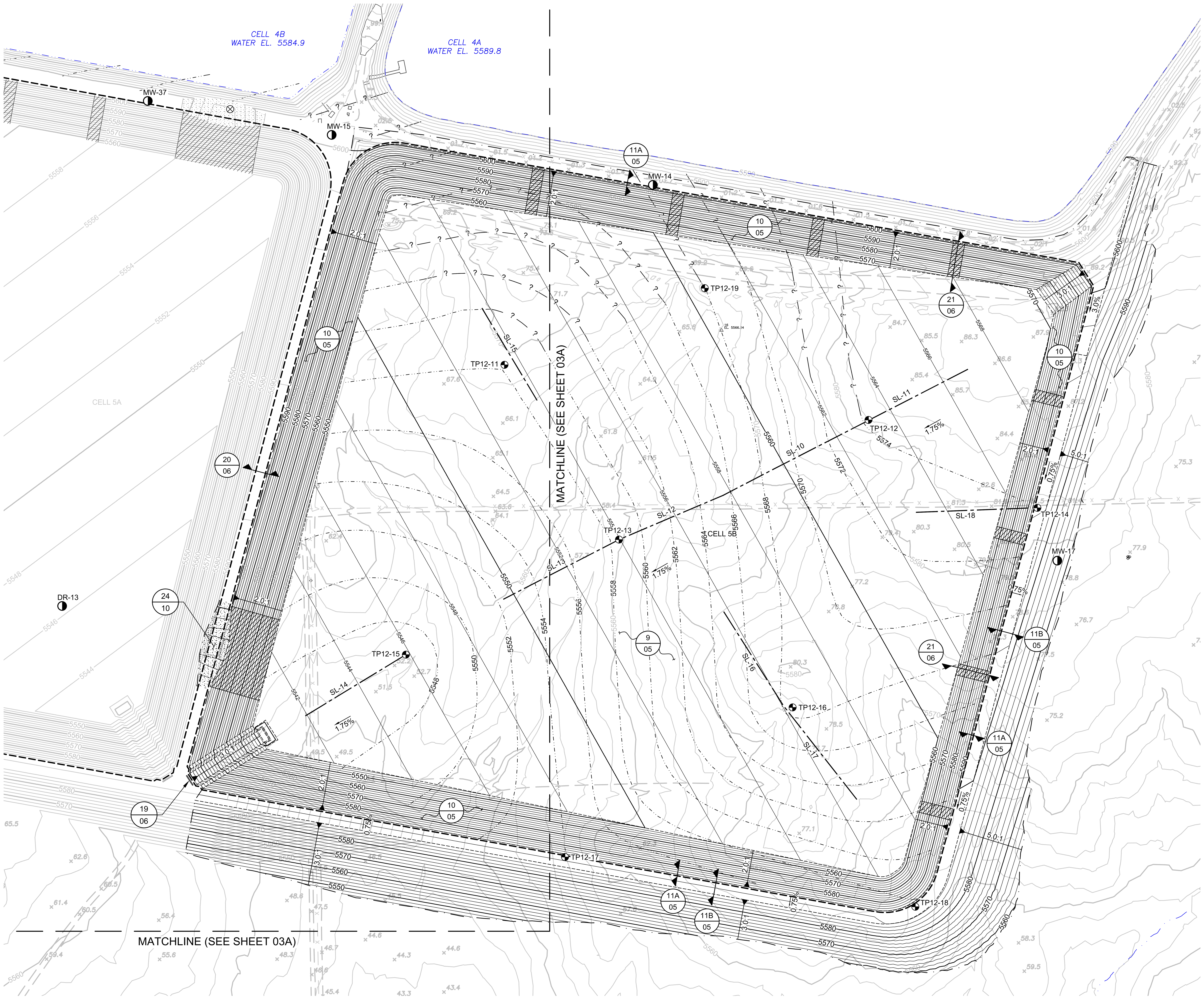
APPROVED BY:	GTC	03A OF 10	



LEGEND

5570	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
	EXISTING DIRT ROAD
x x	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	PROPOSED GRADE BREAK
	LIMIT OF LINER
5570	APPROXIMATE TOP OF ROCK CONTOUR (1') (SEE NOTES 4 AND 5)
	SPLASH PAD 21/06
TP12-03	EXPLORATORY TRENCH LOCATION
	SEISMIC LINE LOCATIONS (SEE NOTE 4)
⊗	CELL 4B SOIL BORINGS (SEE NOTE 4)
MW-33	EXISTING GROUNDWATER MONITORING WELL

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
4. SEISMIC LINE DATA AND CELL 4B BORINGS ARE PROVIDED IN SECTION 02200 OF THE TECHNICAL SPECIFICATIONS.
5. ROCK SURFACE IS APPROXIMATE AND BASED ON TRENCHES PERFORMED AT THE SITE. WHERE QUESTION MARKS ARE SHOWN, SURFACE IS ESTIMATED AND NOT BASED ON TRENCHES.

N

0 100' 200'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUITE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: CELL 5B PROPOSED GRADING

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

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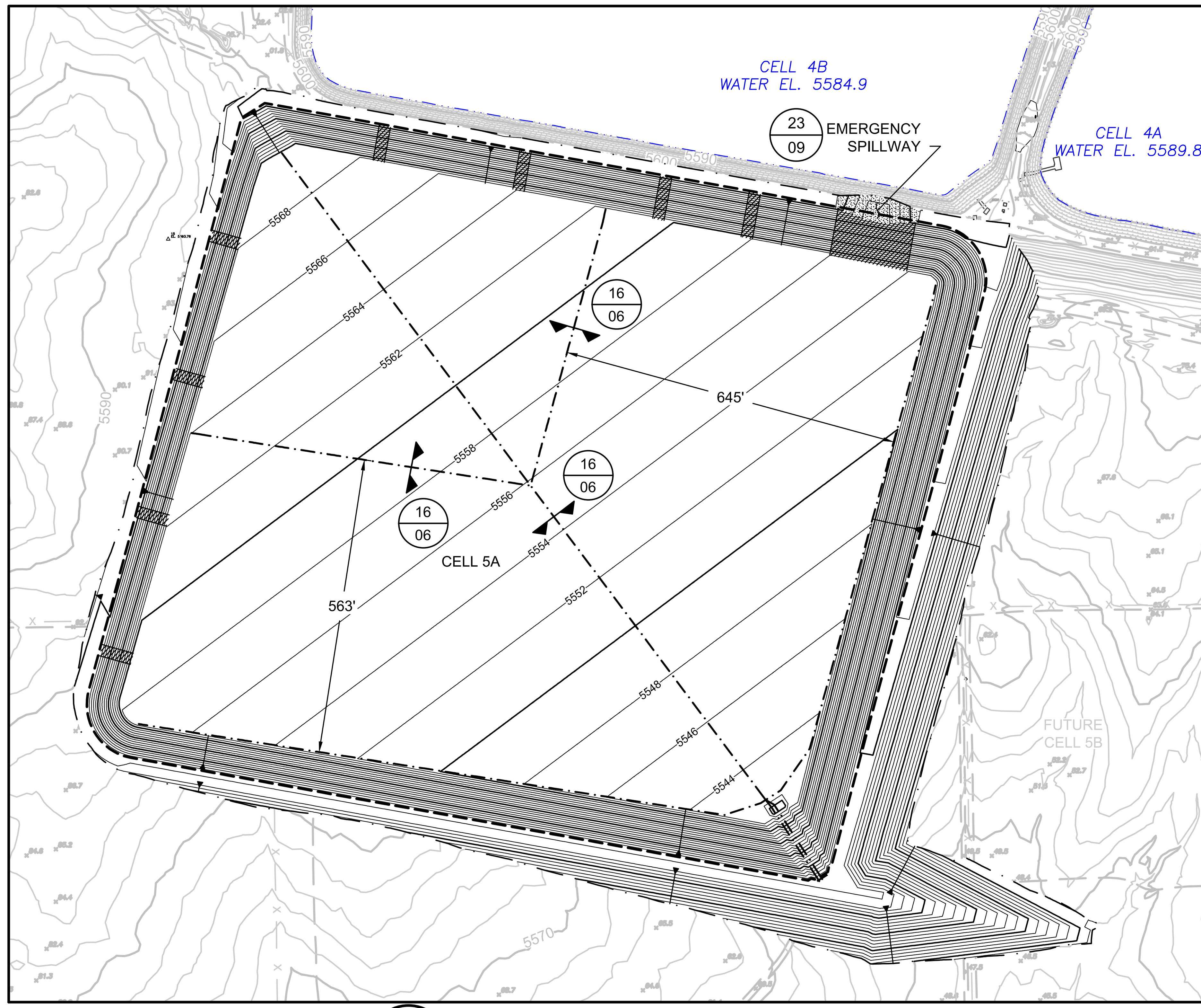
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

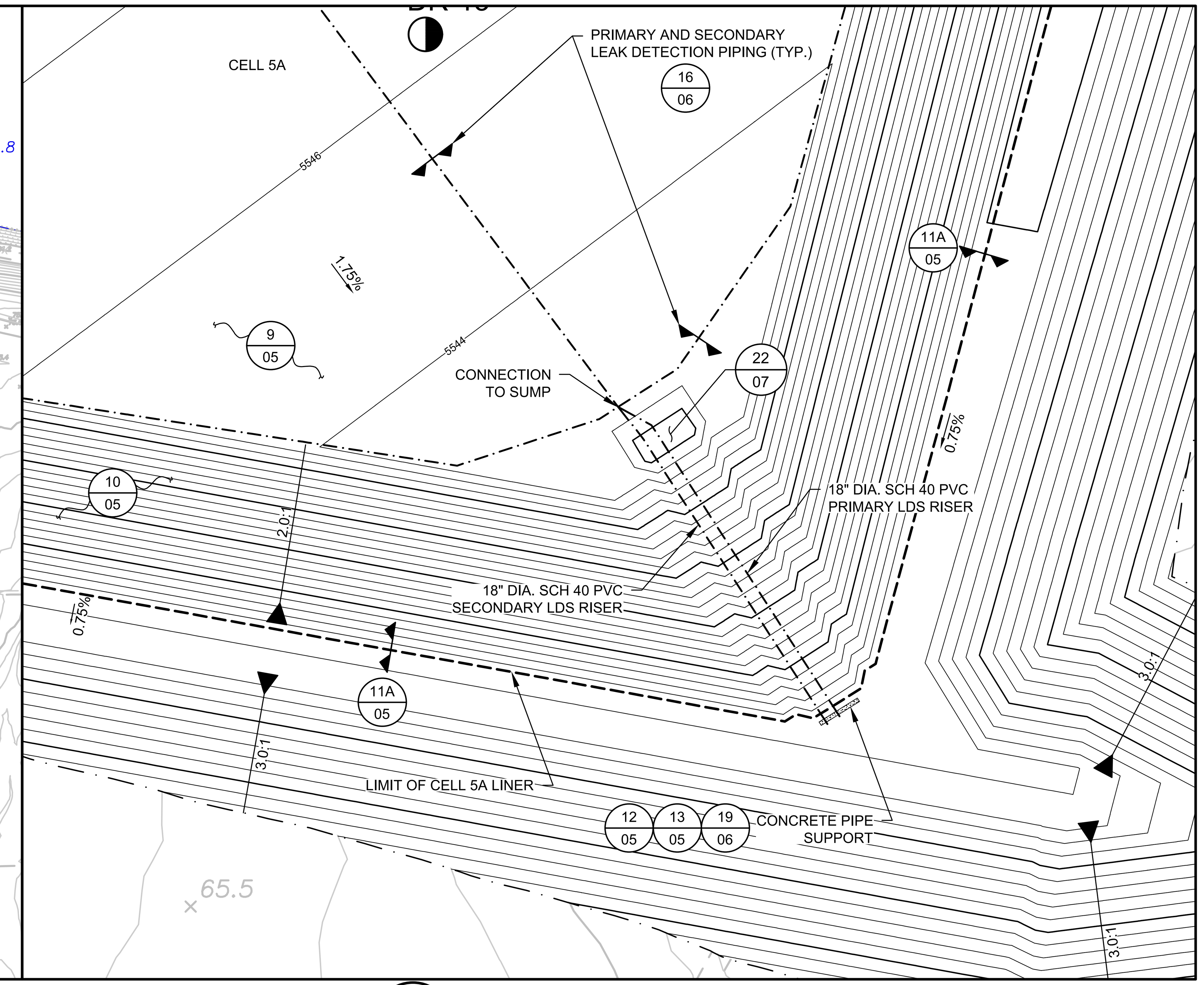
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	03B OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

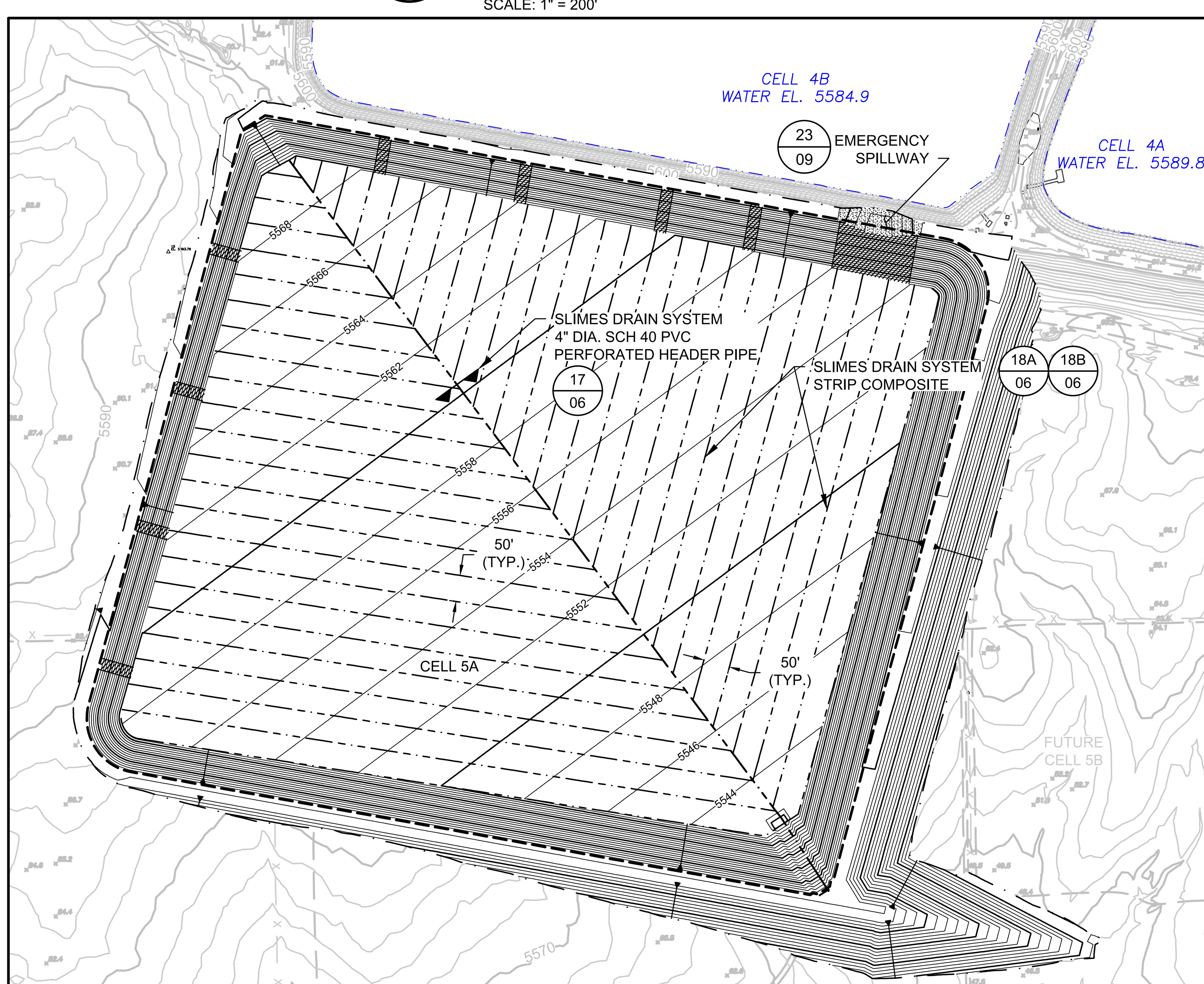
(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



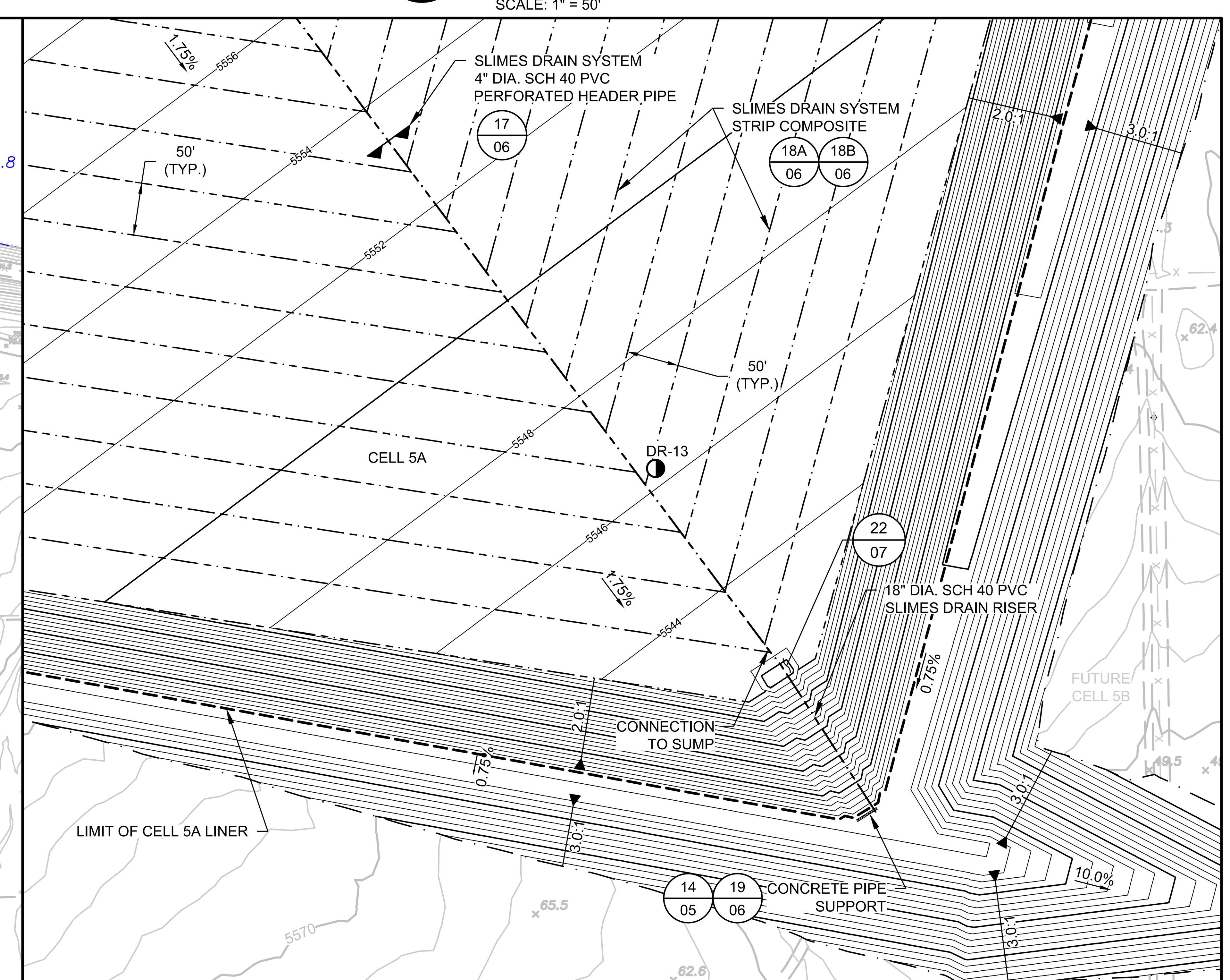
1 - PLAN
CELL 5A LEAK DETECTION SYSTEM
SCALE: 1" = 200'



2 - DETAIL
CELL 5A LEAK DETECTION SYSTEM
SCALE: 1" = 50'



3 - PLAN
CELL 5A SLIMES DRAIN SYSTEM
SCALE: 1" = 200'



4 - DETAIL
CELL 5A SLIMES DRAIN SYSTEM
SCALE: 1" = 100'

LEGEND

5570	JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
	EXISTING DIRT ROAD
x x	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	LIMIT OF LINER SYSTEM
	PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
	SLIMES DRAIN SYSTEM PIPING
	SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
	SPLASH PAD (21/06)

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL, AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5A

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE
06-29-18
DATE

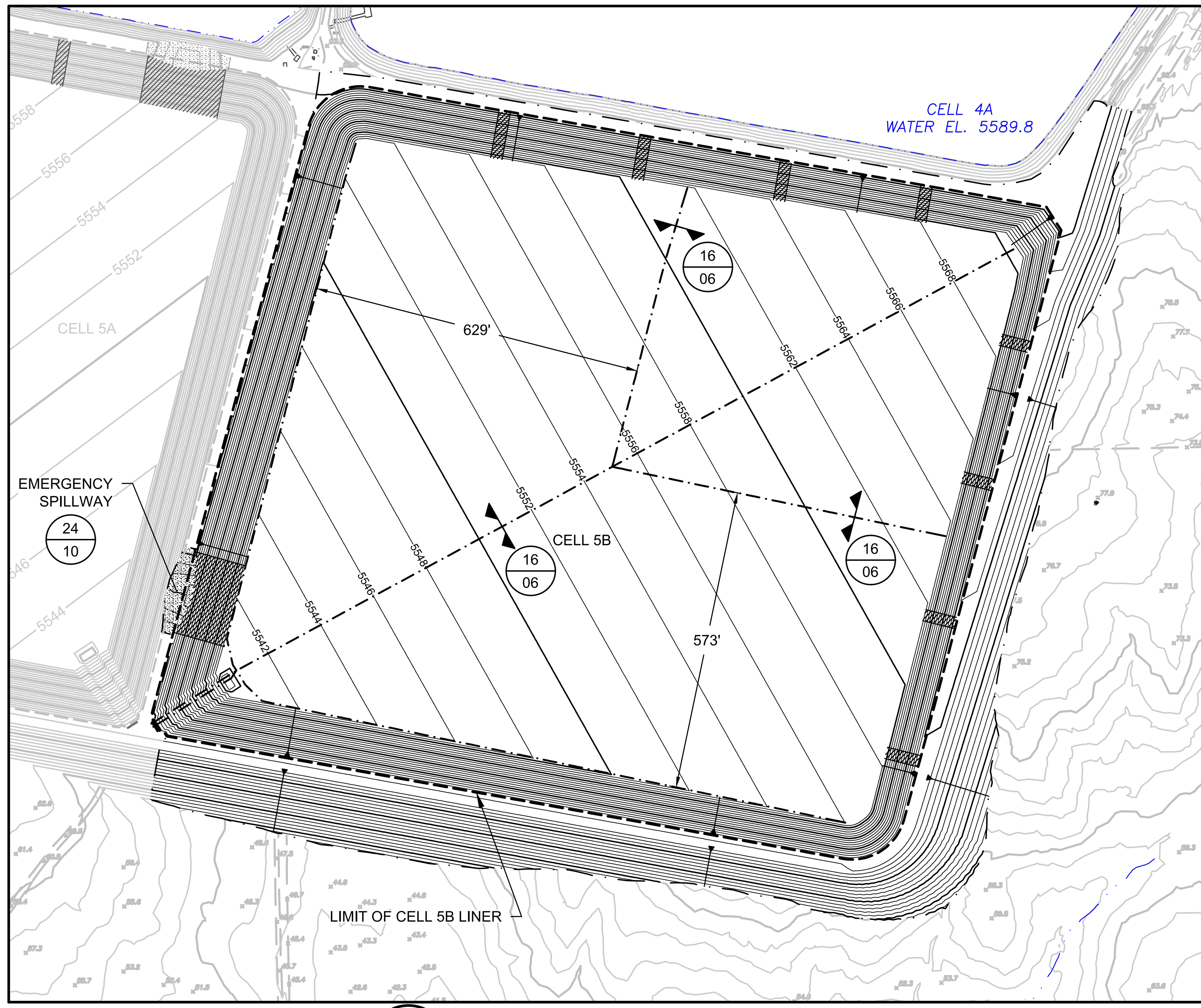
REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	04A OF 10
APPROVED BY:	GTC		

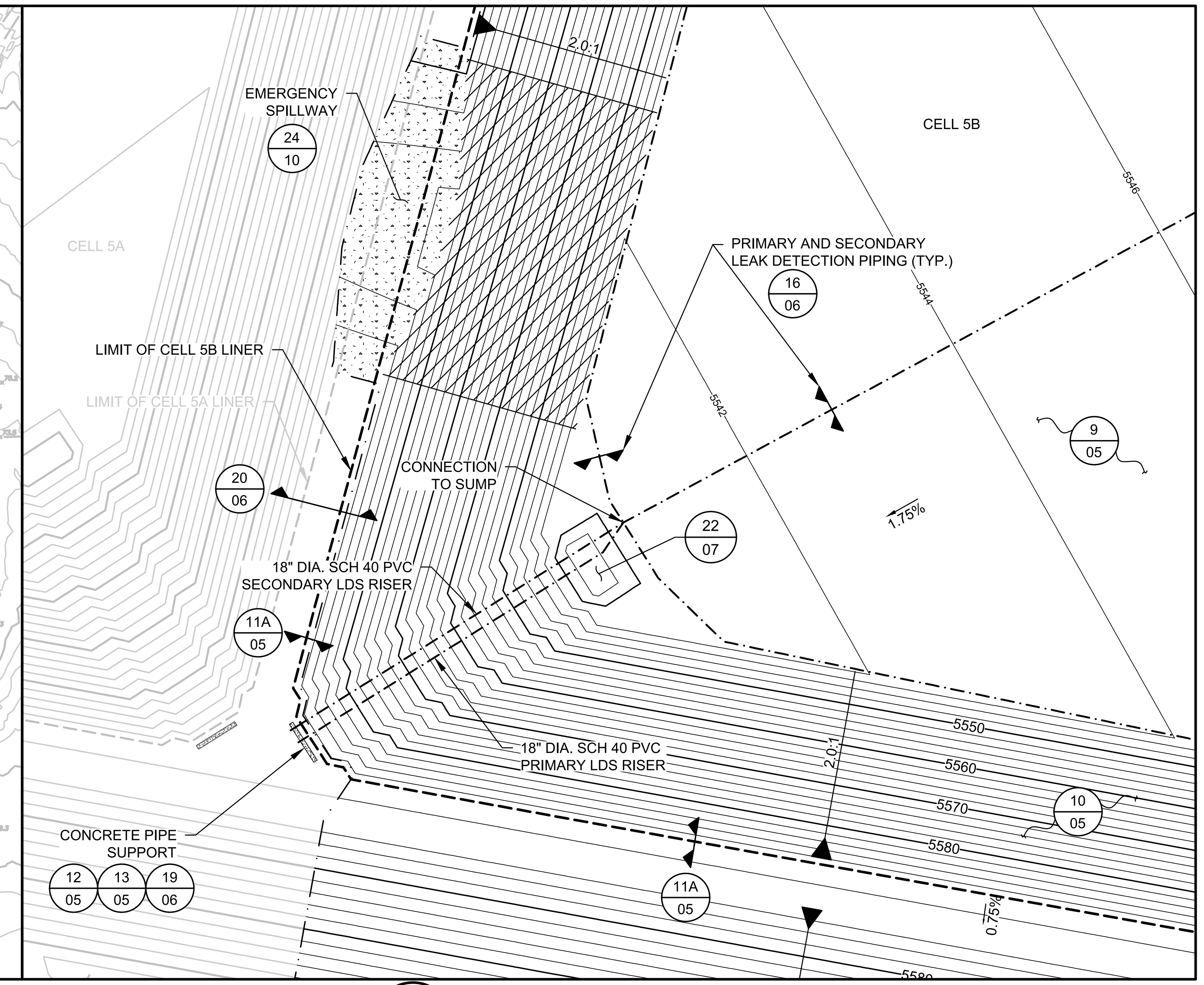
PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

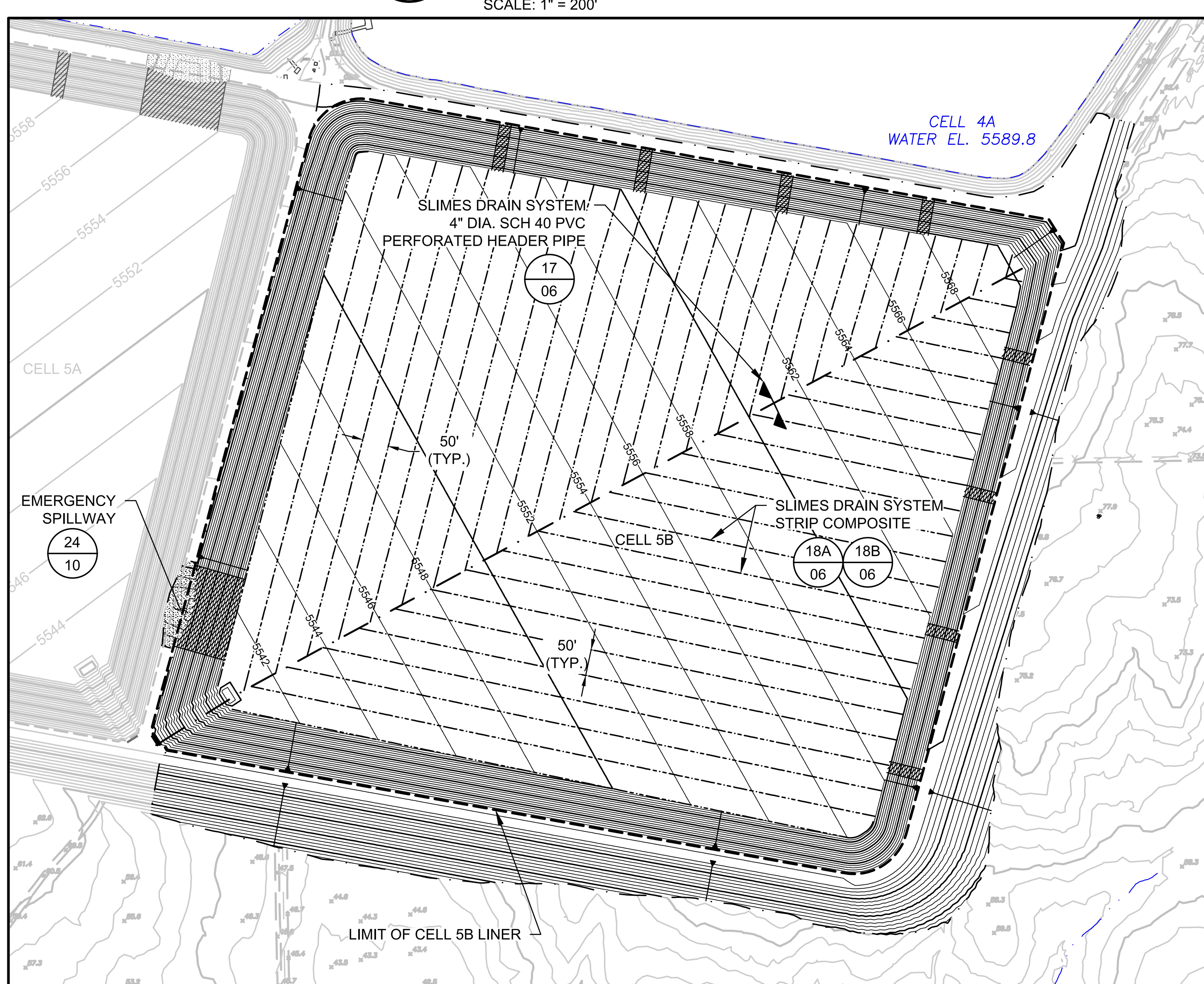
P:\PRJ\SD\Cadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634 - 03A-04B.dwg Last Edited by: SBerdy on 6/25/2018 3:45 PM



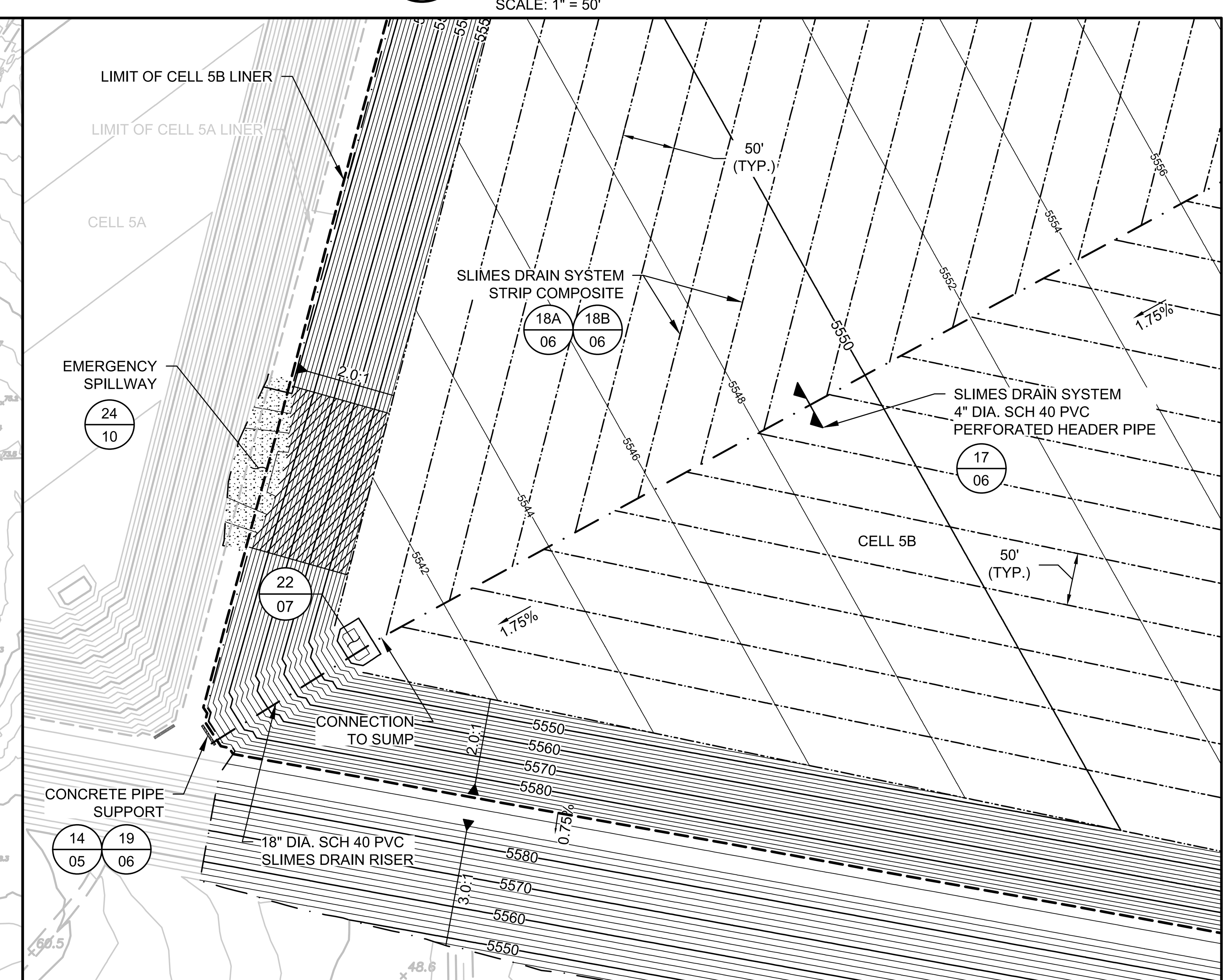
5 PLAN
CELL 5B LEAK DETECTION SYSTEM
SCALE: 1" = 200'



6 DETAIL
CELL 5B LEAK DETECTION SYSTEM
SCALE: 1" = 50'



7 PLAN
CELL 5B SLIMES DRAIN SYSTEM
SCALE: 1" = 200'



8 DETAIL
CELL 5B SLIMES DRAIN SYSTEM
SCALE: 1" = 100'

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

LEGEND

- 5570 — JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- x — x EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- 5602 — PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- LIMIT OF LINER SYSTEM
- PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- SPLASH PAD 21 / 06

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL, AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUITE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5B

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

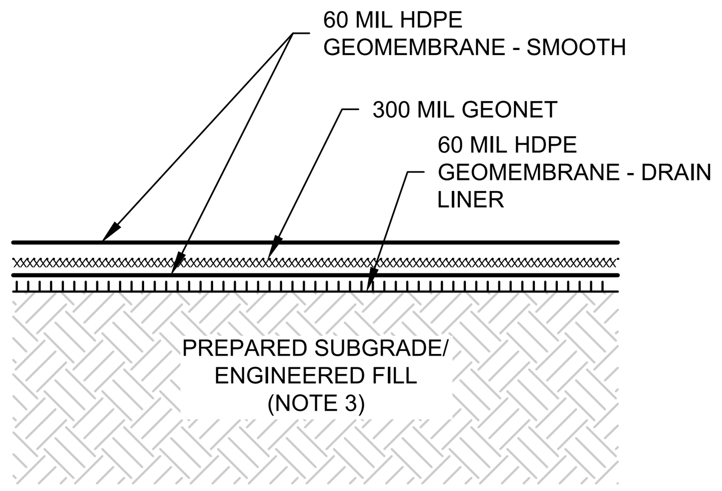
THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE
06-29-18
DATE

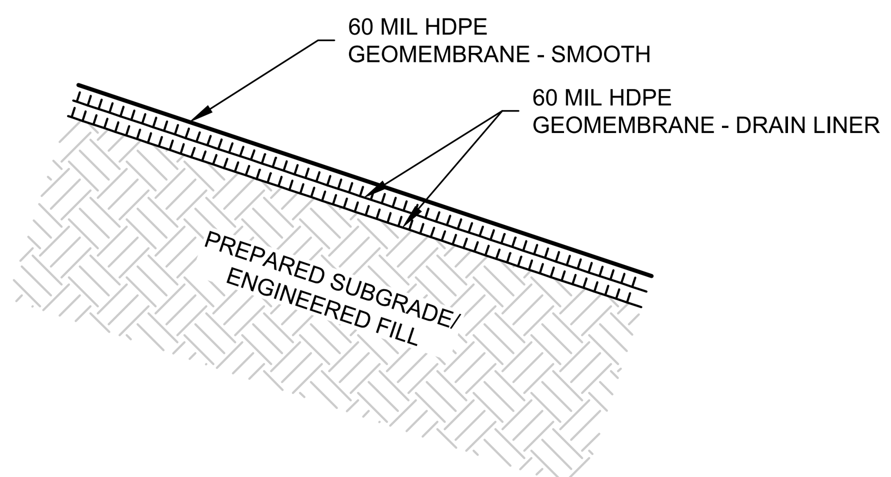
REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	04B OF 10	

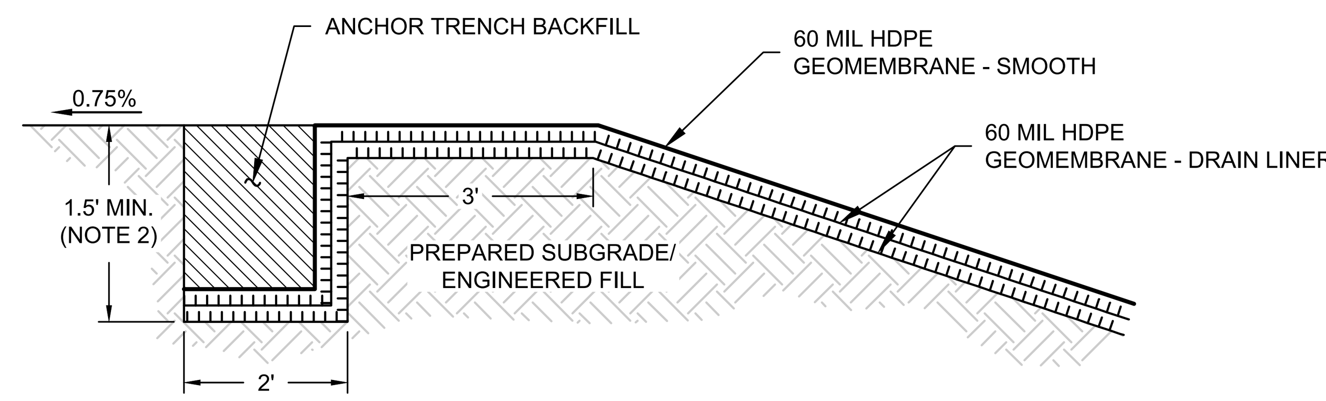
PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION



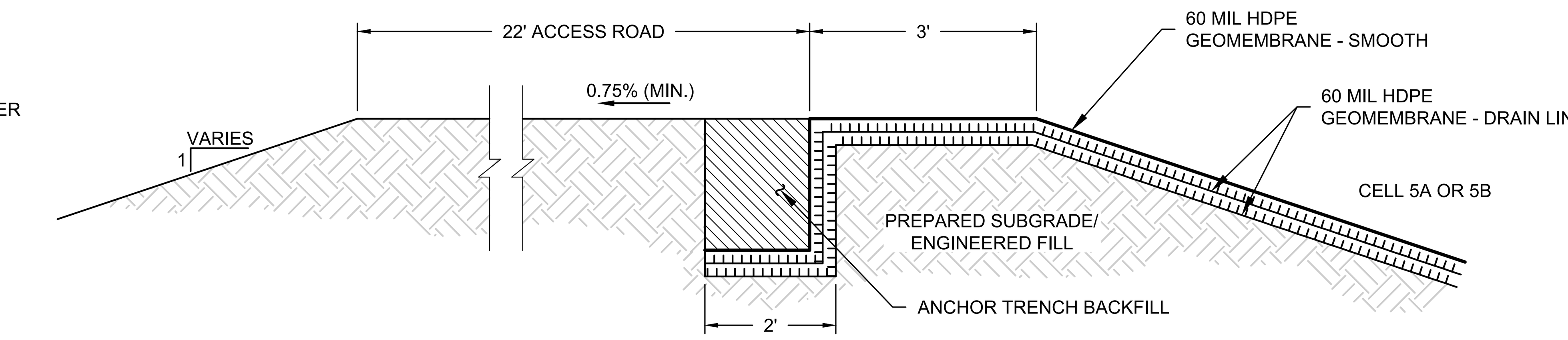
9 DETAIL
03A,03B,04A,04B
BASE LINER SYSTEM
SCALE: 1" = 2'



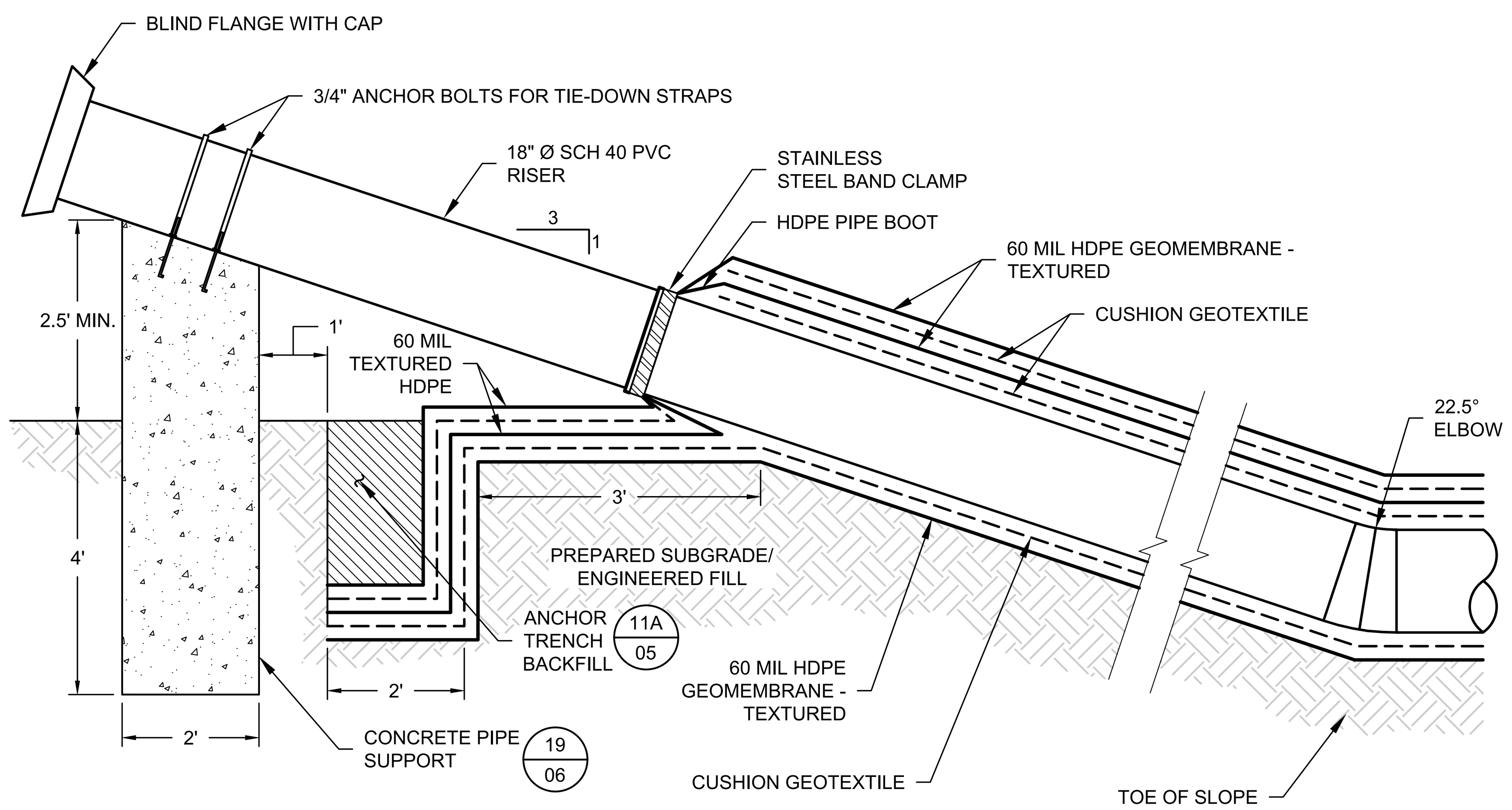
10 DETAIL
03A,03B,04A,04B
SIDE SLOPE LINER SYSTEM
SCALE: 1" = 2'



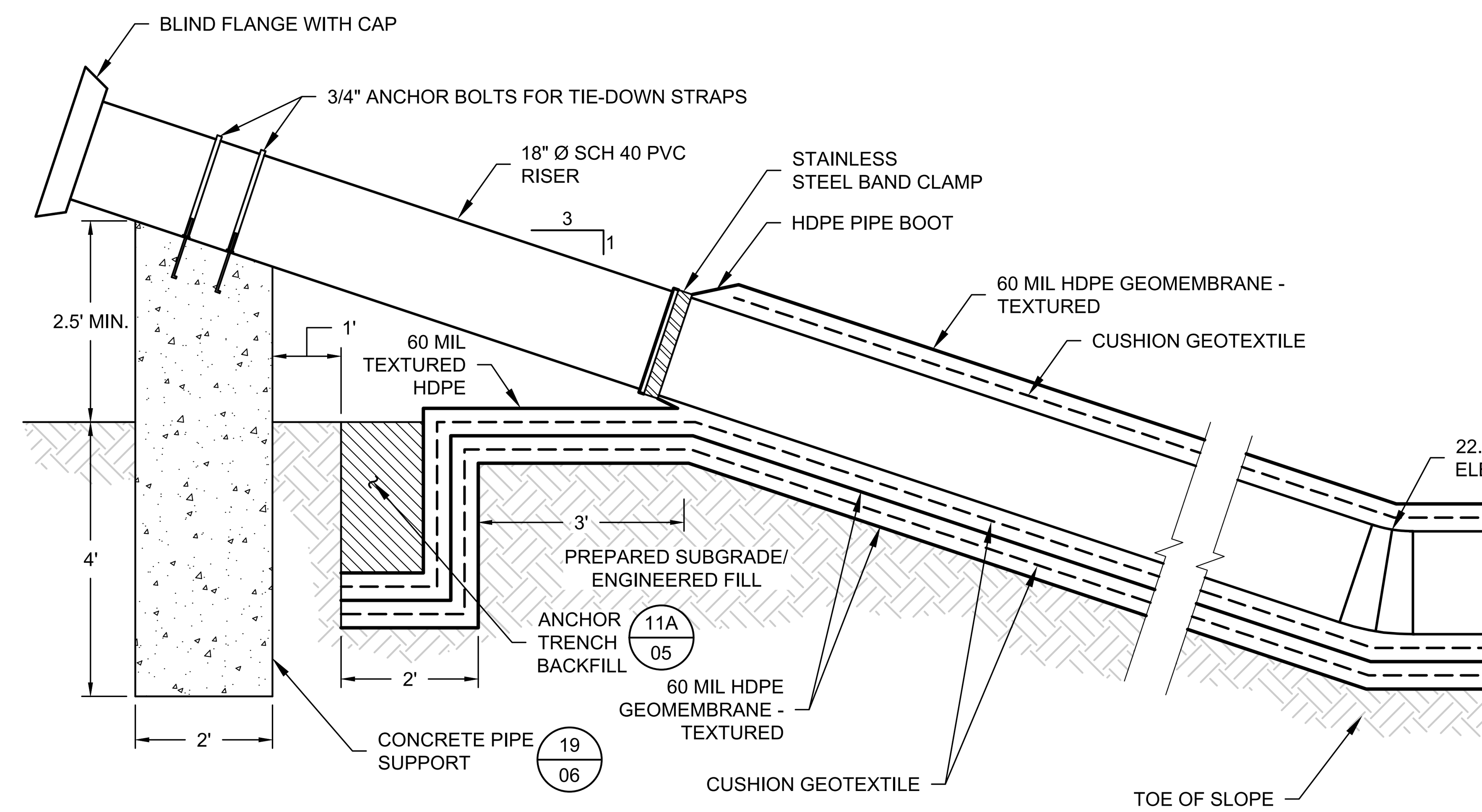
11A DETAIL
03A,03B,04A,04B,05,06,09
ANCHOR TRENCH
SCALE: 1" = 2'



11B DETAIL
03A,03B
ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



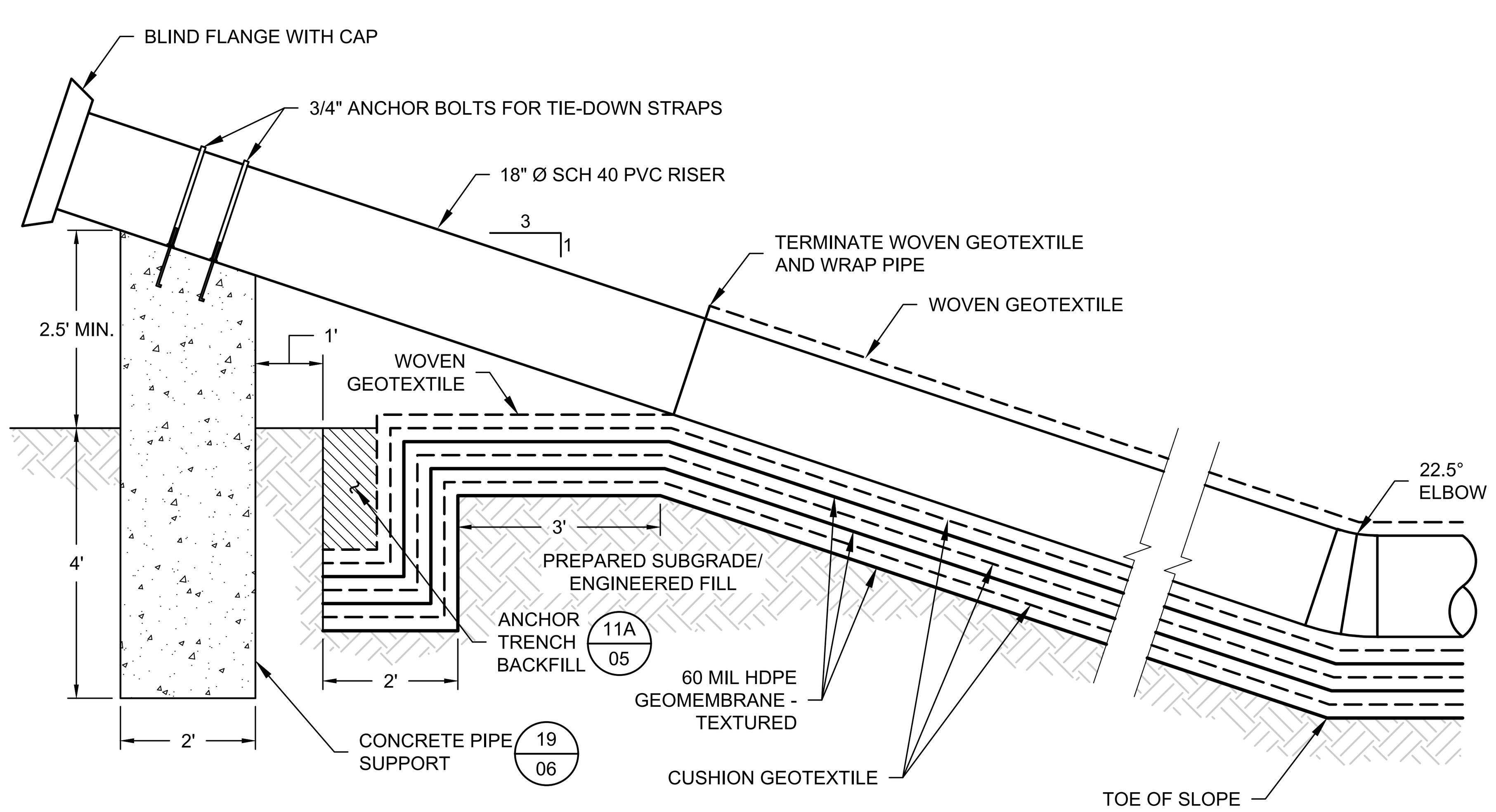
12 DETAIL
04A,04B
SECONDARY LEAK DETECTION
RISER PENETRATION
SCALE: 1" = 2'



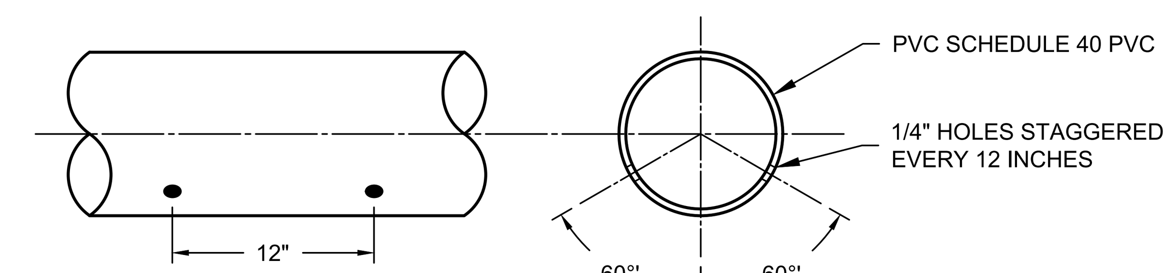
13 DETAIL
04A,04B
PRIMARY LEAK DETECTION
SYSTEM RISER PENETRATION
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. ANCHOR TRENCHES MAY BE CONSTRUCTED WITH A MAXIMUM DEPTH OF 3.5 FEET WITH UP TO 1 FOOT OF BACKFILL BETWEEN EACH GEOMEMBRANE IN BOTTOM OF ANCHOR TRENCH.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.



14 DETAIL
04A,04B
SLIMES DRAIN RISER
PENETRATION
SCALE: 1" = 2'



15 DETAIL
07,08
PERFORATED PIPE
SCALE: 1" = 1'

(3in) (2in) (1in)
(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS I

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

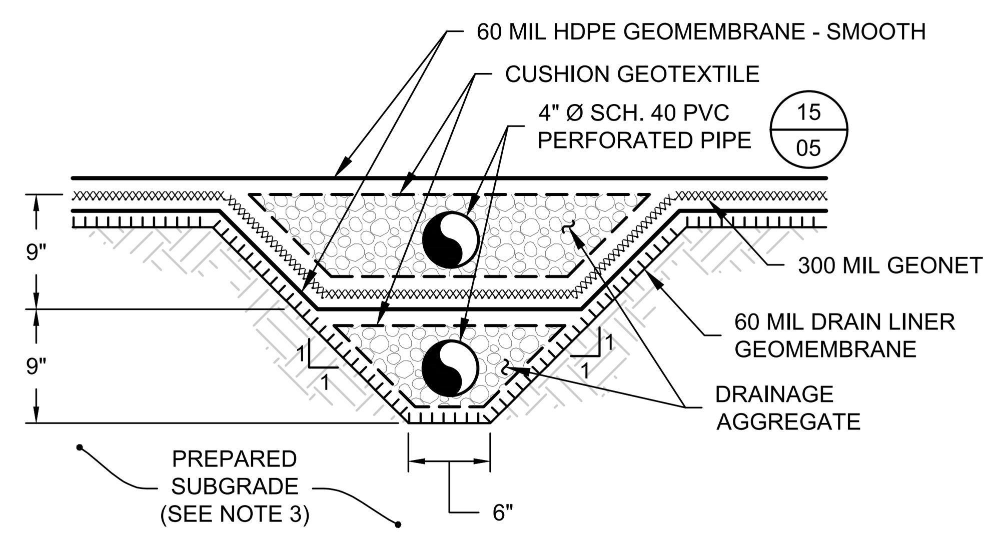
SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

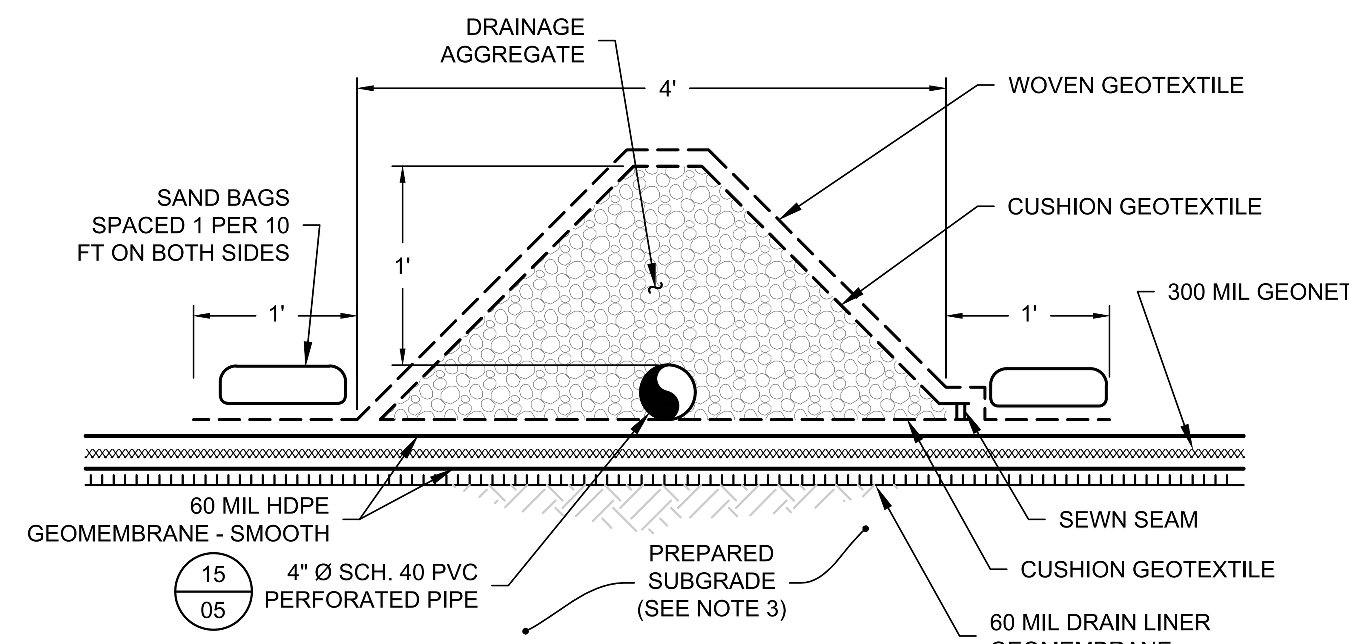
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

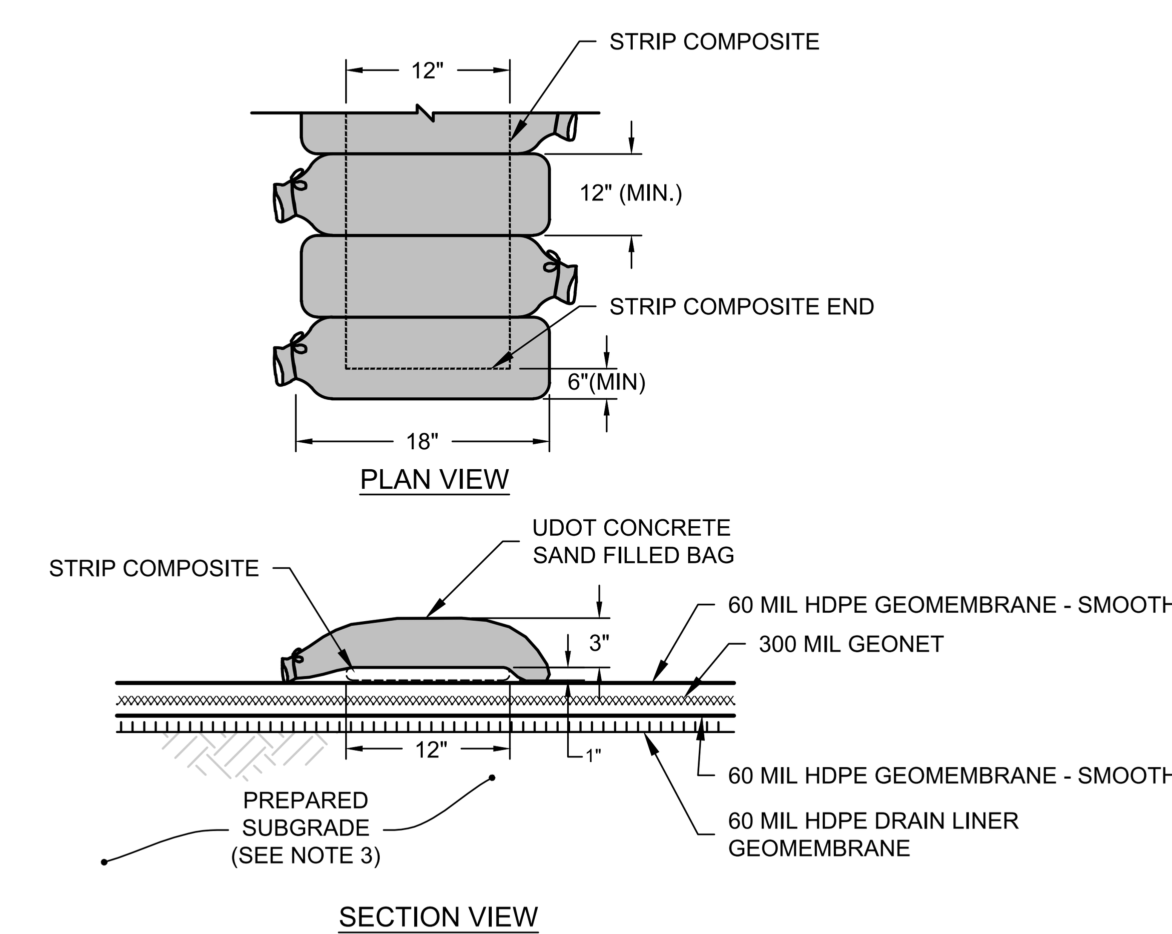
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	05 OF 10	



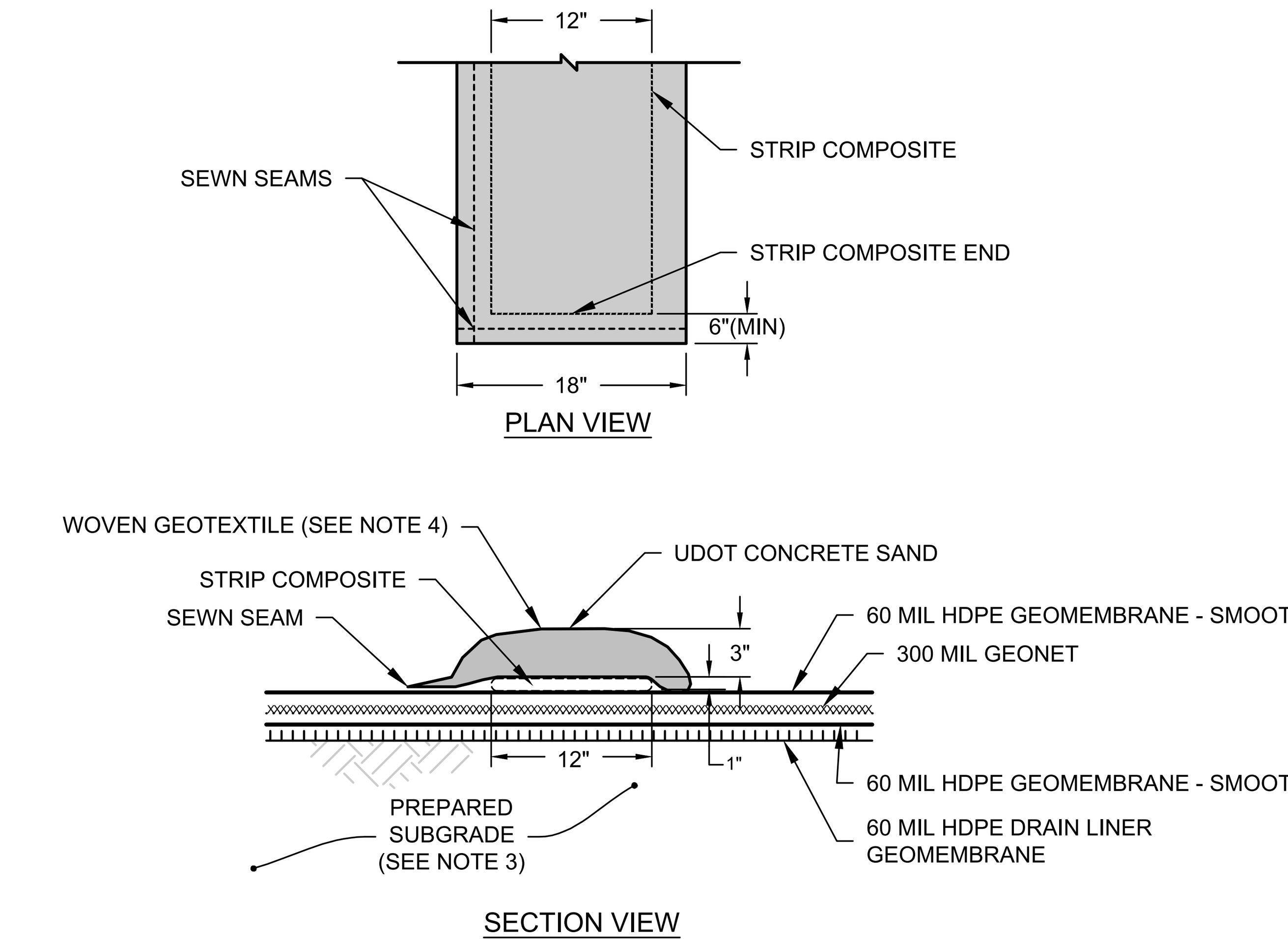
16 04A,04B DETAIL
LEAK DETECTION SYSTEM TRENCHES
SCALE: 1" = 1'



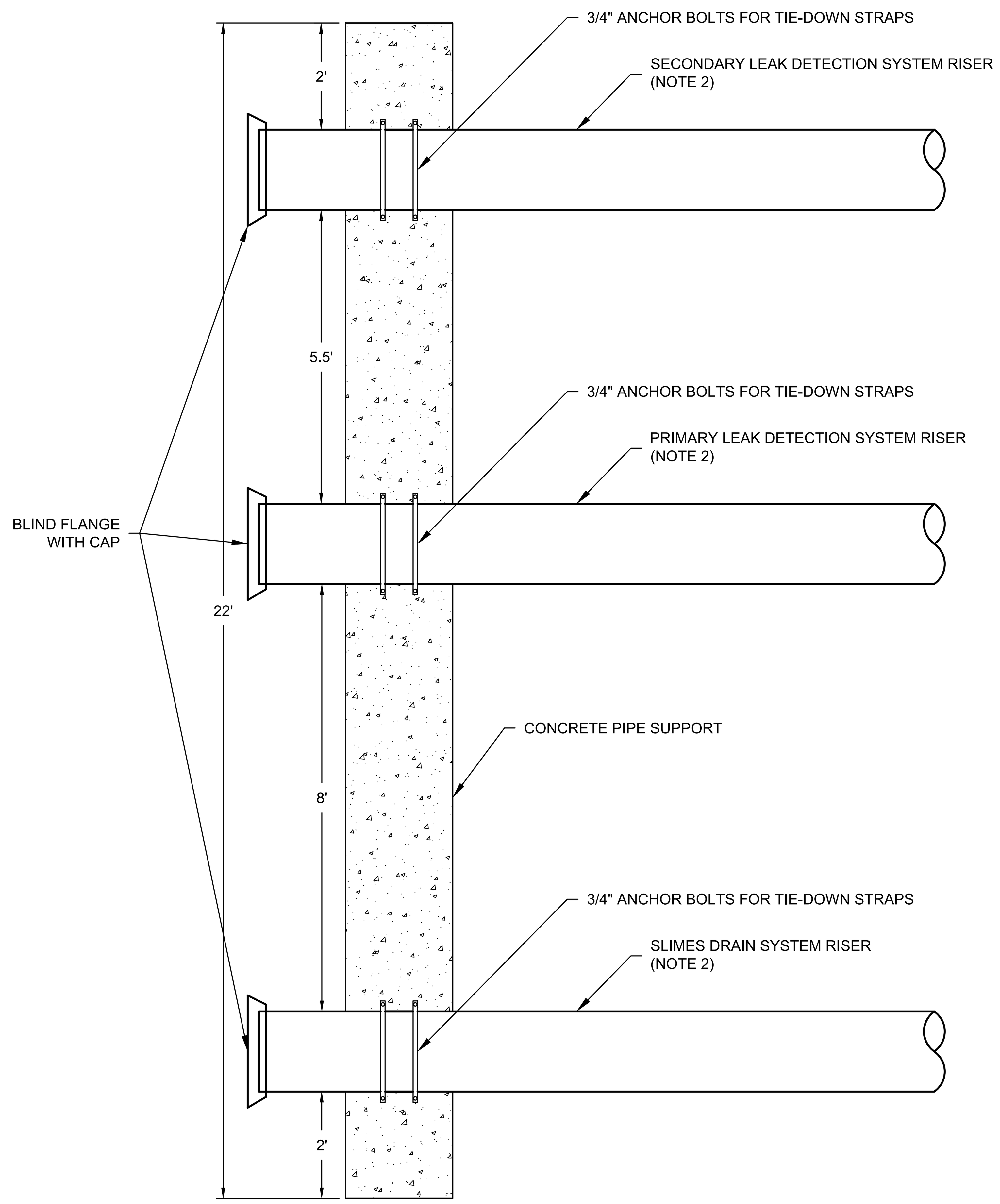
17 04A,04B DETAIL
SLIMES DRAIN HEADER
SCALE: 1" = 1'



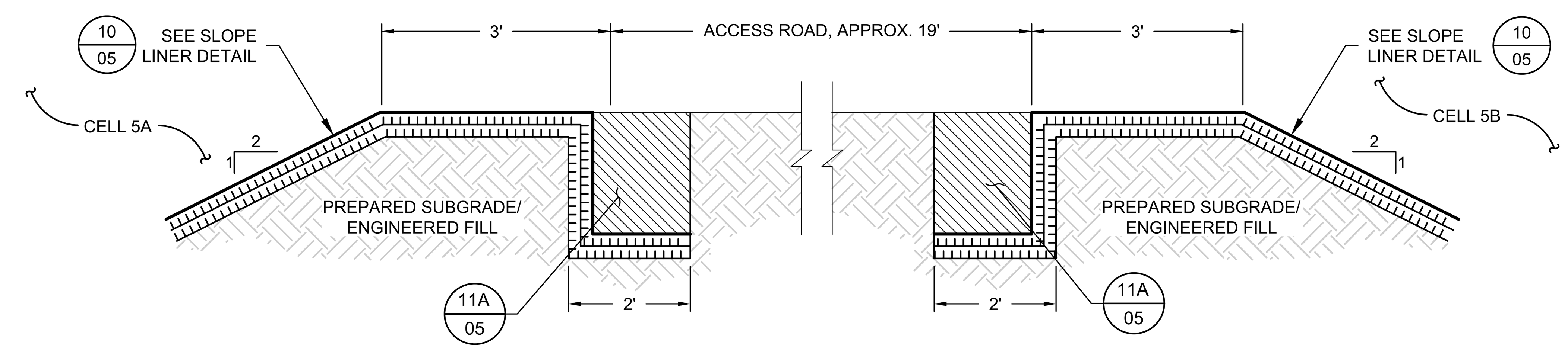
18A 04A,04B DETAIL
SLIMES DRAIN LATERAL - OPTION 1
SCALE: NTS



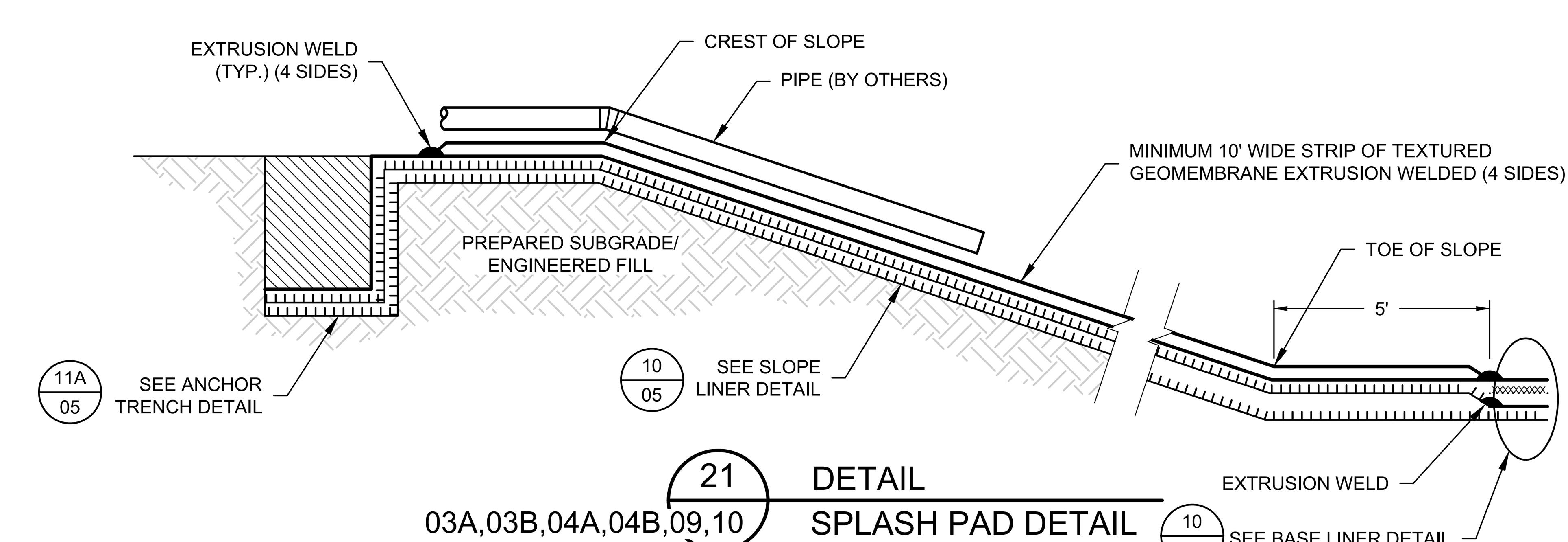
18B 04A,04B DETAIL
SLIMES DRAIN LATERAL - OPTION 2
SCALE: NTS



19 03A,03B,04A,04B DETAIL
CONCRETE PIPE SUPPORT
SCALE: 1" = 2'



20 03B,04B DETAIL
CELL 5A - CELL 5B ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



21 03A,03B,04A,04B,09,10 DETAIL
SPLASH PAD DETAIL
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. EXPOSED PVC PIPE SHALL BE PAINTED TO MINIMIZE DAMAGE DUE TO UV.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.
4. WOVEN GEOTEXTILE SHALL BE FOLDED OVER AND SEAMED. GEOTEXTILE SHALL BE FILLED WITH UDOT CONCRETE SAND TO CREATE A CONTINUOUS SANDBAG-LIKE STRUCTURE WITH A MINIMUM OF 3" OF SAND ABOVE STRIP COMPOSITE. ENDS SHALL BE SEAMED FOLLOWING SAND FILLING.

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS II

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

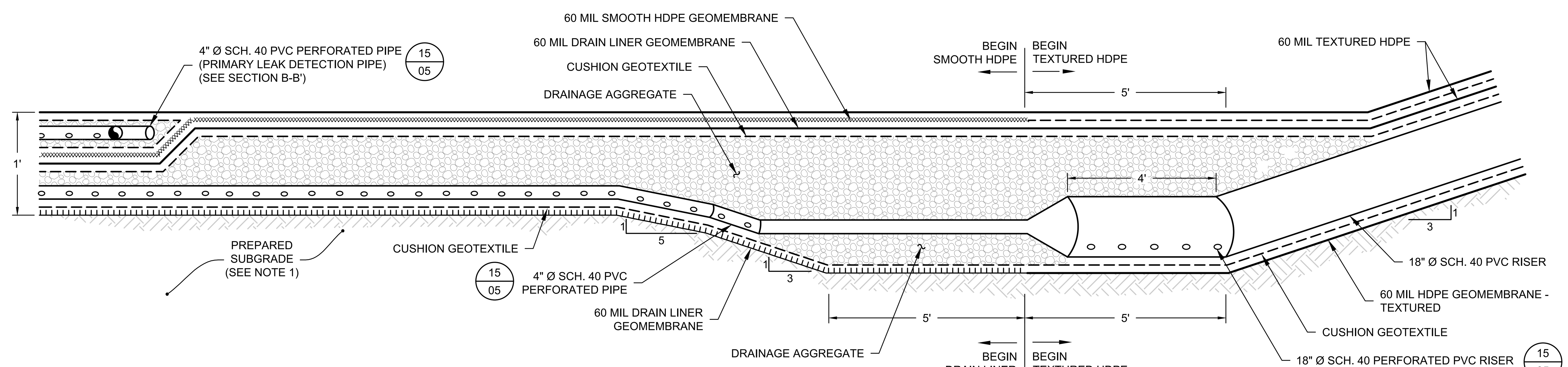
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

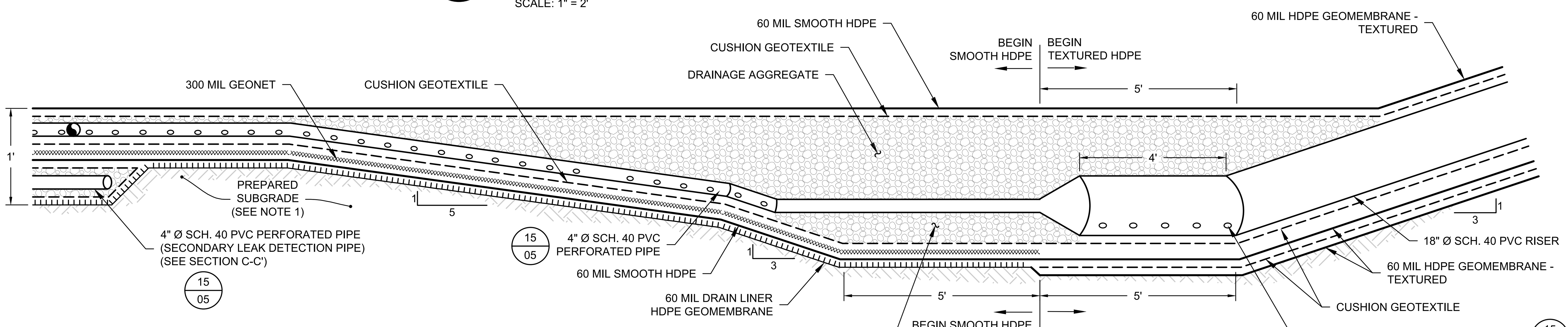
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	06 OF 10	

(3in) (2in) (1in) (1in) (2in) (3in) (4in) SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

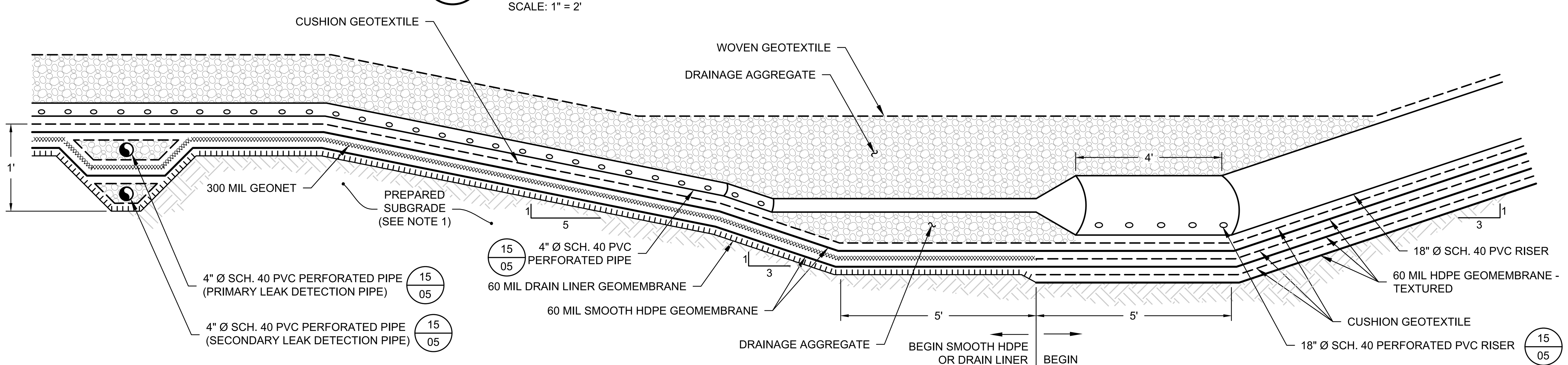
P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634-05-07.dwg Last Edited by: SBerdy on 6/25/2018 3:42 PM



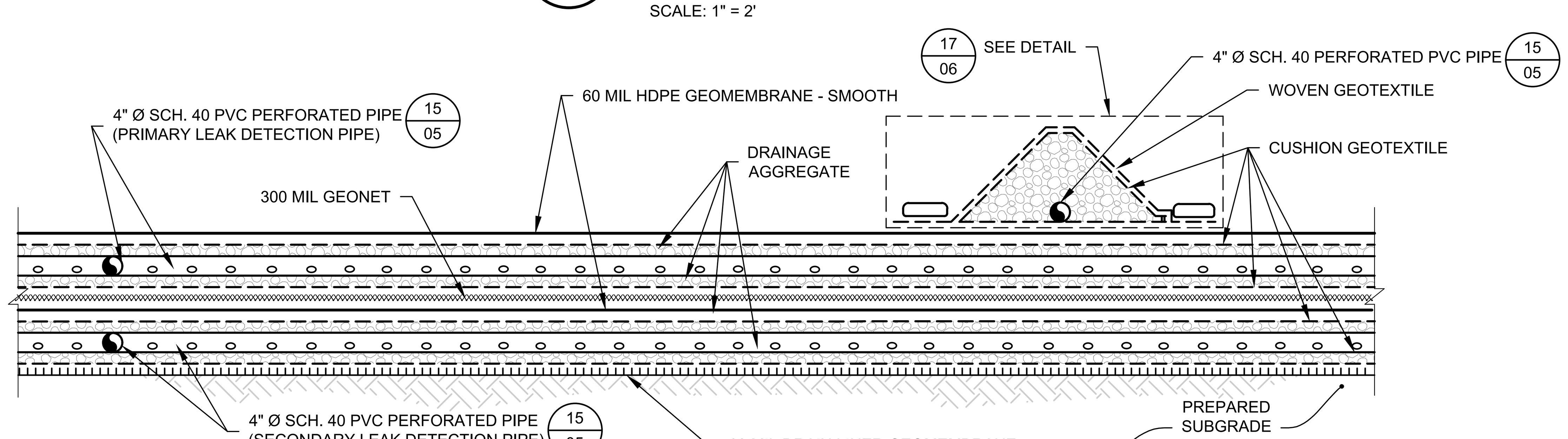
A - SECTION
SECONDARY LEAK DETECTION SUMP
SCALE: 1" = 2'



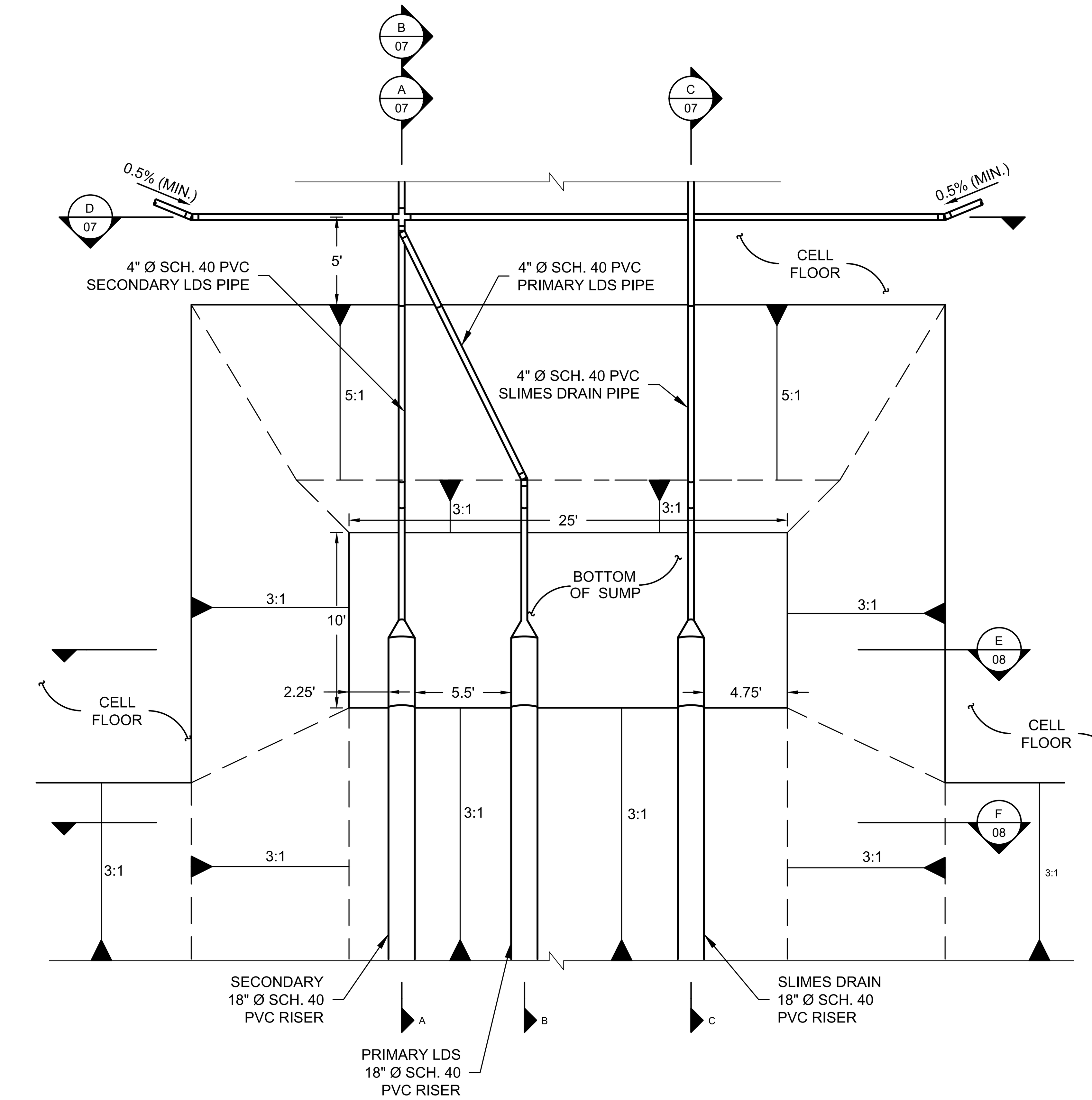
B - SECTION
PRIMARY LEAK DETECTION SUMP
SCALE: 1" = 2'



C - SECTION
SLIMES DRAIN SUMP
SCALE: 1" = 2'



D - SECTION
SLIMES DRAIN AND LDS PIPING SECTION
SCALE: 1" = 2'



22 - PLAN
04A,04B
SUMP PLAN VIEW
SCALE: 1" = 6'

NOTES:

1. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. SOIL THICKNESSES ARE MINIMUMS.

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS III

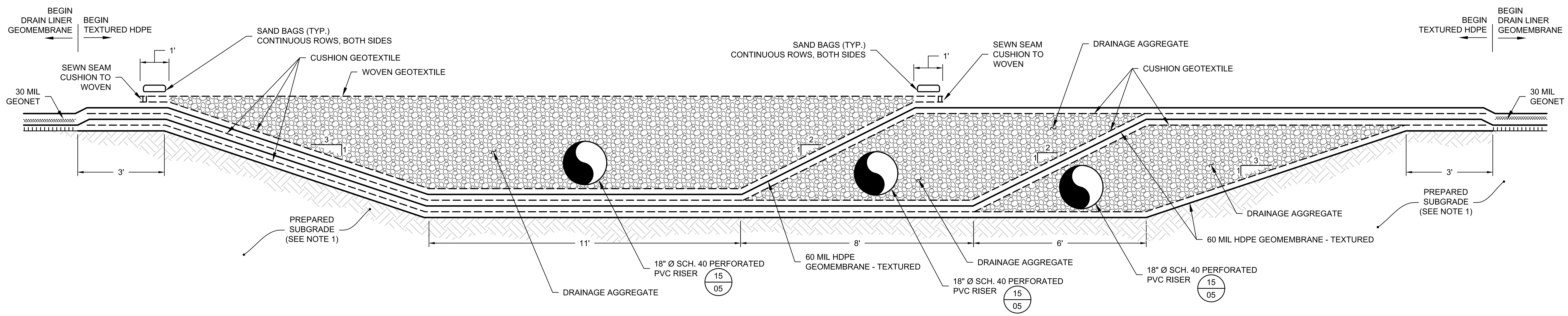
PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

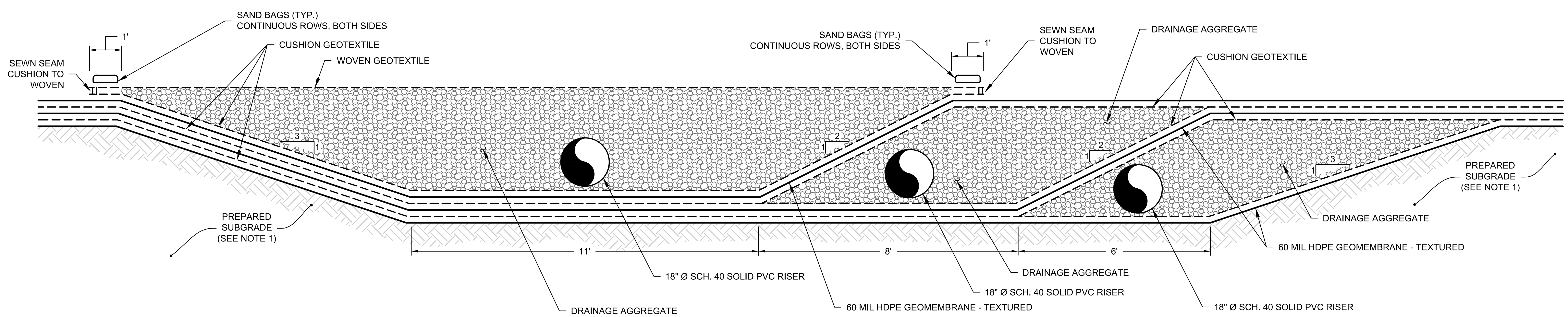
THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	07 OF 10	



E
07
SECTION
SUMP SECTION (FLOOR)
SCALE: 1" = 2'



F
07
SECTION
SUMP SECTION (SLOPE)
SCALE: 1" = 2'

NOTES:

1. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. SOIL THICKNESSES ARE MINIMUMS.

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS IV

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

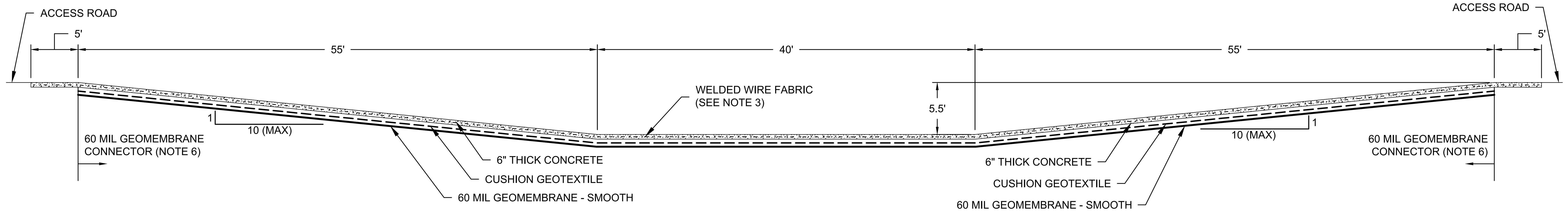
SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

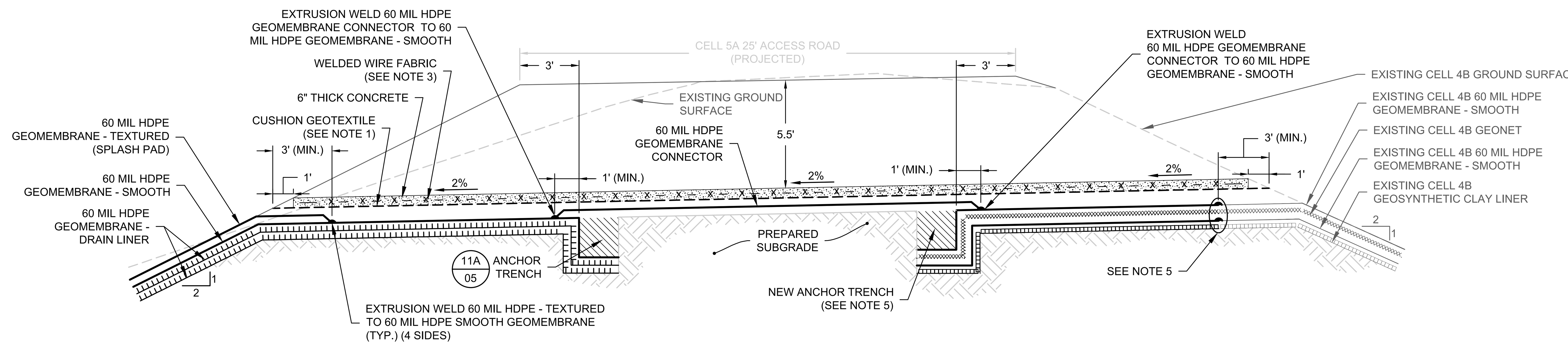
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER
No. 6020077-2202
GREGORY T. CORCORAN
STATE OF UTAH

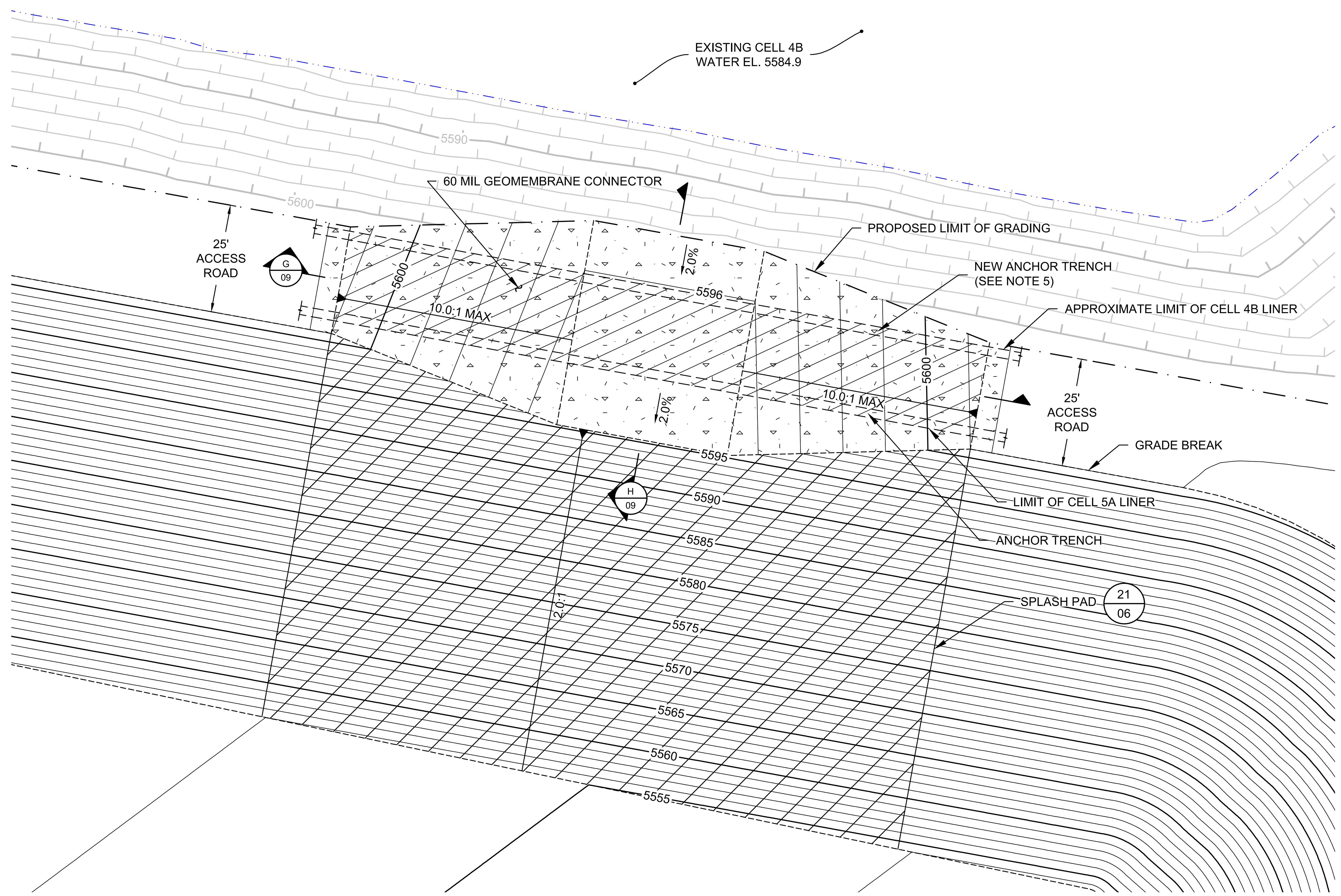
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	08 OF 10	



G / -
SECTION
SPILLWAY - SECTION-5A
SCALE: 1" = 8'



H / -
SECTION
SPILLWAY - SECTION 2-5A
SCALE: 1" = 4'



23 / 03A,04A
PLAN
SPILLWAY PLAN - 5A
SCALE: 1" = 20'

NOTES:

1. CUSHION GEOTEXTILE SHALL BE PLACED OVERLYING PRIMARY GEOMEMBRANE WHERE CONCRETE IS INSTALLED.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
3. WELDED WIRE FABRIC SHALL BE INSTALLED AT CENTER OF CONCRETE SLAB SECTION.
4. SPLASH PAD AT SPILLWAY SHALL BE 150' WIDE, SHALL EXTEND 5' ONTO THE FLOOR AND BE EXTRUSION WELDED ON ALL FOUR (4) SIDES TO PRIMARY GEOMEMBRANE.
5. CUT AND FOLD BACK EXISTING LINER SYSTEM GEOSYNTHETIC LAYERS (60 mil HDPE MEMBRANE, 300 mil GEONET, 60 mil HDPE GEOMEMBRANE, GCL) TO ALLOW EXCAVATION OF SPILLWAY. REPLACE LINER SYSTEM GEOSYNTHETICS LAYERS ONTO NEW SPILLWAY GRADES AND NEW ANCHOR TRENCH. NEW ANCHOR TRENCH SHALL BE TIED INTO EXISTING ANCHOR TRENCH.
6. ANCHOR 60 MIL GEOMEMBRANE CONNECTOR AT TOP OF 10H:1V SLOPE IN 12" DEEP ANCHOR TRENCH.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS V

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

06-29-18
DATE

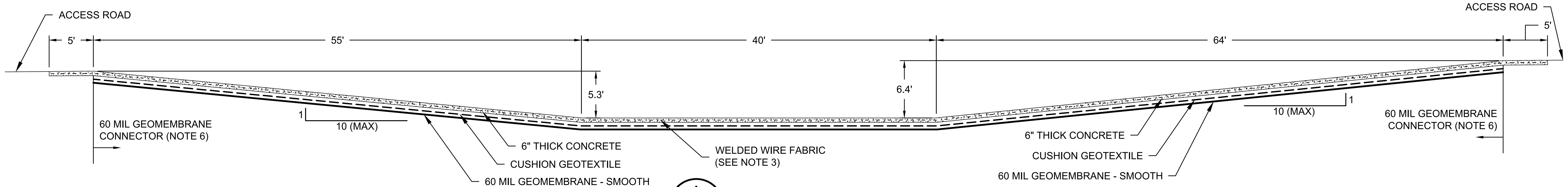
REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	09 OF 10	

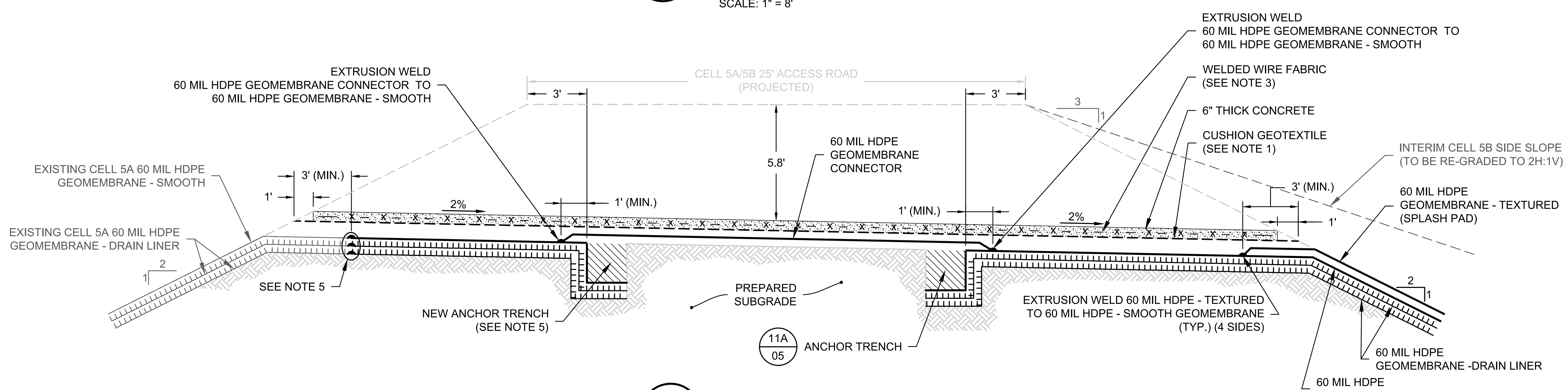
PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

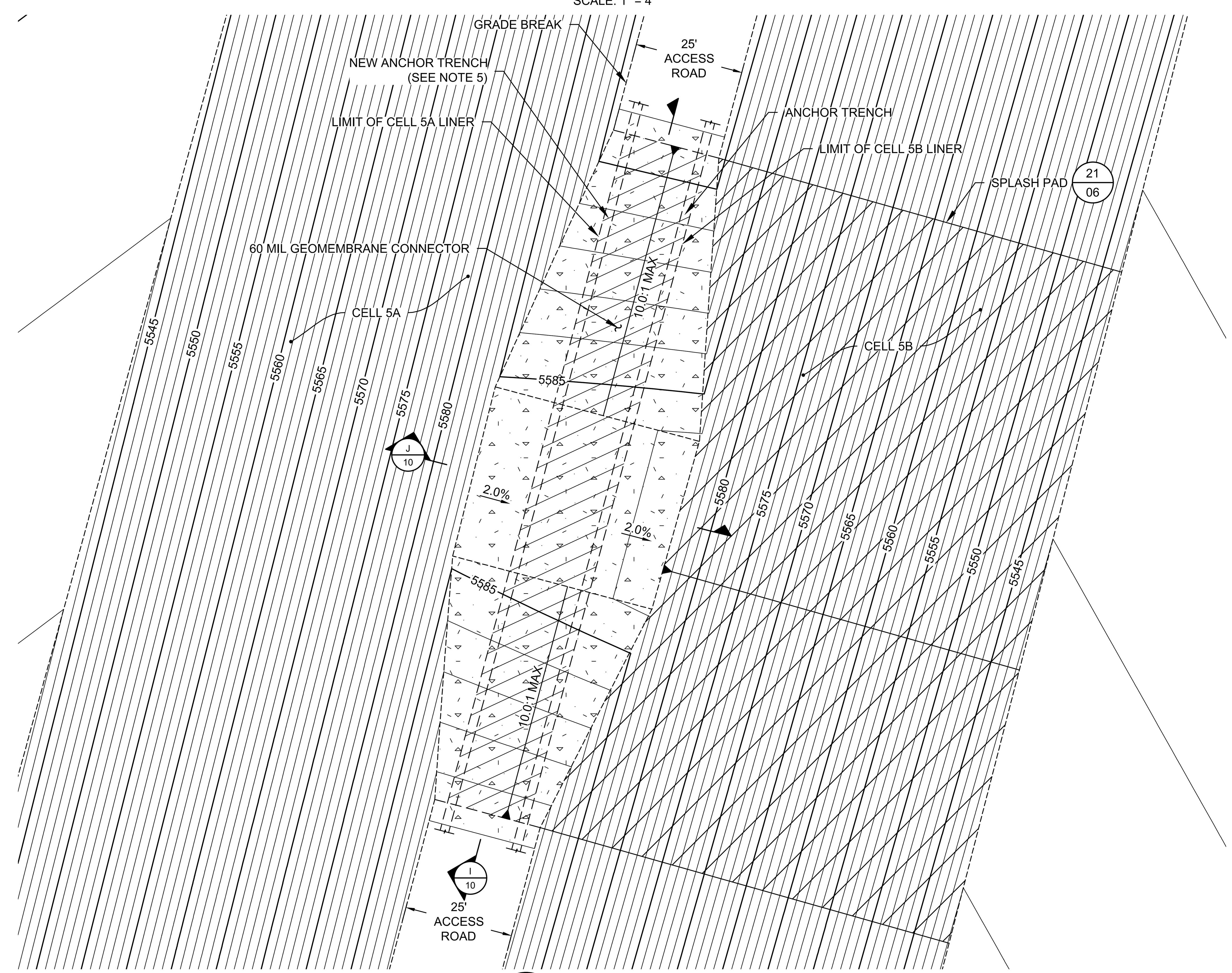
P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634-05-07.dwg Last Edited by: SBerdy on 6/25/2018 3:42 PM



I / -
SECTION
SPILLWAY - SECTION-5B
SCALE: 1" = 8'



J / -
SECTION
SPILLWAY - SECTION 2 - 5B
SCALE: 1" = 4'



24 / 03B,04B
PLAN
SPILLWAY PLAN - 5B
SCALE: 1" = 20'

NOTES:

1. CUSHION GEOTEXTILE SHALL BE PLACED OVERLYING PRIMARY GEOMEMBRANE WHERE CONCRETE IS INSTALLED.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
3. WELDED WIRE FABRIC SHALL BE INSTALLED AT CENTER OF CONCRETE SLAB SECTION.
4. SPLASH PAD AT SPILLWAY SHALL BE 159' WIDE, SHALL EXTEND 5' ONTO THE FLOOR AND BE EXTRUSION WELDED ON ALL FOUR (4) SIDES TO PRIMARY GEOMEMBRANE.
5. CUT AND FOLD BACK EXISTING LINER SYSTEM GEOSYNTHETIC LAYERS (60 mil HDPE MEMBRANE, 300 mil GEONET, 60 mil HDPE GEOMEMBRANE, GCL) TO ALLOW EXCAVATION OF SPILLWAY. REPLACE LINER SYSTEM GEOSYNTHETICS LAYERS ONTO NEW SPILLWAY GRADES AND NEW ANCHOR TRENCH. NEW ANCHOR TRENCH SHALL BE TIED INTO EXISTING ANCHOR TRENCH.
6. ANCHOR 60 MIL GEOMEMBRANE CONNECTOR AT TOP OF 10H:1V SLOPE IN 12" DEEP ANCHOR TRENCH.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS VI

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	10 OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

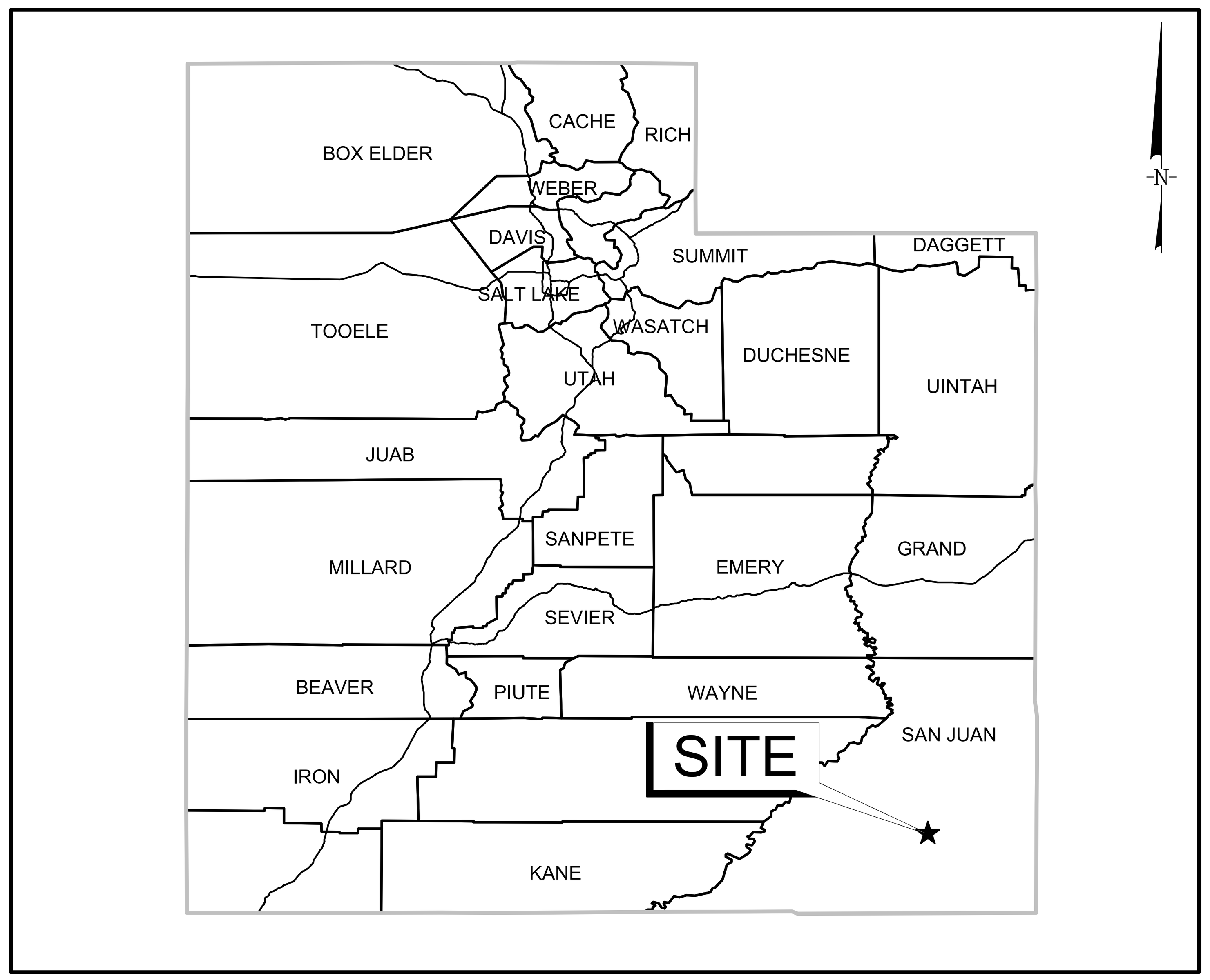
(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

APPENDIX A-2

Construction Drawings

Option B – Double Liner with Geosynthetic Clay Liner

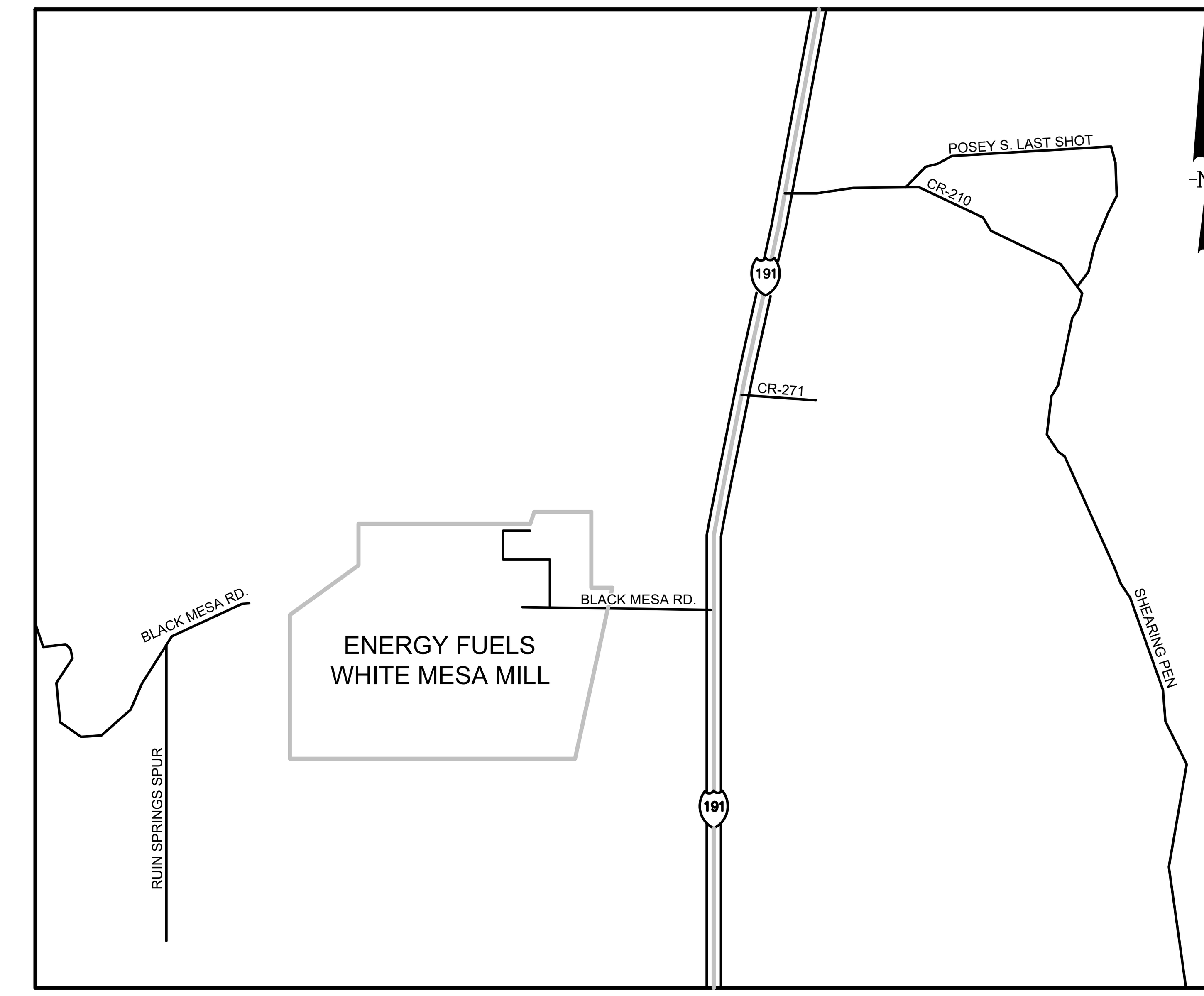
PERMIT LEVEL DESIGN DRAWINGS
CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL
ENERGY FUELS WHITE MESA MILL
BLANDING, UTAH
JUNE 2018



VICINITY MAP
NOT TO SCALE

LIST OF DRAWINGS

DRAWING	DESCRIPTION
01	TITLE SHEET
02	SITE PLAN
03A	CELL 5A PROPOSED GRADING
03B	CELL 5B PROPOSED GRADING
04A	PIPE LAYOUT PLAN AND DETAILS - CELL 5A
04B	PIPE LAYOUT PLAN AND DETAILS - CELL 5B
05	LINER SYSTEM DETAILS I
06	LINER SYSTEM DETAILS II
07	DETAILS & SECTIONS III
08	DETAILS & SECTIONS IV
09	DETAILS & SECTIONS V
10	DETAILS & SECTIONS VI



LOCATION MAP
NOT TO SCALE

DETAIL NUMBER
4
6
SHEET ON WHICH ABOVE DETAIL IS PRESENTED

DETAIL NUMBER
SHEET ON WHICH ABOVE DETAIL WAS FIRST REFERENCED
4
3
DETAIL
TITLE OF DETAIL
SCALE: 1"=2'

EXAMPLE: DETAIL NUMBER 4 PRESENTED ON SHEET NO. 6 WAS REFERENCED FOR THE FIRST TIME ON SHEET NO. 3.

DETAIL IDENTIFICATION LEGEND

(ABOVE SYSTEM ALSO APPLIES TO SECTION IDENTIFICATIONS, HOWEVER, LETTERS ARE USED INSTEAD OF NUMBERS.)

PREPARED FOR:

Energy Fuels Resources (USA) Inc.

ENERGY FUELS RESOURCES (USA) INC.
6425 S. HIGHWAY 191
P.O. BOX 809
BLANDING, UTAH 84511
(306) 628-7798

PREPARED BY:

Geosyntec consultants

GEOSYNTEC CONSULTANTS
16644 WEST BERNARDO DRIVE, SUITE 301
SAN DIEGO, CALIFORNIA 92127
(858) 674-6559

(3in) (2in) (1in) (1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUITE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: TITLE SHEET

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

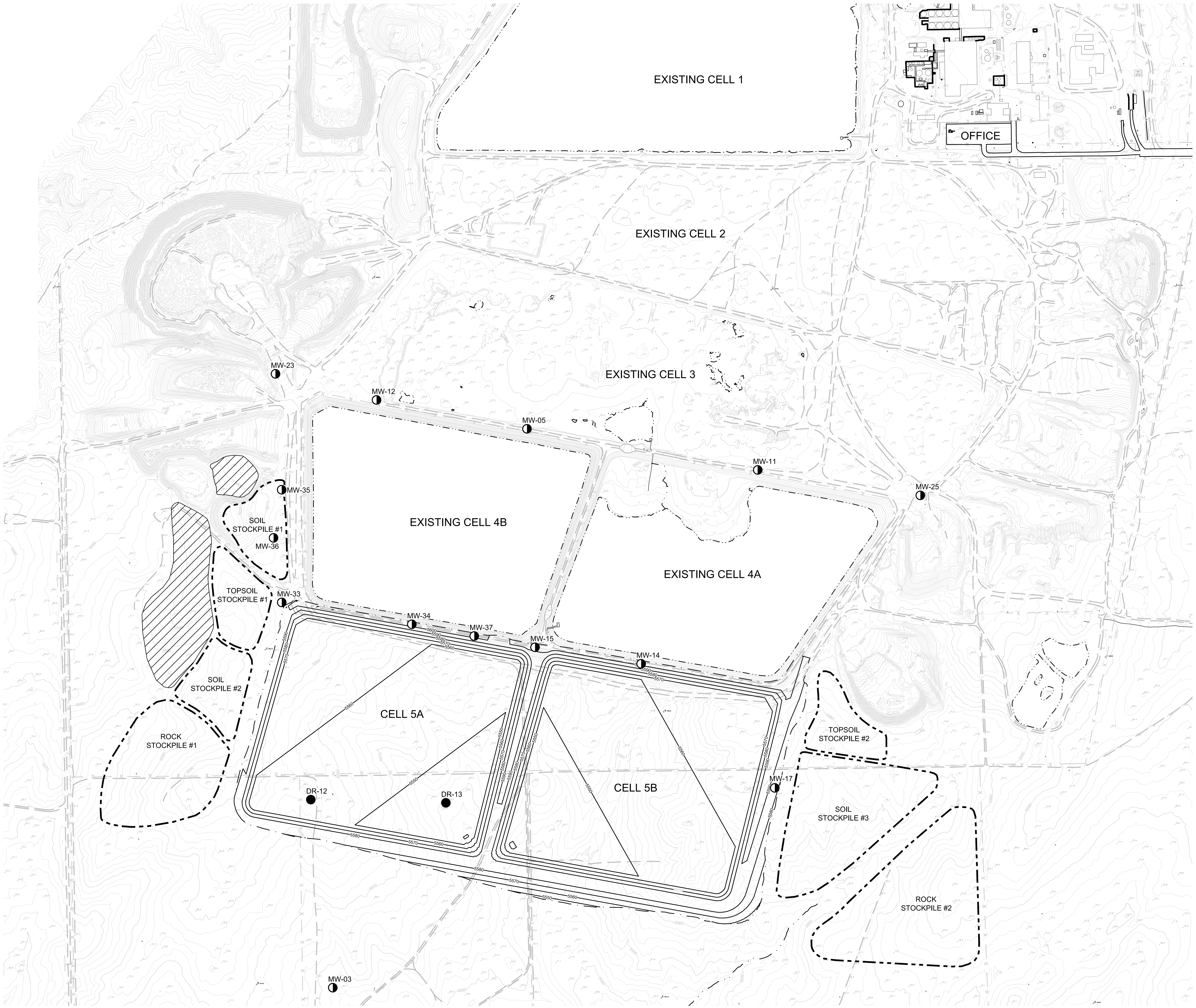
SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-01
REVIEWED BY:	GTC	DRAWING NO.:	01 OF 10
APPROVED BY:	GTC		



LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- SURFACE WATER BOUNDARY
- SURFACE WATER DRAINAGE
- PROPOSED GRADING MAJOR CONTOUR (10')
- PROPOSED GRADING LIMIT
- PROPOSED STOCKPILE BOUNDARIES
- KNOWN ARCHEOLOGICAL AREAS (SEE NOTE 6)
- DR-13 MW-12 EXISTING GROUNDWATER MONITORING WELLS

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. EXISTING WELLS, PIPING, AND OTHER SITE FEATURES SHALL BE PROTECTED IN PLACE, EXCEPT AS NOTED OTHERWISE.
3. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL, AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
4. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
5. CONSTRUCTION WATER TO BE PROVIDED BY OWNER AT NORTHEAST CORNER OF CELL 4A.
6. CONTRACTOR TO AVOID KNOWN ARCHEOLOGICAL AREAS. OWNER TO CLEAR ARCHEOLOGICAL AREAS WITHIN LIMITS OF WORK PRIOR TO BEGINNING EXCAVATION.

N

0 300' 600'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: SITE PLAN

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-02
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	02 OF 10	

PERMIT LEVEL DESIGN
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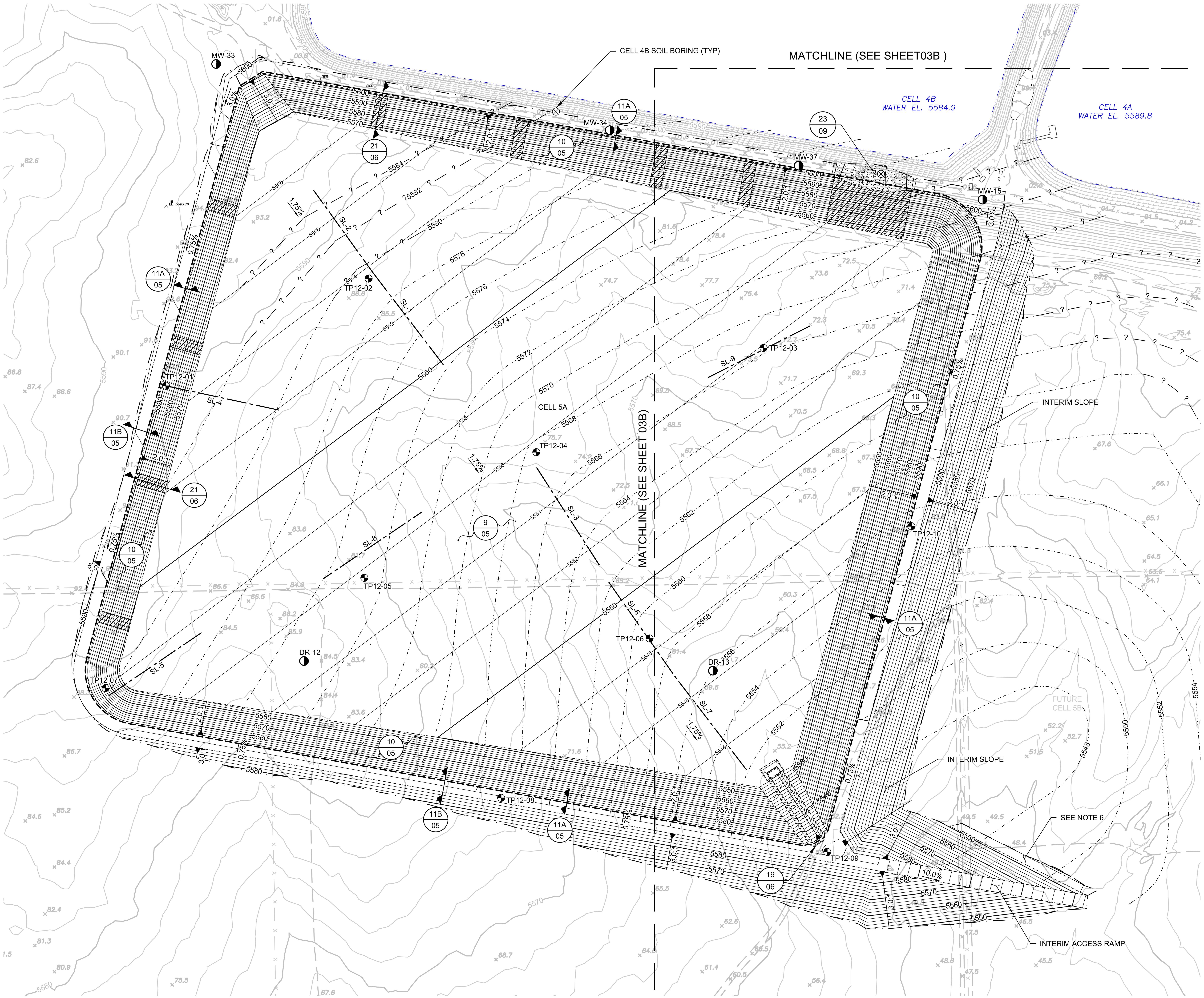
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



LEGEND

5570	JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
	EXISTING DIRT ROAD
x — x	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	PROPOSED GRADE BREAK
	LIMIT OF LINER SYSTEM
5570	APPROXIMATE TOP OF ROCK CONTOUR (1') (SEE NOTES 4 AND 5)
	SPLASH PAD 21/06
TP12-03	EXPLORATORY TRENCH LOCATION
	SEISMIC LINE LOCATIONS (SEE NOTE 4)
	CELL 4B SOIL BORINGS (SEE NOTE 4)
MW-33	EXISTING GROUNDWATER MONITOR WELL

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
4. SEISMIC LINE DATA AND CELL 4B BORINGS ARE PROVIDED IN SECTION 02200 OF THE TECHNICAL SPECIFICATIONS.
5. ROCK SURFACE IS APPROXIMATE AND BASED ON TRENCHES PERFORMED AT THE SITE. WHERE QUESTION MARKS ARE SHOWN, SURFACE IS ESTIMATED AND NOT BASED ON TRENCHES.
6. LOCALLY GRADE AREA NORTH OF BERM TO DRAIN AROUND BERM.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: CELL 5A PROPOSED GRADING

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

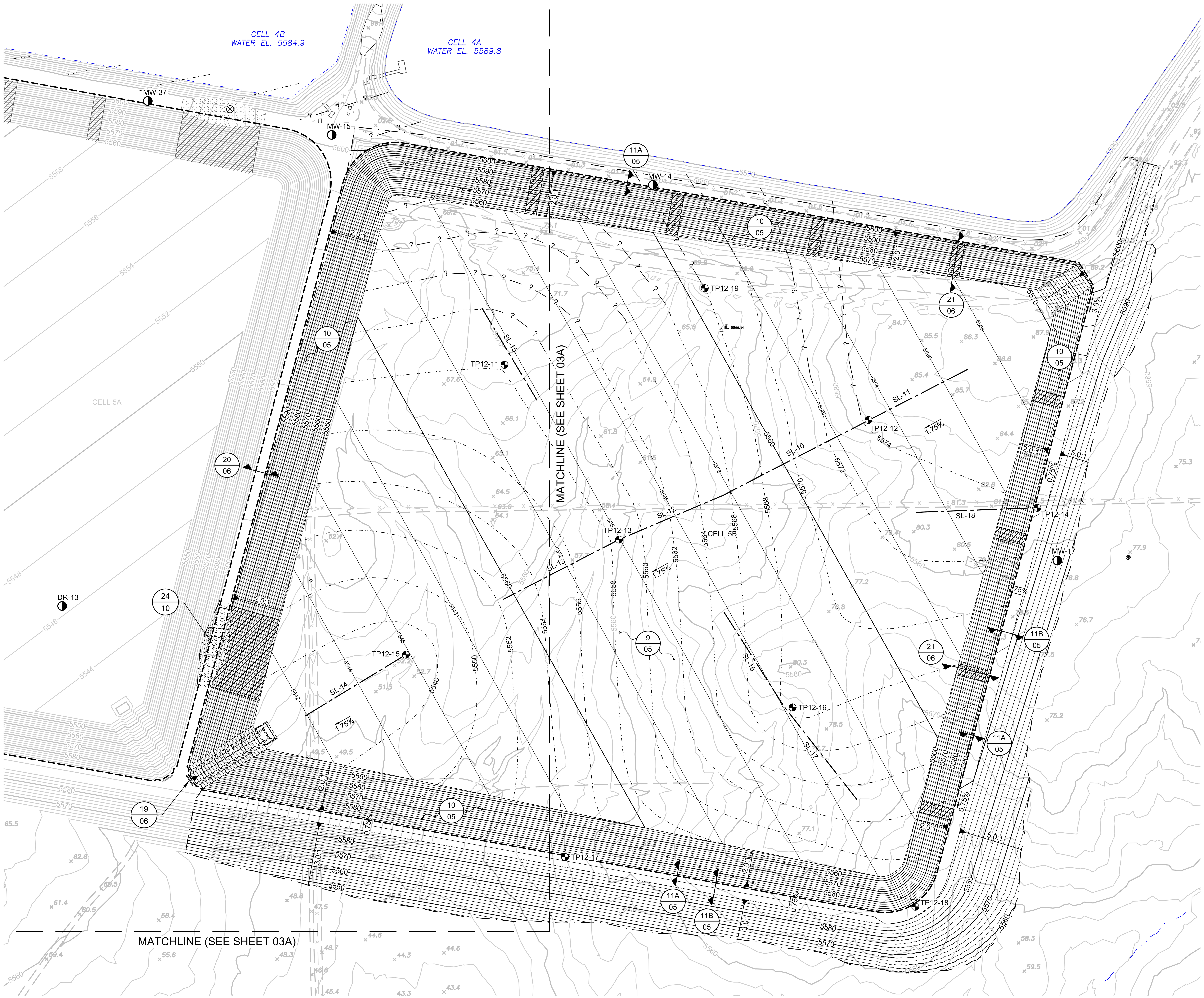
SIGNATURE 06-29-18 DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	03A OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

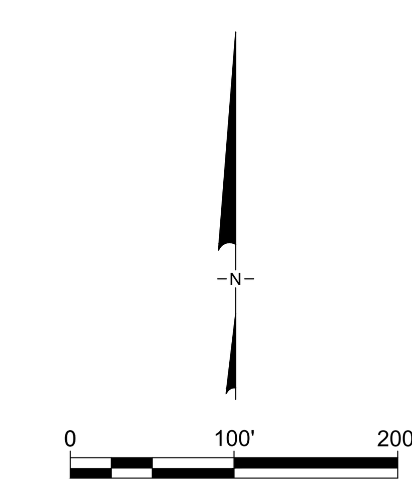


LEGEND

5570	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
	EXISTING DIRT ROAD
x x	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	PROPOSED GRADE BREAK
	LIMIT OF LINER
5570	APPROXIMATE TOP OF ROCK CONTOUR (1') (SEE NOTES 4 AND 5)
	SPLASH PAD 21/06
TP12-03	EXPLORATORY TRENCH LOCATION
	SEISMIC LINE LOCATIONS (SEE NOTE 4)
⊗	CELL 4B SOIL BORINGS (SEE NOTE 4)
MW-33	EXISTING GROUNDWATER MONITORING WELL

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
4. SEISMIC LINE DATA AND CELL 4B BORINGS ARE PROVIDED IN SECTION 02200 OF THE TECHNICAL SPECIFICATIONS.
5. ROCK SURFACE IS APPROXIMATE AND BASED ON TRENCHES PERFORMED AT THE SITE. WHERE QUESTION MARKS ARE SHOWN, SURFACE IS ESTIMATED AND NOT BASED ON TRENCHES.



REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: **CELL 5B PROPOSED GRADING**

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

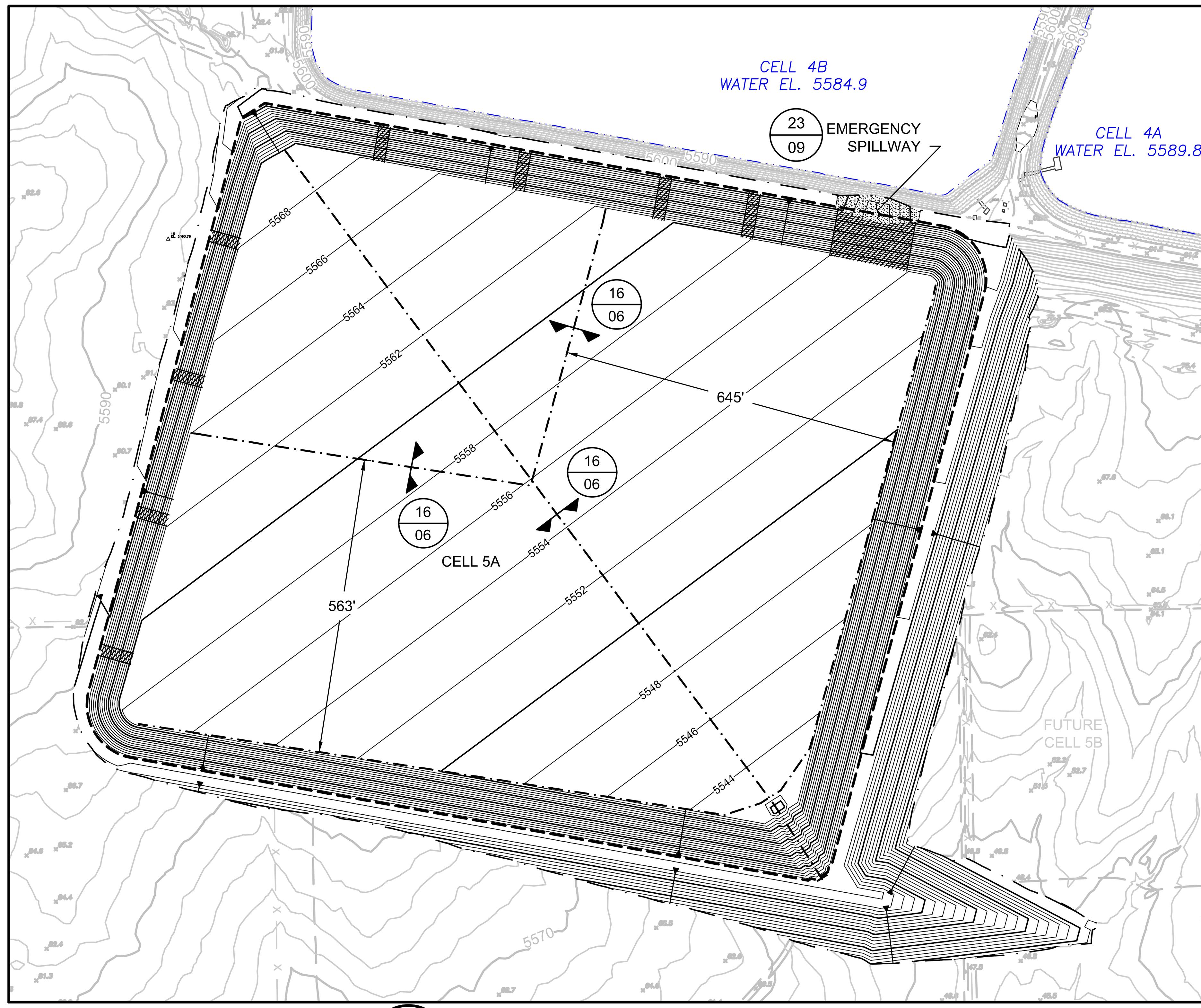
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

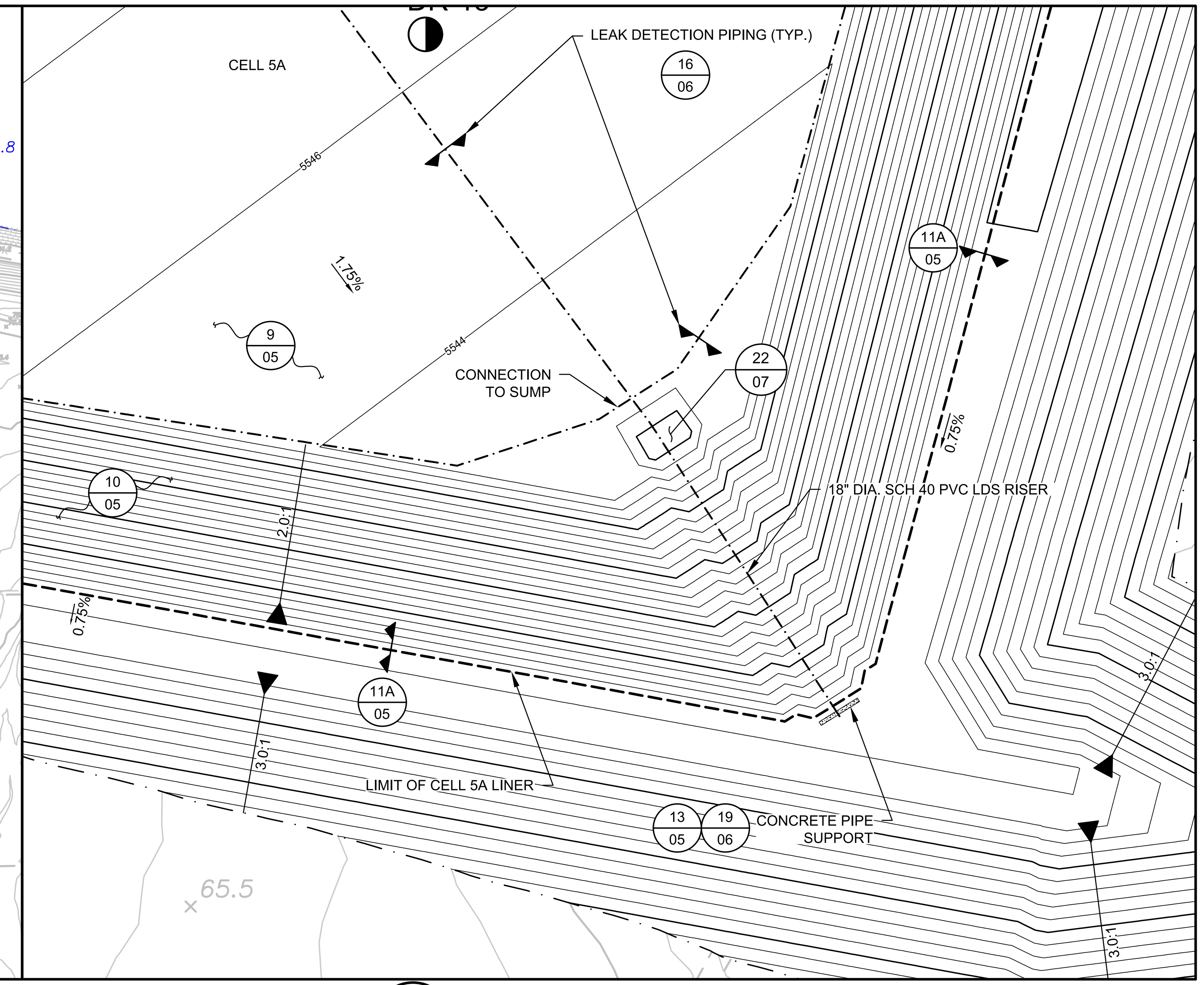
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	03B OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

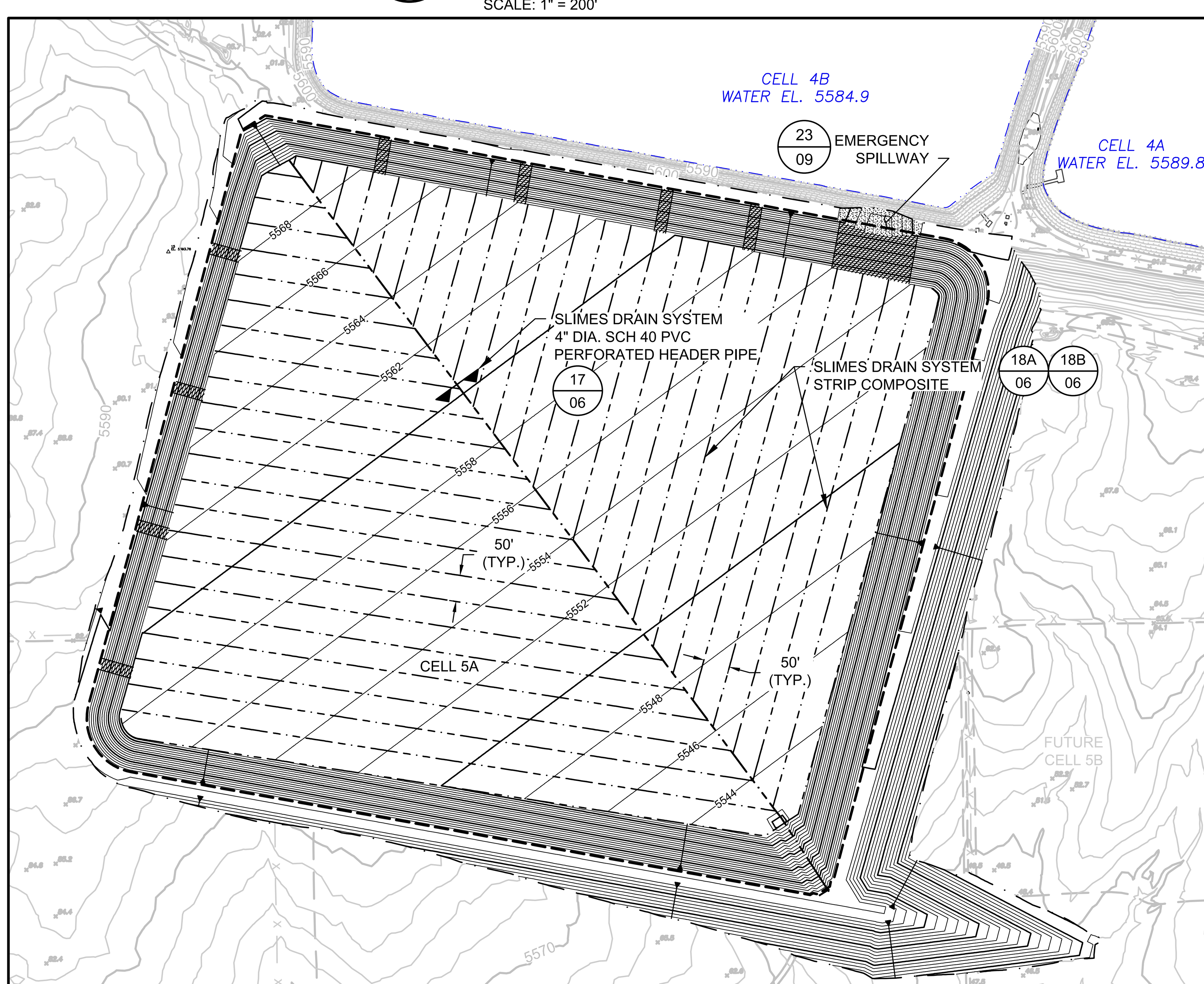
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



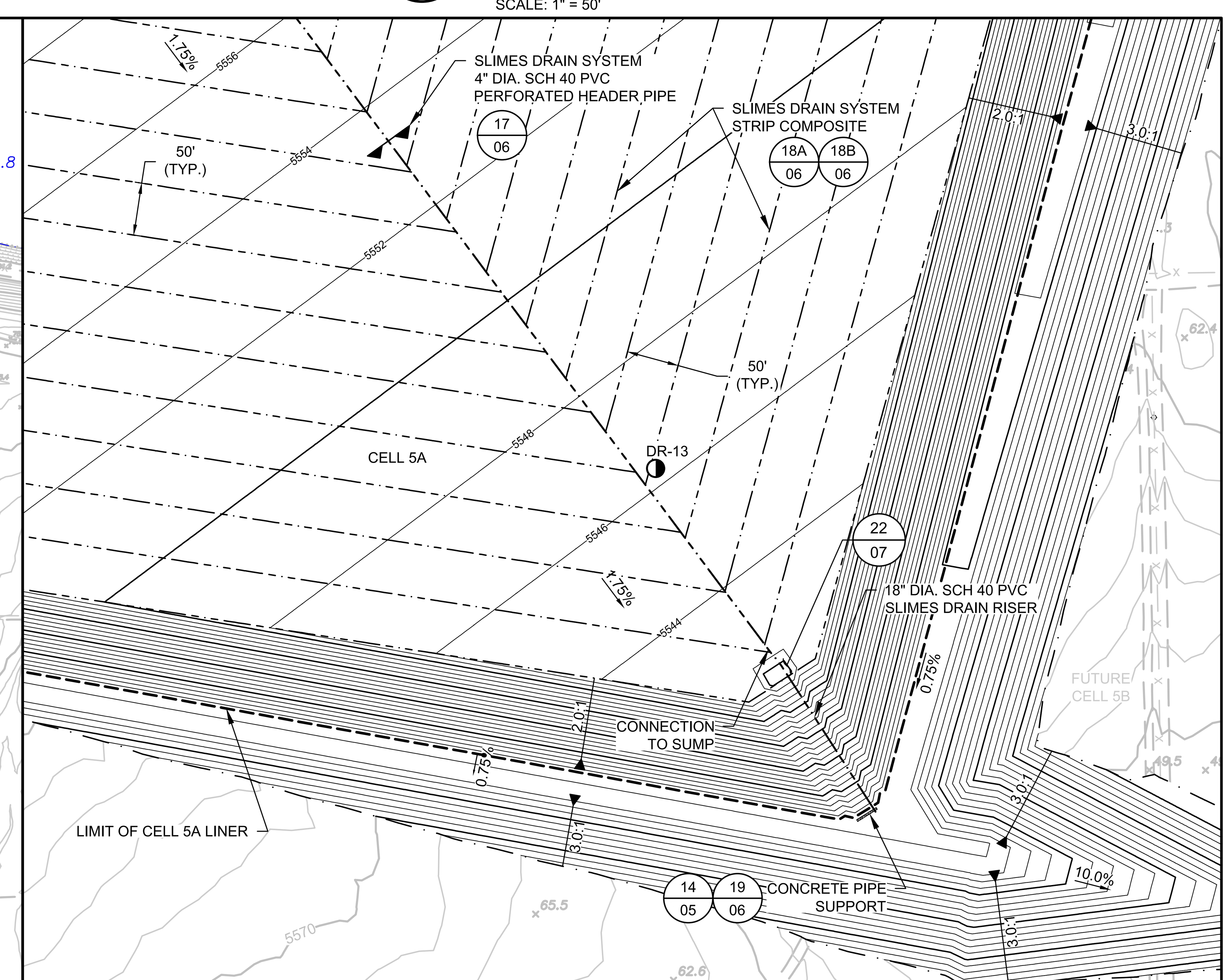
1 PLAN
CELL 5A LEAK DETECTION SYSTEM
SCALE: 1" = 200'



2 DETAIL
CELL 5A LEAK DETECTION SYSTEM
SCALE: 1" = 50'



3 PLAN
CELL 5A SLIMES DRAIN SYSTEM
SCALE: 1" = 200'



4 DETAIL
CELL 5A SLIMES DRAIN SYSTEM
SCALE: 1" = 100'

LEGEND

- 5570 — JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- 5602 — PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- LIMIT OF LINER SYSTEM
- PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- DR-12 — EXISTING GROUNDWATER MONITOR WELL
- SPLASH PAD (21/06)

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL, AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUITE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5A

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

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SIGNATURE

06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	04A OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

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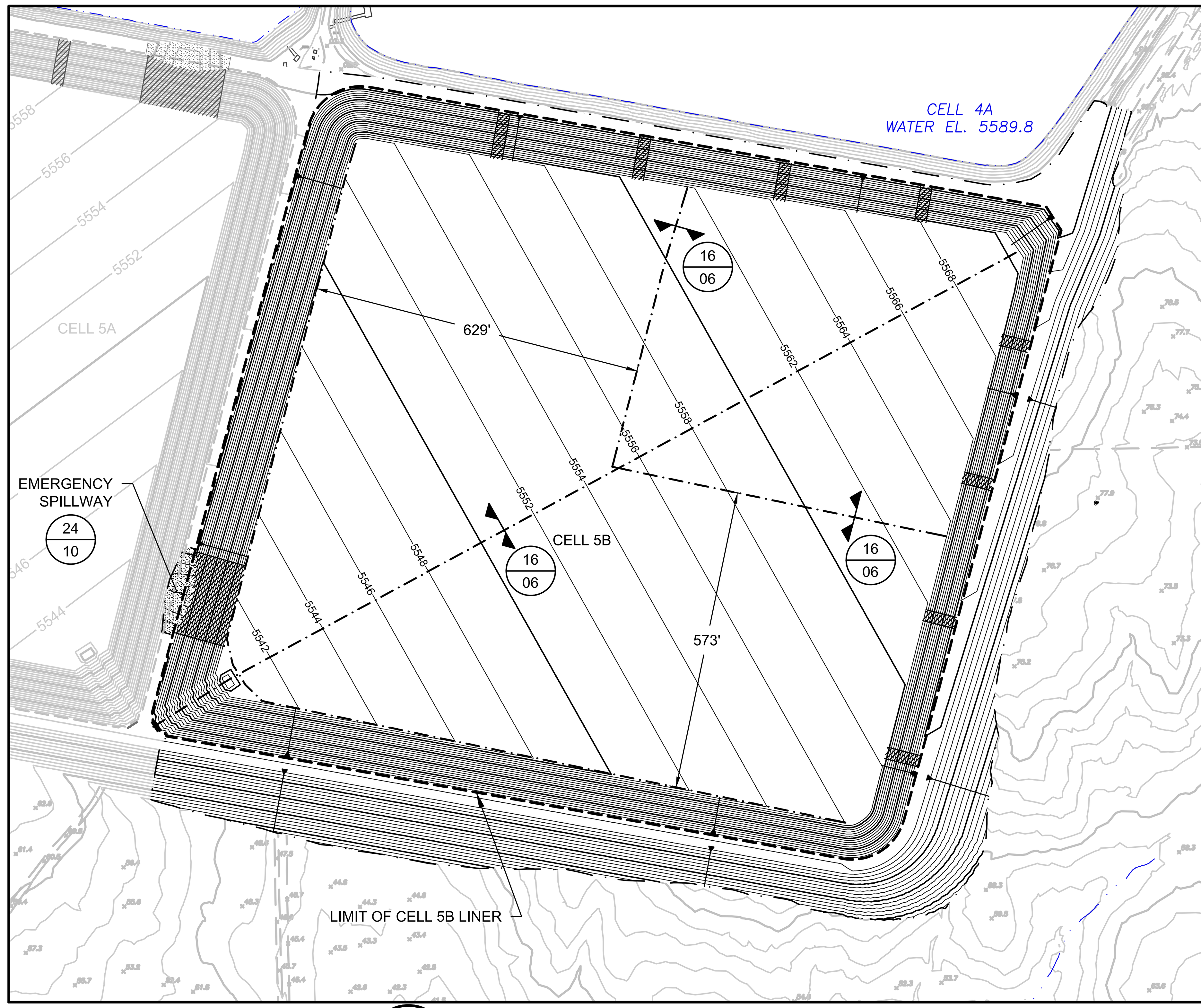
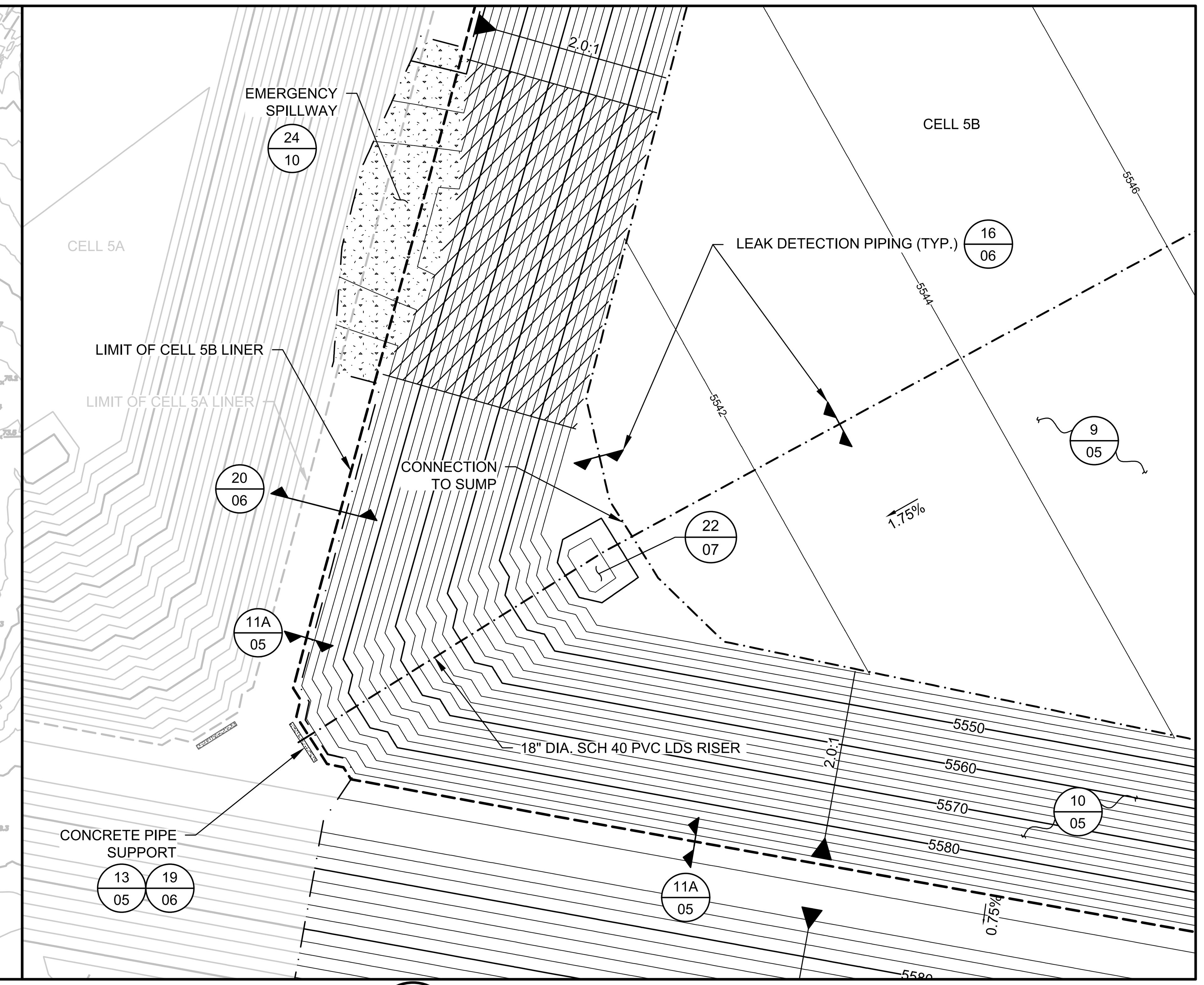


5 PLAN
CELL 5B LEAK DETECTION SYSTEM
SCALE: 1" = 200'



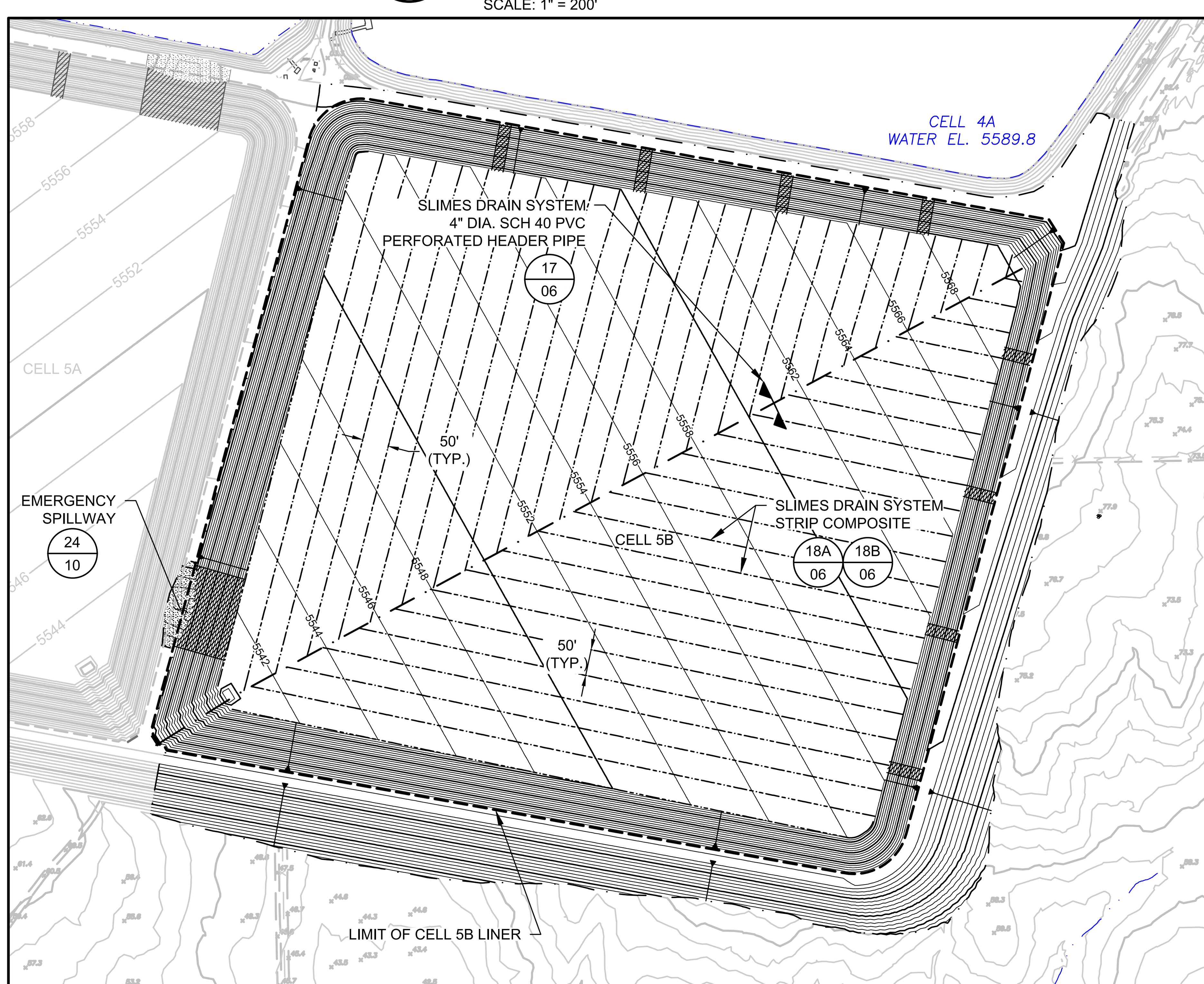
6 DETAIL
CELL 5B LEAK DETECTION SYSTEM
SCALE: 1" = 50'

LEGEND

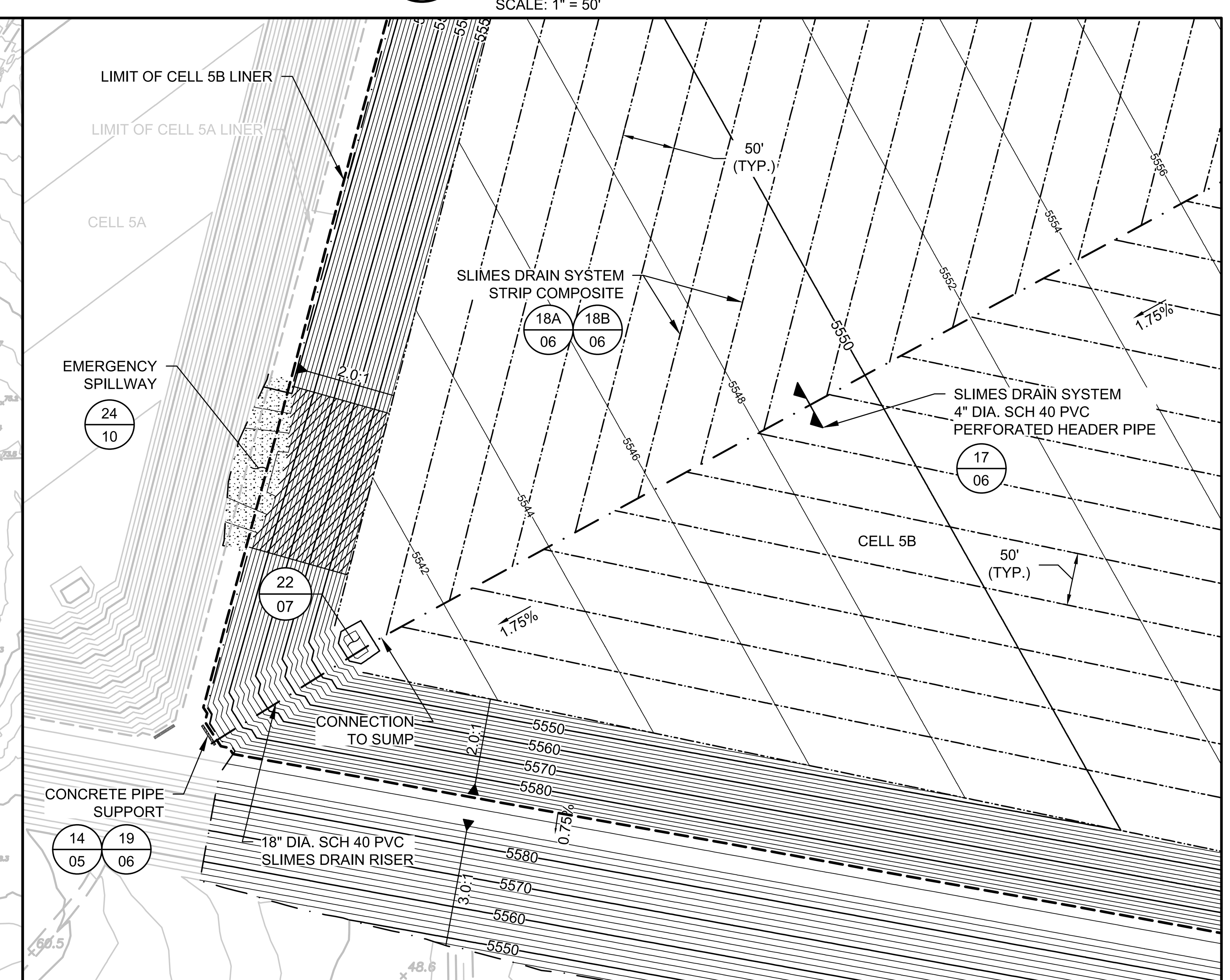
- 5570 — JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- x — x EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- 5602 — PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- LIMIT OF LINER SYSTEM
- PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- SPLASH PAD (21/06)

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL, AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.



7 PLAN
CELL 5B SLIMES DRAIN SYSTEM
SCALE: 1" = 200'



8 DETAIL
CELL 5B SLIMES DRAIN SYSTEM
SCALE: 1" = 100'

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

EF Energy Fuels Resources (USA) Inc.

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5B

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

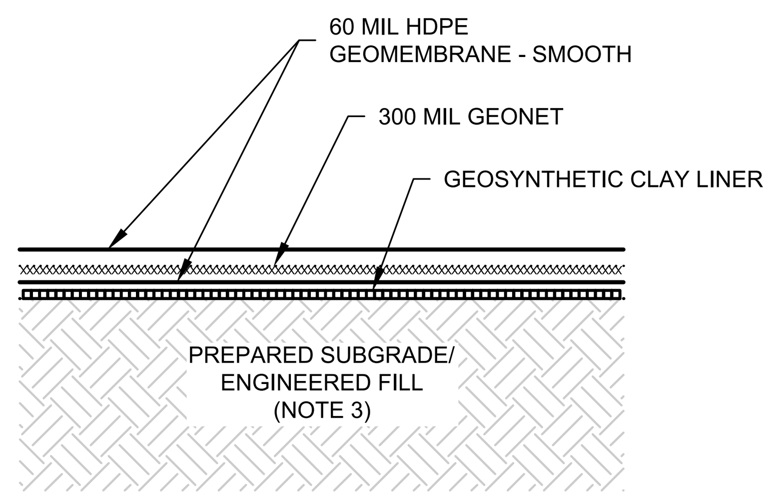
SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

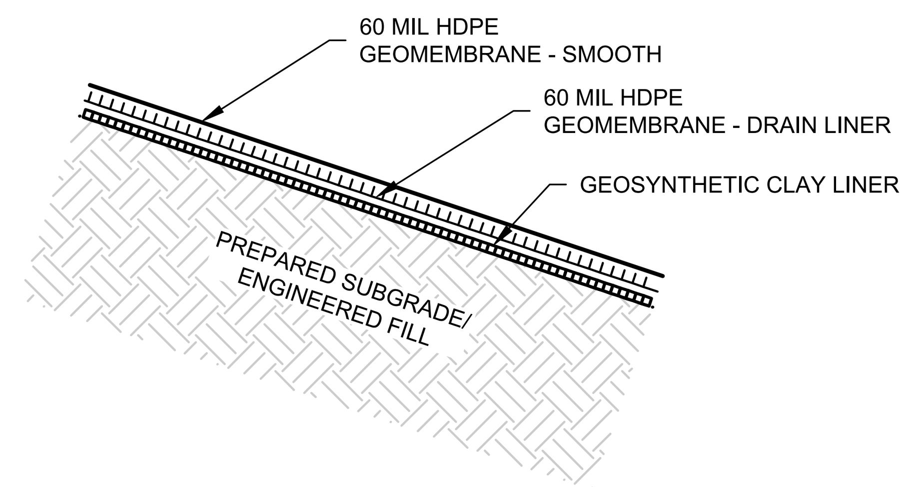
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

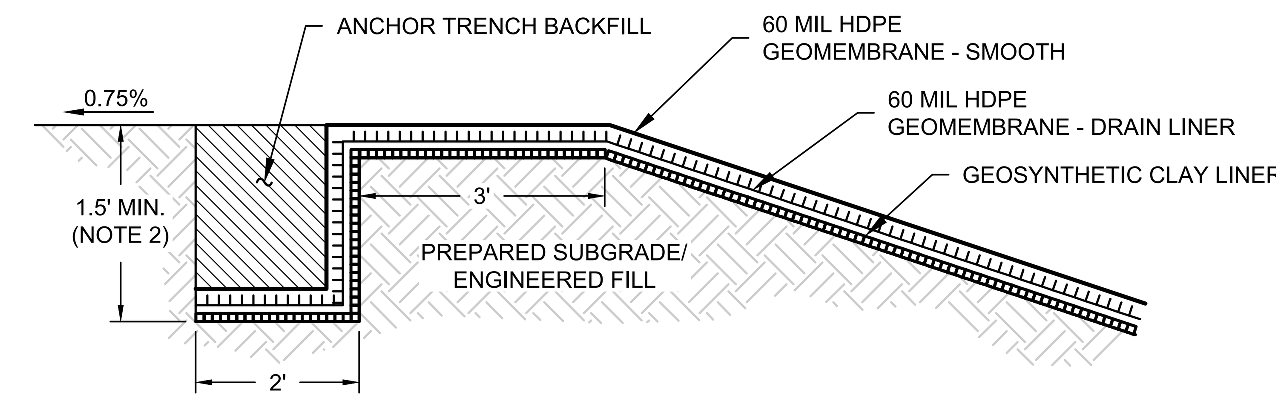
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	04B OF 10	



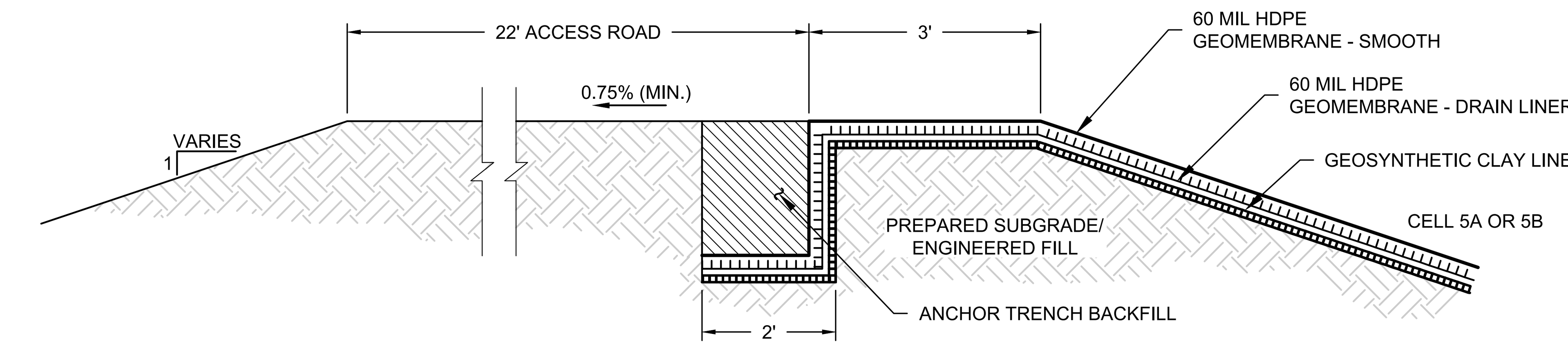
9 DETAIL
03A,03B,04A,04B BASE LINER SYSTEM
SCALE: 1" = 2'



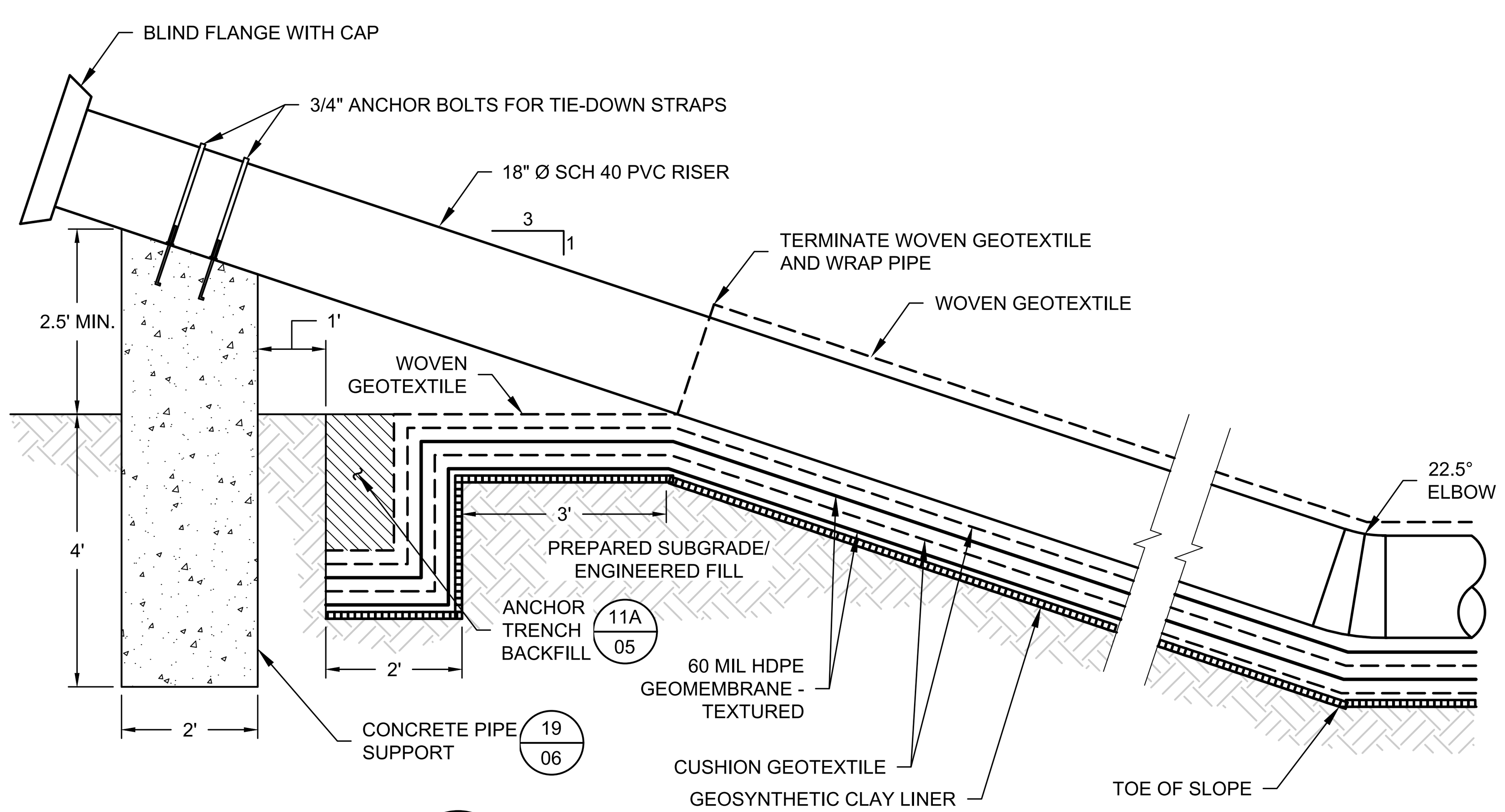
10 DETAIL
03A,03B,04A,04B SIDE SLOPE LINER SYSTEM
SCALE: 1" = 2'



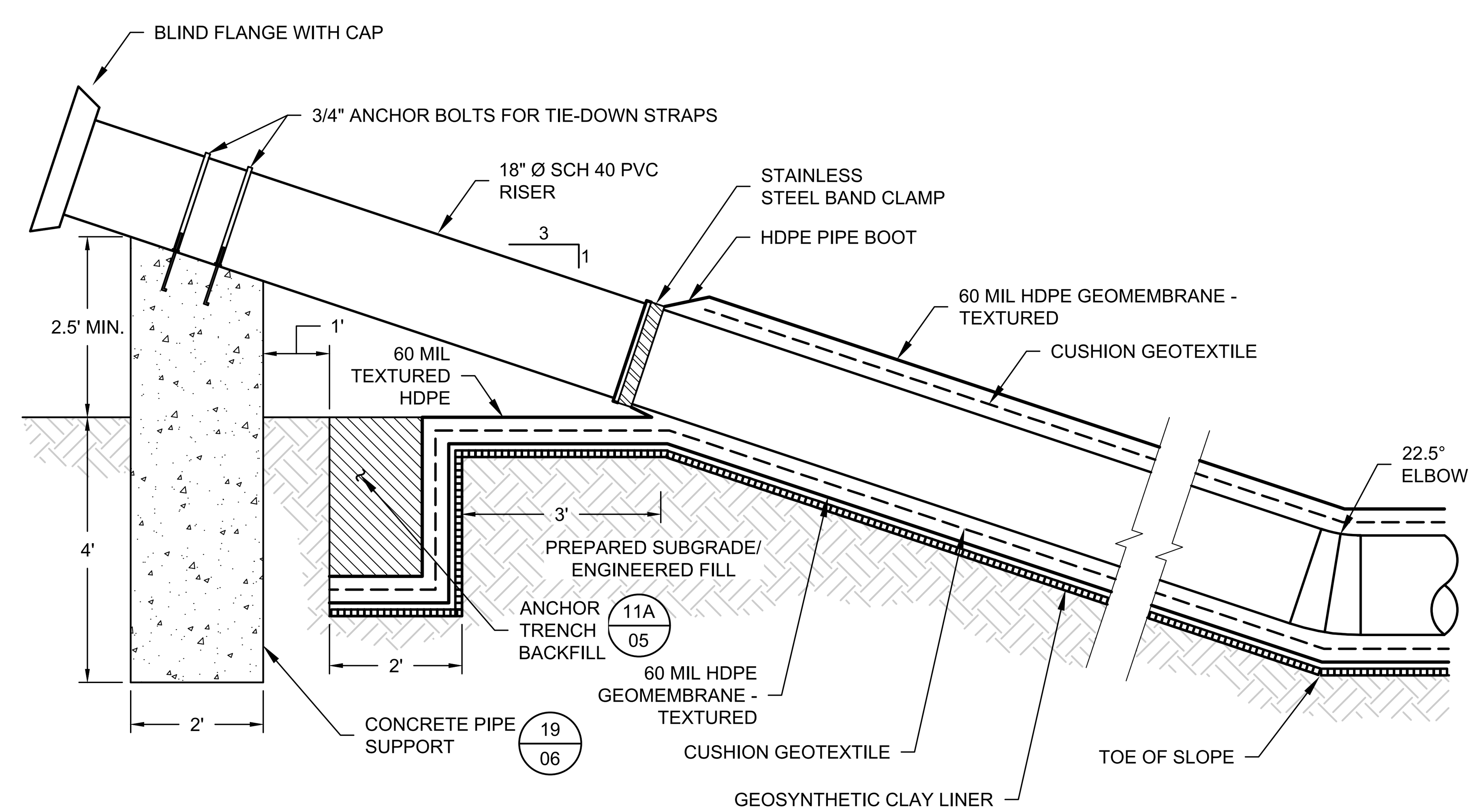
11A DETAIL
03A,03B,04A,04B,05,06,09 ANCHOR TRENCH
SCALE: 1" = 2'



11B DETAIL
03A,03B ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



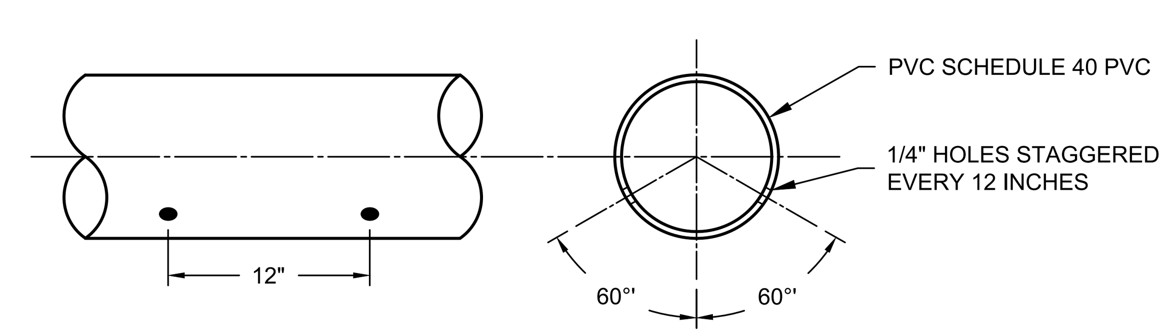
14 DETAIL
04A,04B SLIMES DRAIN RISER PENETRATION
SCALE: 1" = 2'



13 DETAIL
04A,04B LEAK DETECTION SYSTEM RISER PENETRATION
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. ANCHOR TRENCHES MAY BE CONSTRUCTED WITH A MAXIMUM DEPTH OF 3.5 FEET WITH UP TO 1 FOOT OF BACKFILL BETWEEN EACH GEOMEMBRANE IN BOTTOM OF ANCHOR TRENCH.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.



15 DETAIL
07,08 PERFORATED PIPE
SCALE: 1" = 1'

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS I

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION UNLESS SEALED.

SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	05 OF 10	

(3in) (2in) (1in)
(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

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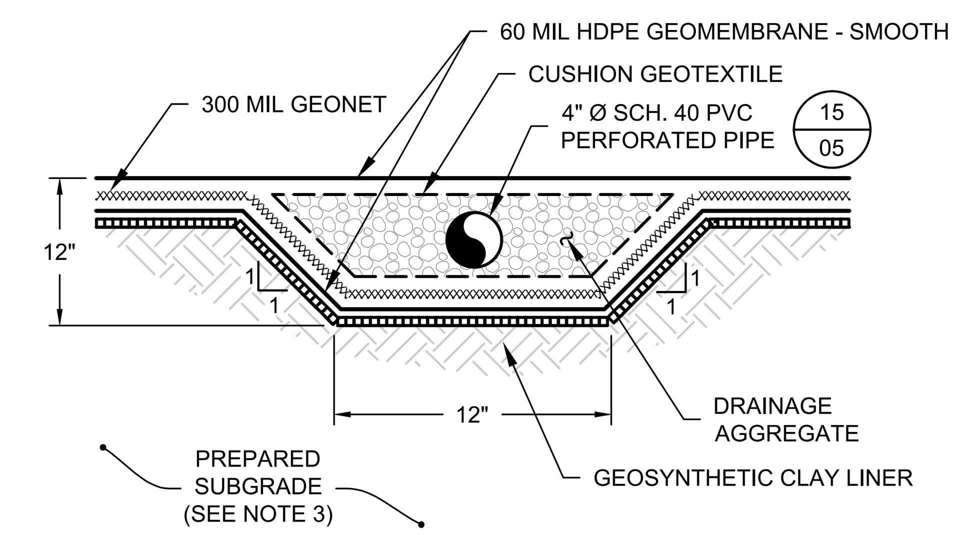
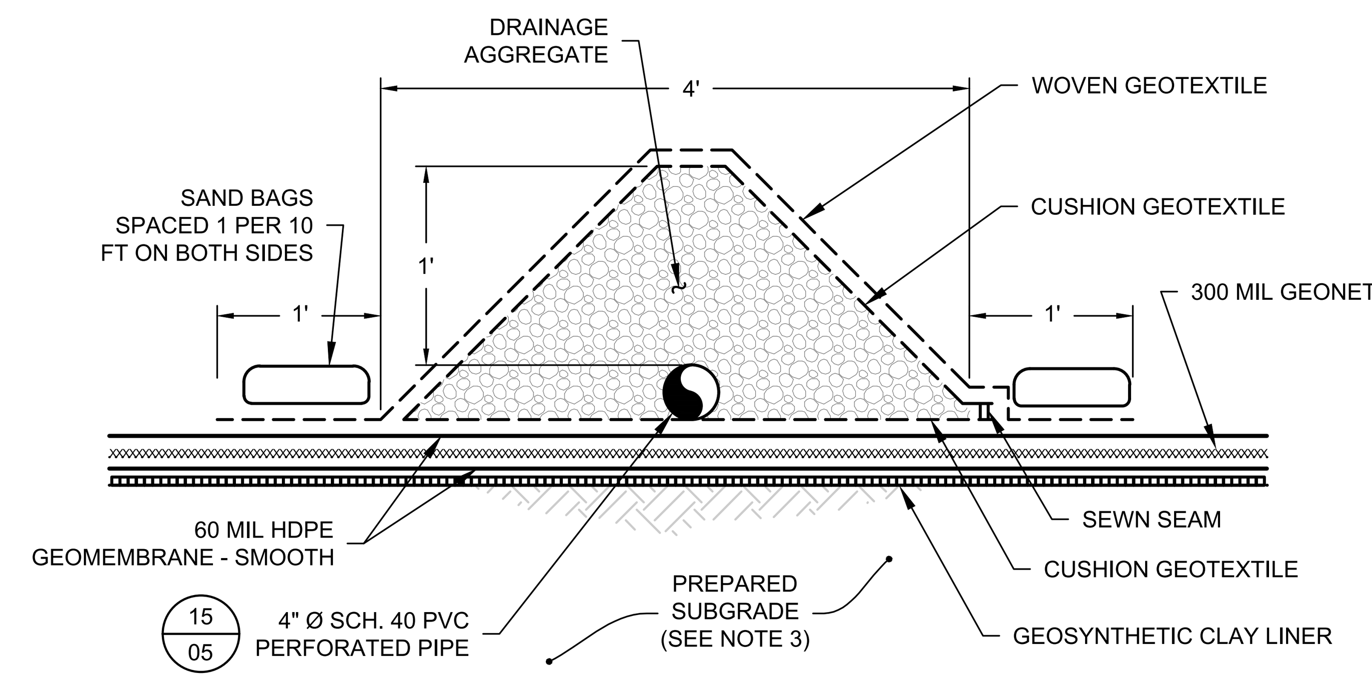
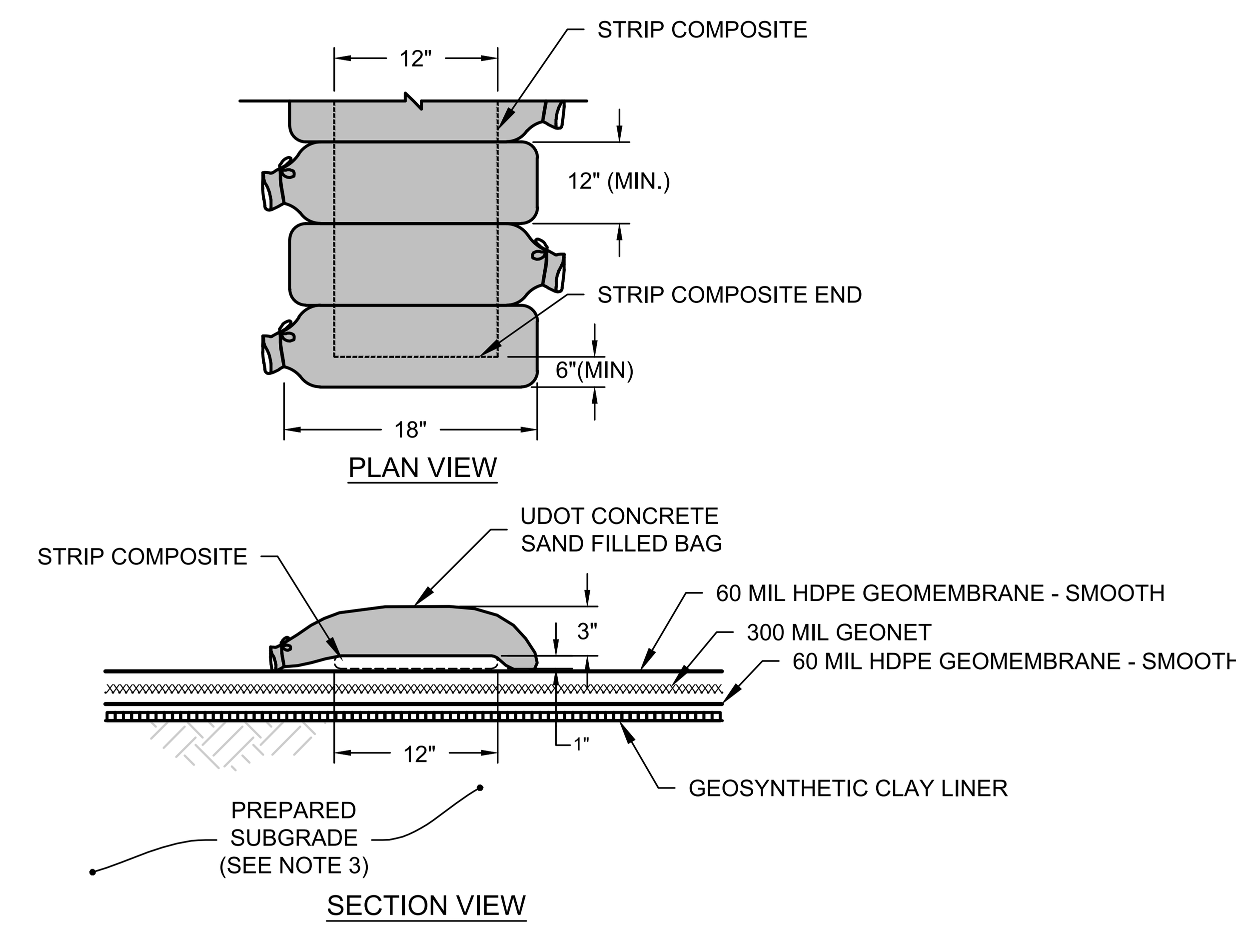


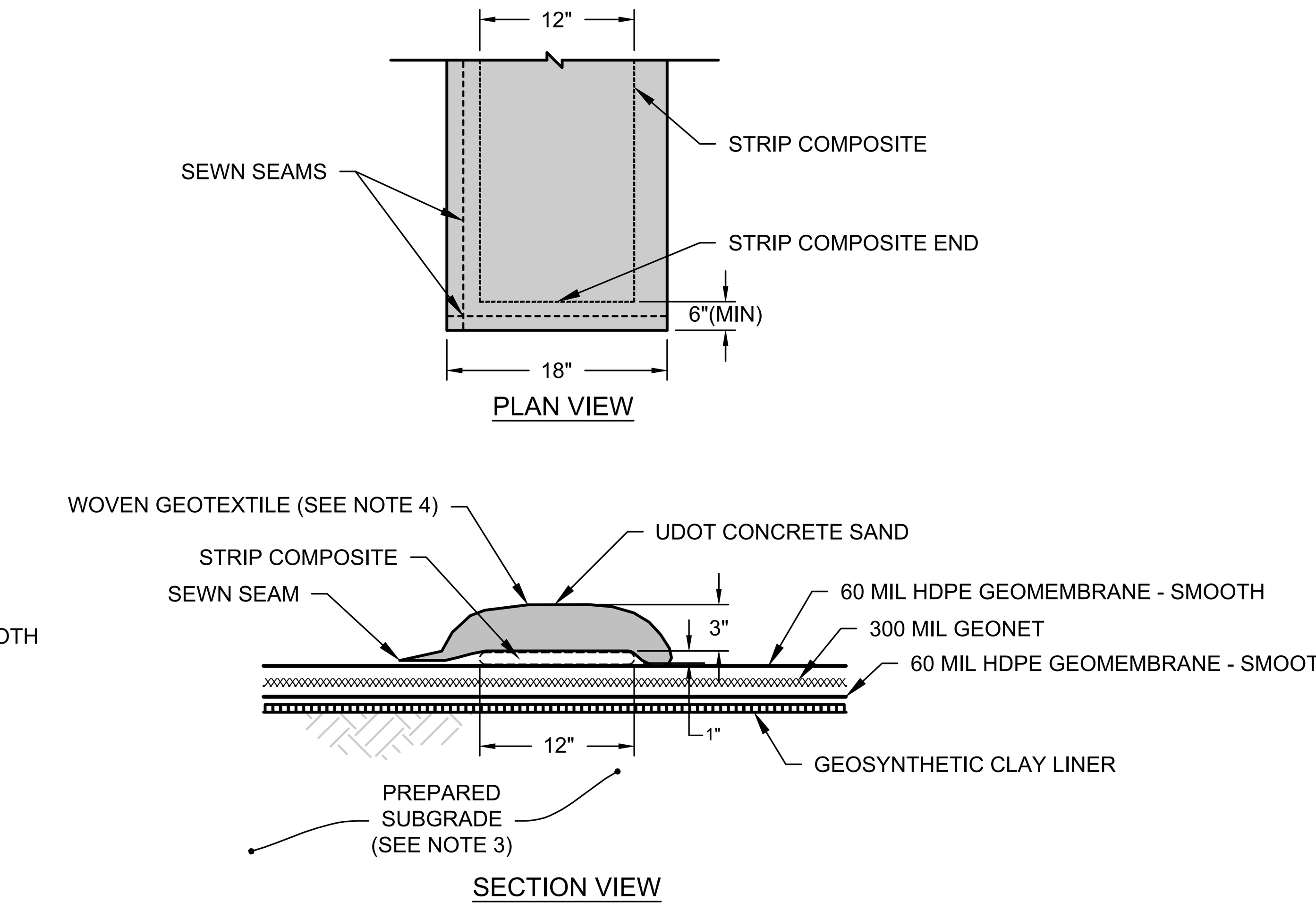
16 DETAIL
04A,04B
LEAK DETECTION SYSTEM TRENCH
SCALE: 1" = 1'



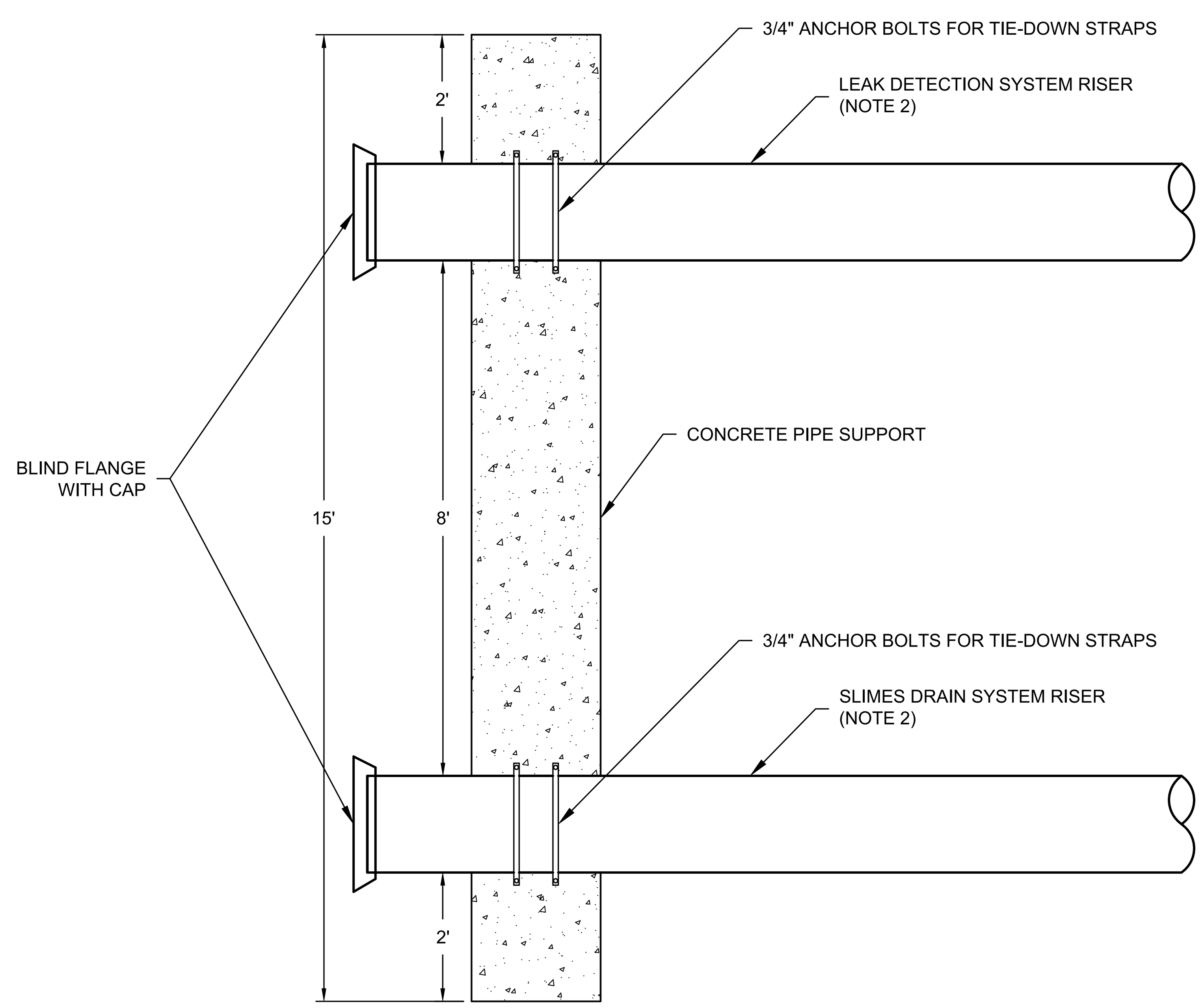
17 DETAIL
04A,04B
SLIMES DRAIN HEADER
SCALE: 1" = 1'



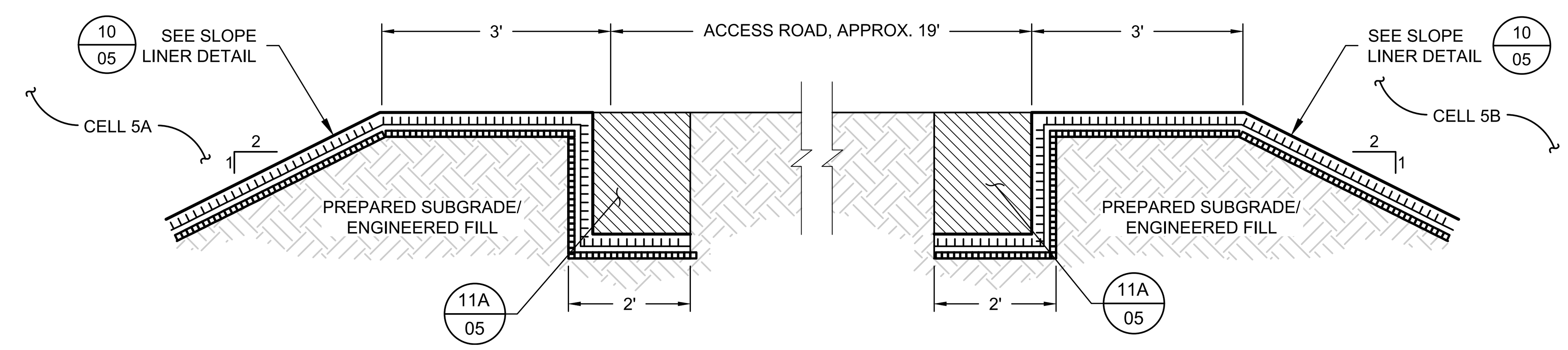
18A DETAIL
04A,04B
SLIMES DRAIN LATERAL - OPTION 1
SCALE: NTS



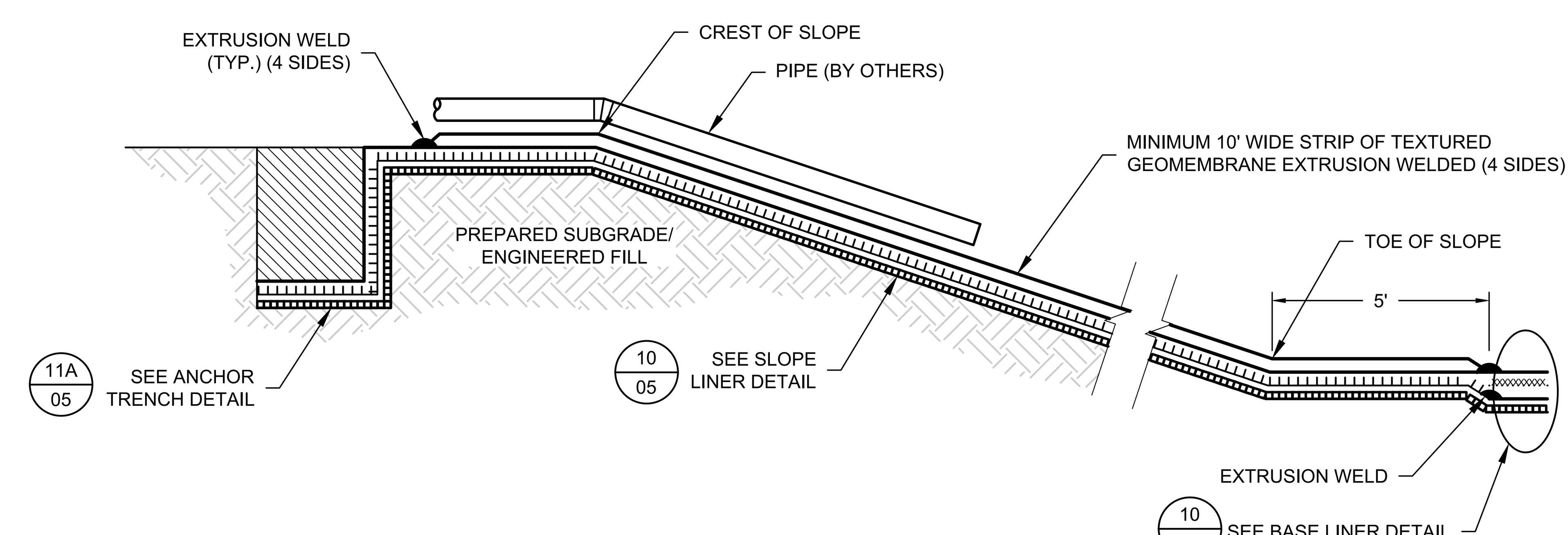
18B DETAIL
04A,04B
SLIMES DRAIN LATERAL - OPTION 2
SCALE: NTS



19 DETAIL
03A,03B,04A,04B
CONCRETE PIPE SUPPORT
SCALE: 1" = 2'



20 DETAIL
03B,04B
CELL 5A - CELL 5B ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



21 DETAIL
03A,03B,04A,04B,09,10
SPLASH PAD DETAIL
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. EXPOSED PVC PIPE SHALL BE PAINTED TO MINIMIZE DAMAGE DUE TO UV.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.
4. WOVEN GEOTEXTILE SHALL BE FOLDED OVER AND SEAMED. GEOTEXTILE SHALL BE FILLED WITH UDOT CONCRETE SAND TO CREATE A CONTINUOUS SANDBAG-LIKE STRUCTURE WITH A MINIMUM OF 3" OF SAND ABOVE STRIP COMPOSITE. ENDS SHALL BE SEAMED FOLLOWING SAND FILLING.

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS II

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

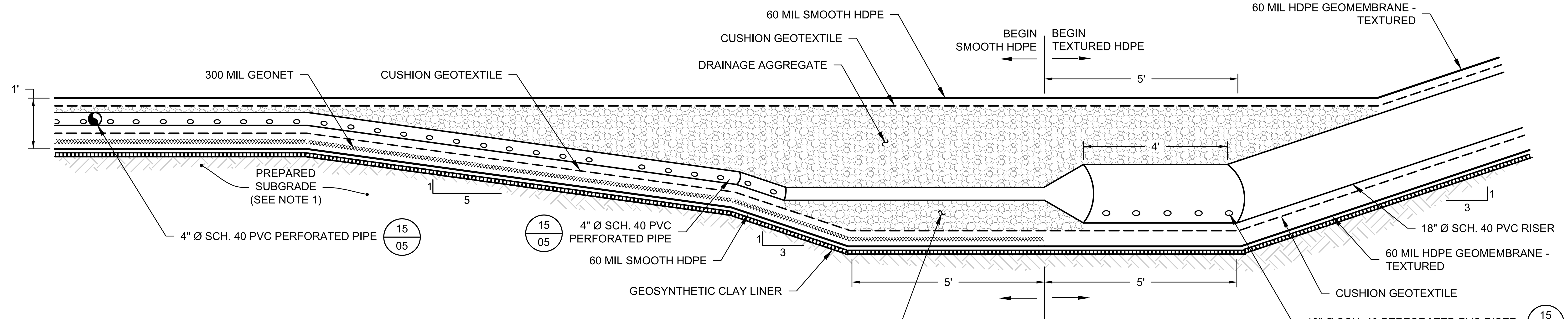
SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

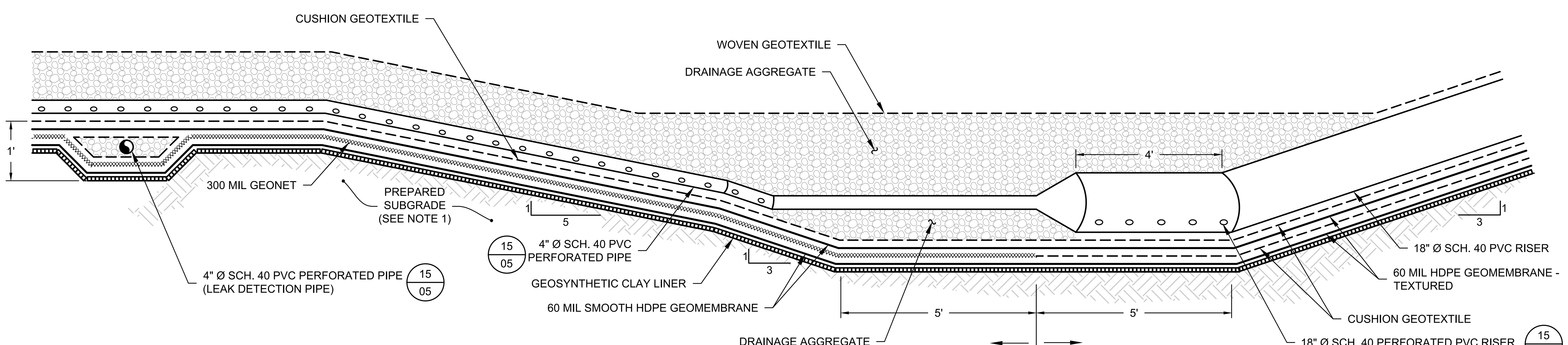
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

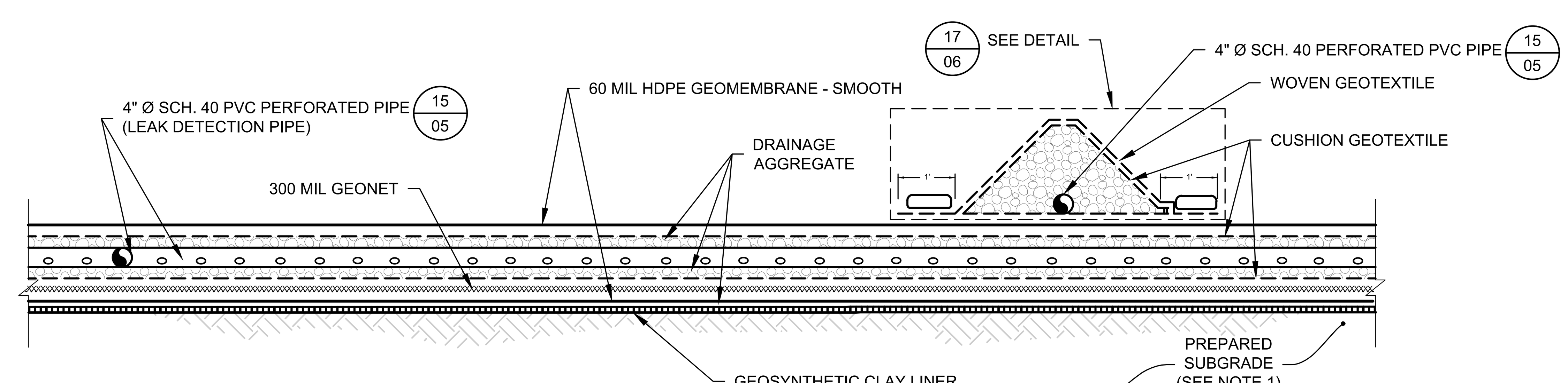
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	06 OF 10	



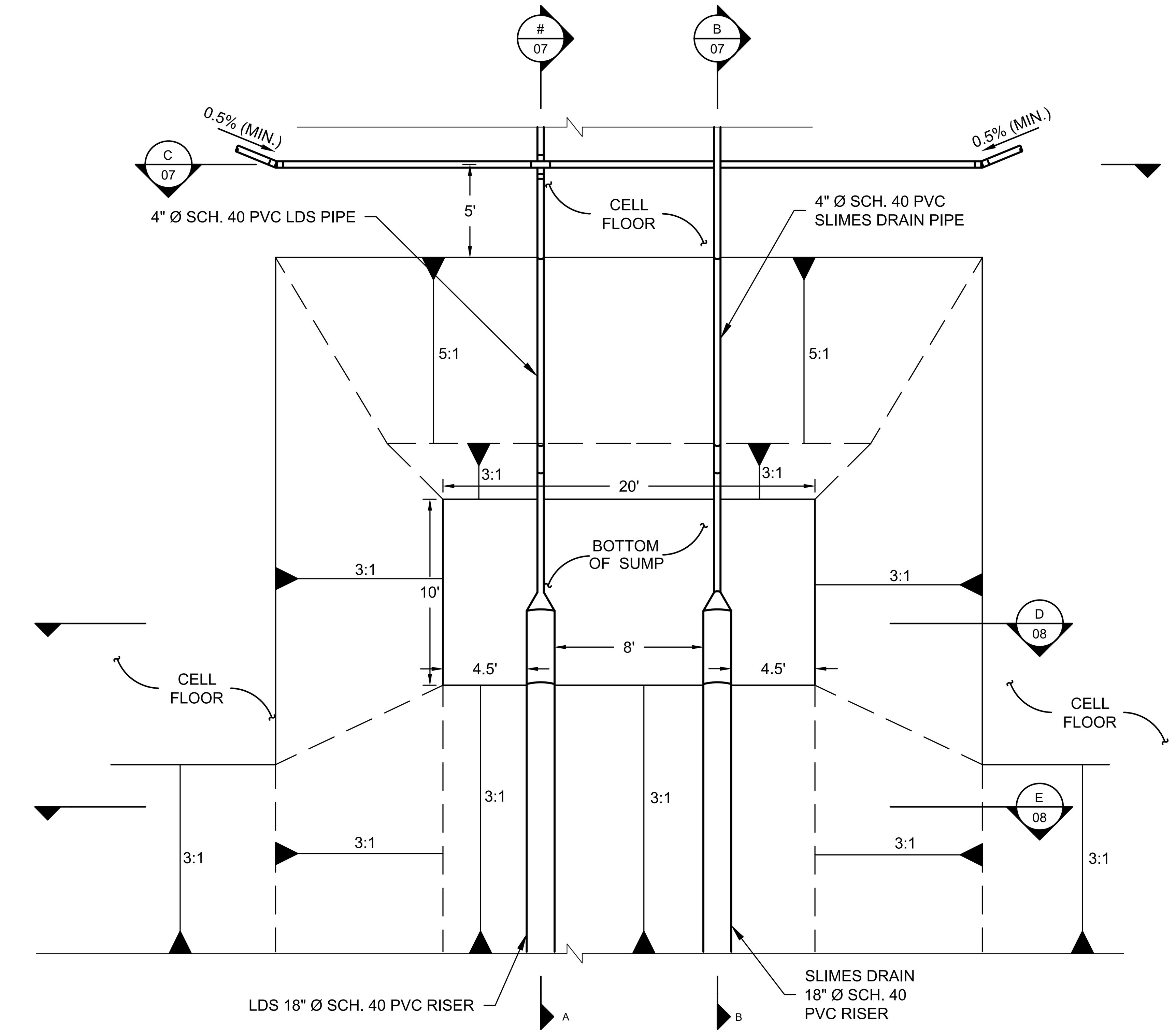
A / - SECTION
LEAK DETECTION SUMP
SCALE: 1" = 2'



B / - SECTION
SLIMES DRAIN SUMP
SCALE: 1" = 2'



C / - SECTION
SLIMES DRAIN AND LDS PIPING SECTION
SCALE: 1" = 2'



22 / 04A,04B PLAN
SUMP PLAN VIEW
SCALE: 1" = 6'

NOTES:

1. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. SOIL THICKNESSES ARE MINIMUMS.

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

(3in) (2in) (1in)
(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS III

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

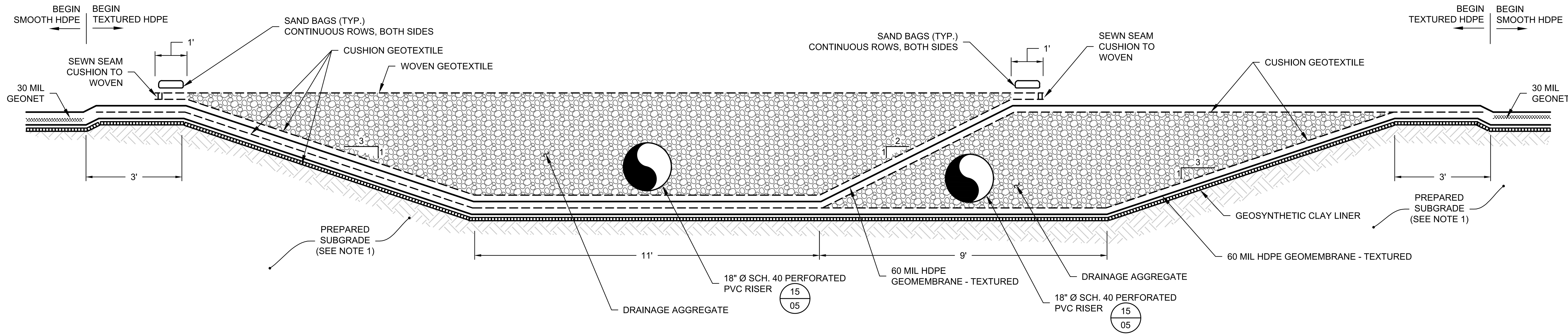
SIGNATURE

06-29-18
DATE

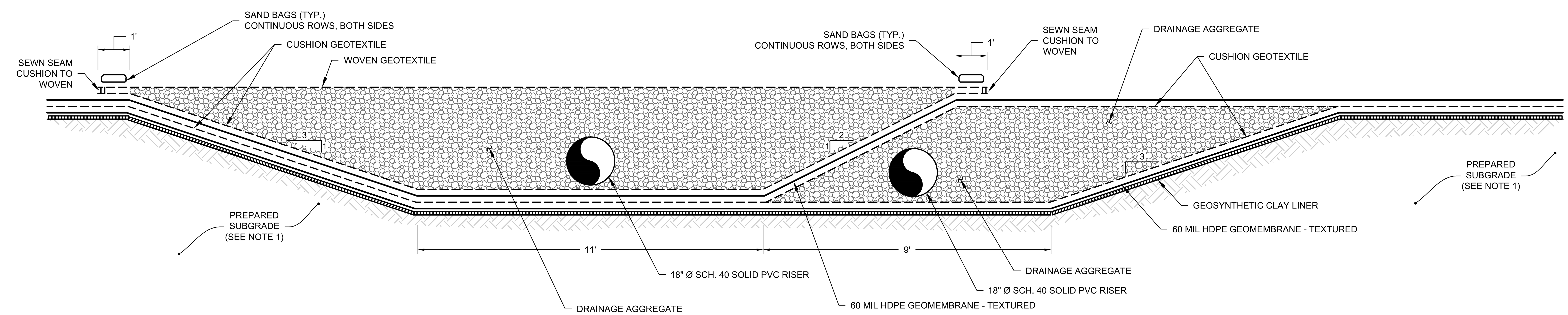
REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	07 OF 10	

P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\2018 REV\SC0634-05-07.dwg Last Edited by: SBerdy on 6/25/2018 3:00 PM



D/07 SECTION
SUMP SECTION (FLOOR)
SCALE: 1" = 2'



E/07 SECTION
SUMP SECTION (SLOPE)
SCALE: 1" = 2'

NOTES:

1. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.

2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. SOIL THICKNESSES ARE MINIMUMS.

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS IV

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE
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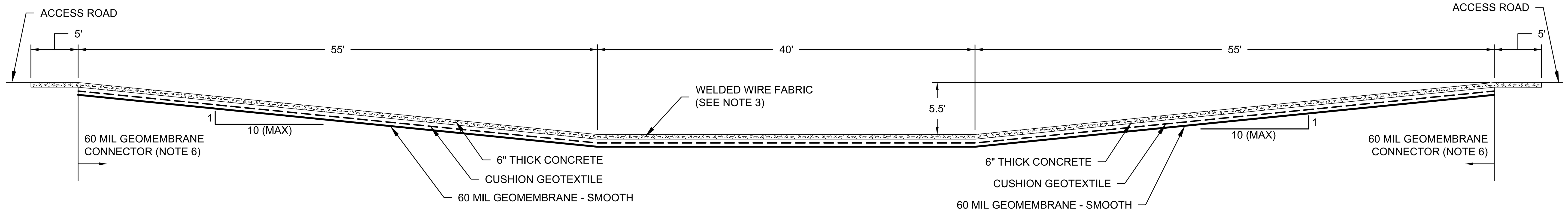
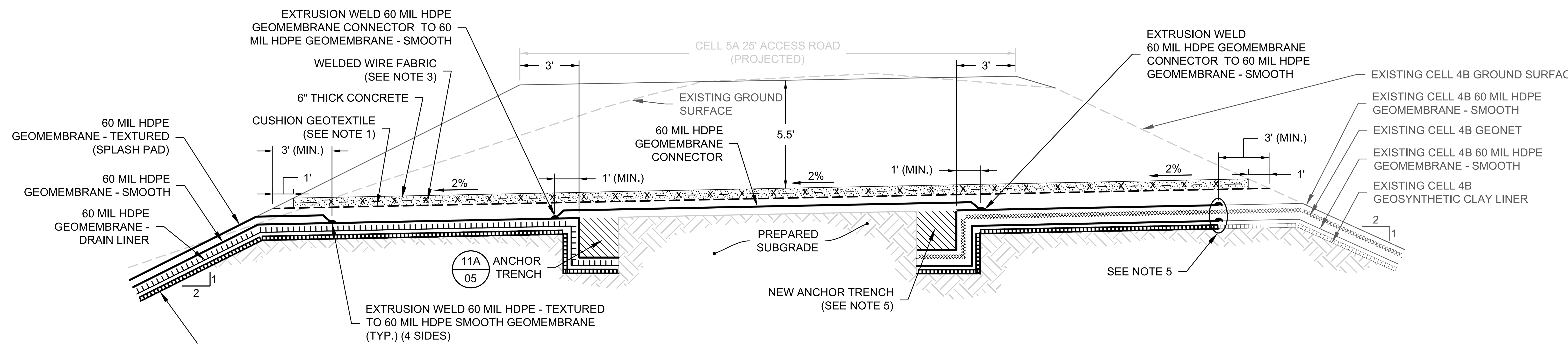
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

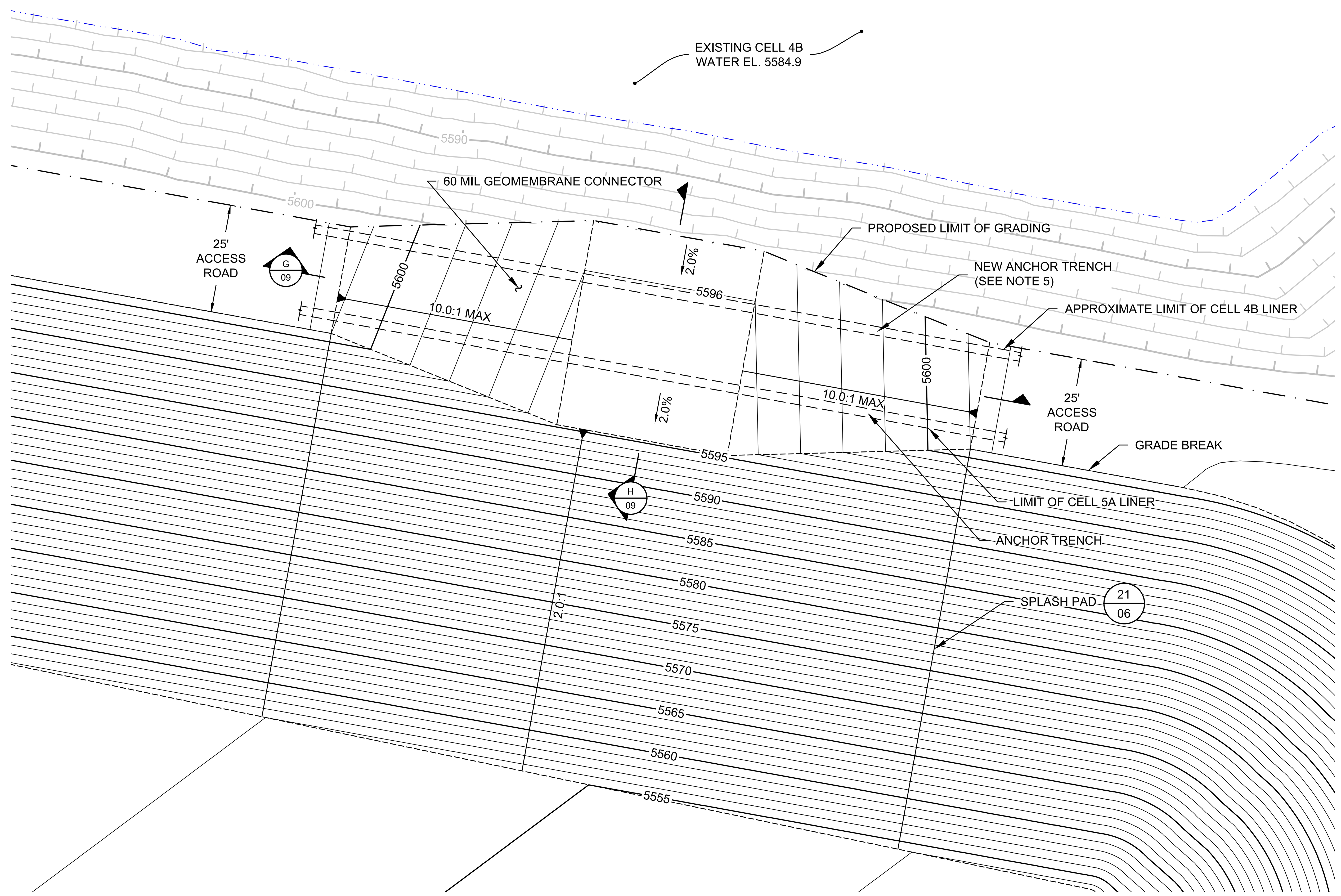
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	08 OF 10	



G / -
SECTION
SPILLWAY - SECTION-5A
SCALE: 1" = 8'



H / -
SECTION
SPILLWAY - SECTION 2-5A
SCALE: 1" = 4'



23 / 03A,04A
PLAN
SPILLWAY PLAN - 5A
SCALE: 1" = 20'

NOTES:

1. CUSHION GEOTEXTILE SHALL BE PLACED OVERLYING PRIMARY GEOMEMBRANE WHERE CONCRETE IS INSTALLED.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
3. WELDED WIRE FABRIC SHALL BE INSTALLED AT CENTER OF CONCRETE SLAB SECTION.
4. SPLASH PAD AT SPILLWAY SHALL BE 150' WIDE, SHALL EXTEND 5' ONTO THE FLOOR AND BE EXTRUSION WELDED ON ALL FOUR (4) SIDES TO PRIMARY GEOMEMBRANE.
5. CUT AND FOLD BACK EXISTING LINER SYSTEM GEOSYNTHETIC LAYERS (60 mil HDPE MEMBRANE, 300 mil GEONET, 60 mil HDPE GEOMEMBRANE, GCL) TO ALLOW EXCAVATION OF SPILLWAY. REPLACE LINER SYSTEM GEOSYNTHETICS LAYERS ONTO NEW SPILLWAY GRADES AND NEW ANCHOR TRENCH. NEW ANCHOR TRENCH SHALL BE TIED INTO EXISTING ANCHOR TRENCH.
6. ANCHOR 60 MIL GEOMEMBRANE CONNECTOR AT TOP OF 10H:1V SLOPE IN 12" DEEP ANCHOR TRENCH.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS V

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

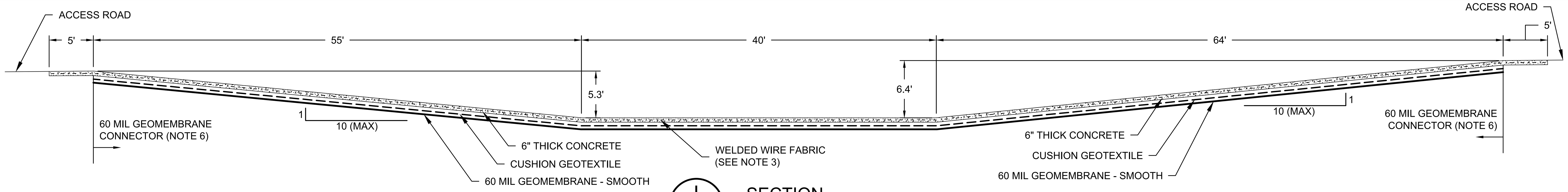
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

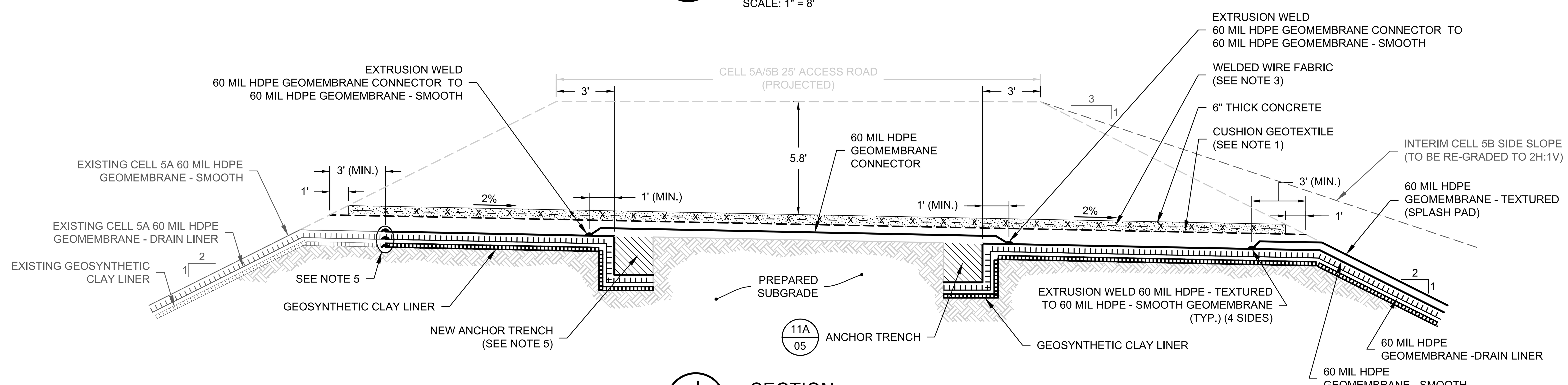
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	09 OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

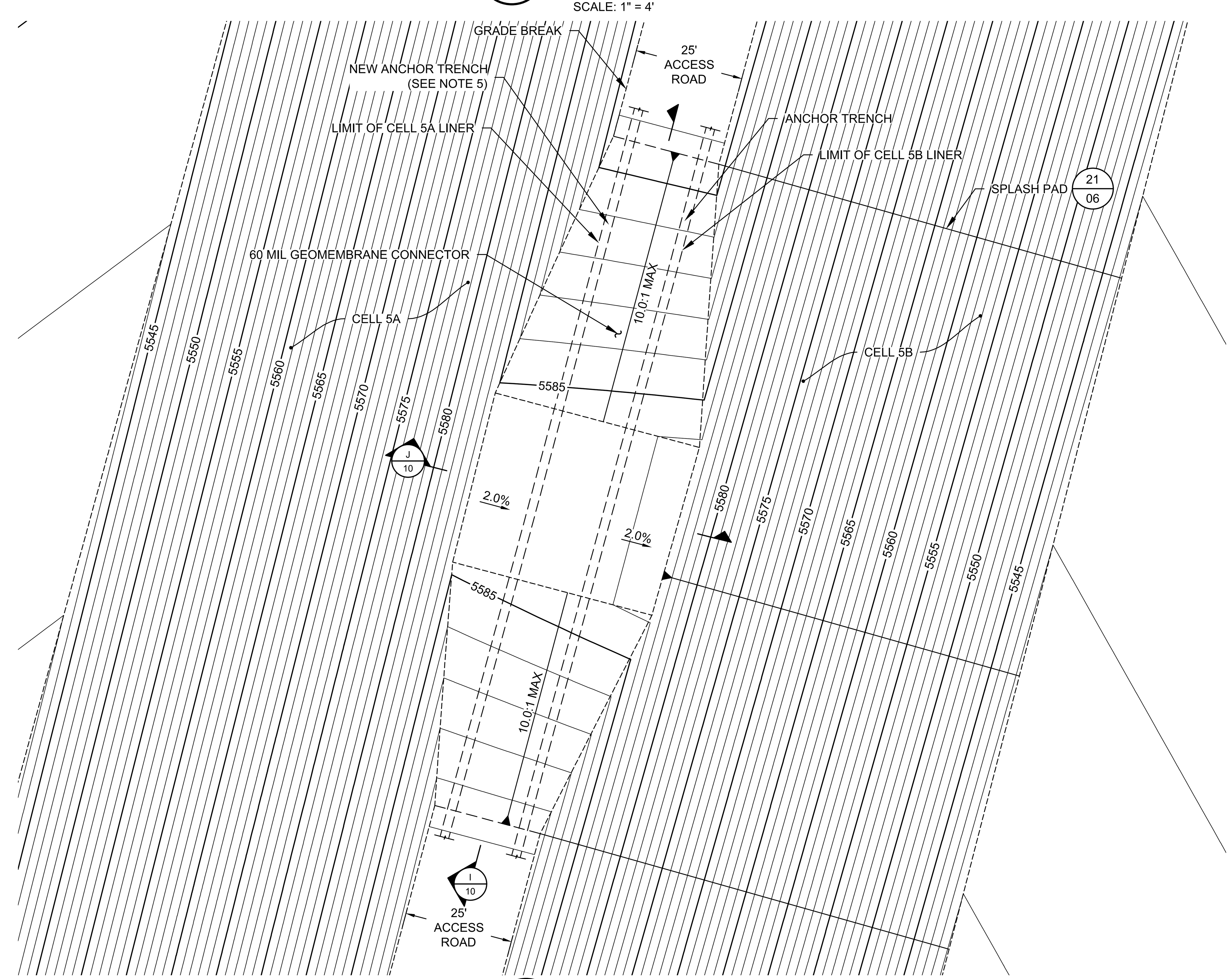
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



SECTION I
SPILLWAY - SECTION-5B
SCALE: 1" = 8'



SECTION J
SPILLWAY - SECTION 2 - 5B
SCALE: 1" = 4'



PLAN 24 03B,04B
SPILLWAY PLAN - 5B
SCALE: 1" = 20'

NOTES:

1. CUSHION GEOTEXTILE SHALL BE PLACED OVERLYING PRIMARY GEOMEMBRANE WHERE CONCRETE IS INSTALLED.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
3. WELDED WIRE FABRIC SHALL BE INSTALLED AT CENTER OF CONCRETE SLAB SECTION.
4. SPLASH PAD AT SPILLWAY SHALL BE 159' WIDE, SHALL EXTEND 5' ONTO THE FLOOR AND BE EXTRUSION WELDED ON ALL FOUR (4) SIDES TO PRIMARY GEOMEMBRANE.
5. CUT AND FOLD BACK EXISTING LINER SYSTEM GEOSYNTHETIC LAYERS (60 mil HDPE MEMBRANE, 300 mil GEONET, 60 mil HDPE GEOMEMBRANE, GCL) TO ALLOW EXCAVATION OF SPILLWAY. REPLACE LINER SYSTEM GEOSYNTHETICS LAYERS ONTO NEW SPILLWAY GRADES AND NEW ANCHOR TRENCH. NEW ANCHOR TRENCH SHALL BE TIED INTO EXISTING ANCHOR TRENCH.
6. ANCHOR 60 MIL GEOMEMBRANE CONNECTOR AT TOP OF 10H:1V SLOPE IN 12" DEEP ANCHOR TRENCH.

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS VI

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	10 OF 10	

(3in) (2in) (1in) (1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\2018 REV\SC0634-05-07.dwg Last Edited by: SBerdy on 6/25/2018 3:00 PM

APPENDIX B

Construction Quality Assurance Plan

Prepared for

Energy Fuels Resources (USA), Inc.
6425 S. Highway 191
P.O. Box 809
Blanding, UT 84511

CONSTRUCTION QUALITY ASSURANCE PLAN

CELLS 5A AND 5B

WHITE MESA MILL
BLANDING, UTAH

Prepared by

Geosyntec consultants

engineers | scientists | innovators

16644 West Bernardo Rd, Suite 301
San Diego, CA 92127

Project Number SC0634

June 2018

CERTIFICATION PAGE

CONSTRUCTION QUALITY ASSURANCE (CQA) PLAN FOR CELLS 5A AND 5B CONSTRUCTION ENERGY FUELS RESOURCES (USA), INC. WHITE MESA MILL BLANDING, UTAH

The Engineering material and data contained in this CQA Plan were prepared under the supervision and direction of the undersigned, whose seal as a registered Professional Engineer is affixed below.

Gregory T. Corcoran, P.E.
Engineer of Record

REGISTERED PROFESSIONAL ENGINEER
No. 6020077-2202
GREGORY T. CORCORAN
STATE OF UTAH

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TABLES

1. INTRODUCTION

1.1 Terms of Reference

Geosyntec Consultants (Geosyntec) has prepared this Construction Quality Assurance (CQA) Plan for the construction of liner systems associated with the Cells 5A and 5B Lining Systems Construction at the Energy Fuels Resources (USA), Inc. (Energy Fuels) White Mesa Mill Facility (site), located at 6425 South Highway 191, Blanding, Utah 84511. This CQA Plan was prepared by Ms. Rebecca Oliver, of Geosyntec, and was reviewed by Mr. Gregory T. Corcoran, P.E., also of Geosyntec, in general accordance with the peer review policies of the firm.

1.2 Purpose and Scope of the Construction Quality Assurance Plan

The purpose of the CQA Plan is to address the CQA procedures and monitoring requirements for construction of the project. The CQA Plan is intended to: (i) define the responsibilities of parties involved with the construction; (ii) provide guidance in the proper construction of the major components of the project; (iii) establish testing protocols; (iv) establish guidelines for construction documentation; and (v) provide the means for assuring that the project is constructed in conformance to the *Technical Specifications*, permit conditions, applicable regulatory requirements, and *Construction Drawings*.

This CQA Plan addresses the earthwork and geosynthetic components of the liner system for the project. Two alternative liner systems are proposed for the Cells: Option A – Triple Liner and Option B- Double Liner with Geosynthetic Clay Liner (GCL). These are described in detail in the Design Report prepared by Geosyntec in June 2018. The earthwork, geosynthetic, and appurtenant components include well abandonment, excavation, fill, prepared subgrade, geomembrane, geotextile, geosynthetic clay liner (GCL), geonet, drainage aggregate, and polyvinyl chloride (PVC) pipe. It should be emphasized that care and documentation are required in the placement of aggregate and in the production and installation of the geosynthetic materials installed during construction. This CQA Plan delineates procedures to be followed for monitoring construction utilizing these materials.

The CQA monitoring activities associated with the selection, evaluation, and placement of drainage aggregate are included in the scope of this plan. The CQA protocols applicable to manufacturing, shipping, handling, and installing all geosynthetic materials are also included. However, this CQA Plan does not specifically address either installation specifications or specification of soils and geosynthetic materials as these requirements are addressed in the *Technical Specifications*.

1.3 References

The CQA Plan includes references to test procedures in the latest editions of the ASTM International.

1.4 Organization of the Construction Quality Assurance Plan

The remainder of the CQA Plan is organized as follows:

- Section 2 presents definitions relating to CQA;
- Section 3 describes the CQA personnel and duties;
- Section 4 describes site and project control requirements;
- Section 5 presents CQA documentation;
- Section 6 presents CQA of well abandonment;
- Section 7 presents CQA of earthwork;
- Section 8 presents CQA of the drainage aggregate;
- Section 9 presents CQA of the pipe and fittings;
- Section 10 presents CQA of the geomembrane;
- Section 11 presents CQA of the geotextile;
- Section 12 presents CQA of the GCL;
- Section 13 presents CQA of the geonet;
- Section 14 presents CQA of the concrete spillway; and
- Section 15 presents CQA surveying.

2. DEFINITIONS RELATING TO CONSTRUCTION QUALITY ASSURANCE

This CQA Plan is devoted to Construction Quality Assurance. In the context of this document, Construction Quality Assurance and Construction Quality Control are defined as follows:

Construction Quality Assurance (CQA) - A planned and systematic pattern of means and actions designed to assure adequate confidence that materials or services meet contractual and regulatory requirements and will perform satisfactorily in service. CQA refers to means and actions employed by the CQA Consultant to assure conformity of the project "Work" with this CQA Plan, the *Construction Drawings*, and the *Technical Specifications*. CQA testing of aggregate, pipe, and geosynthetic components is provided by the CQA Consultant.

Construction Quality Control (CQC) - Actions which provide a means to measure and regulate the characteristics of an item or service in relation to contractual and regulatory requirements. Construction Quality Control refers to those actions taken by the Contractor, Manufacturer, or Geosynthetic Installer to verify that the materials and the workmanship meet the requirements of this CQA Plan, the *Construction Drawings*, and the *Technical Specifications*. In the case of the geosynthetic components and piping of the Work, CQC is provided by the Manufacturer, Geosynthetic Installer, and Contractor.

2.1 Owner

The Owner of this project is Energy Fuels Resources (USA), Inc. (Energy Fuels).

2.2 Construction Manager

Responsibilities

The Construction Manager is responsible for managing the construction and implementation of the *Construction Drawings* and *Technical Specifications* for the project work. The Construction Manager is selected/appointed by the Owner.

2.3 Design Engineer

Responsibilities

The Design Engineer is responsible for the design, *Construction Drawings*, and *Technical Specifications* for the project work. In this CQA Plan, the term "Design Engineer" refers to Geosyntec.

Qualifications

The Engineer of Record shall be a qualified engineer, registered as required by regulations in the State of Utah. The Design Engineer should have expertise, which demonstrates significant familiarity with piping, geosynthetics and soils, as appropriate, including design and construction experience related to liner systems.

2.4 Contractor

Responsibilities

In this CQA Plan, Contractor refers to an independent party or parties, contracted by the Owner, performing the work in accordance with this CQA Plan, the *Construction Drawings*, and the *Technical Specifications*. The Contractor will be responsible for the installation of the soils, pipe, drainage aggregate, and geosynthetic components of the liner systems. This work will include subgrade preparation, anchor trench excavation and backfill, placement of drainage aggregate for the slimes drain and two leak detection systems, installation of PVC piping, placement of cast-in-place concrete, and coordination of work with the Geosynthetic Installer and other subcontractors.

The Contractor will be responsible for constructing the liner system and appurtenant components in accordance with the *Construction Drawings* and complying with the quality control requirements specified in the *Technical Specifications*.

Qualifications

Qualifications of the Contractor are specific to the construction contract. The Contractor should have a demonstrated history of successful earthworks, piping, and liner system construction and shall maintain current state and federal licenses as appropriate.

2.5 Resin Supplier

Responsibilities

The Resin Supplier produces and delivers the resin to the Geosynthetics Manufacturer.

Qualifications

Qualifications of the Resin Supplier are specific to the Manufacturer's requirements. The Resin Supplier will have a demonstrated history of providing resin with consistent properties.

2.6 Manufacturers

Responsibilities

The Manufacturers are responsible for the production of finished material (geomembrane, geotextile, GCL, geonet, and pipe) from appropriate raw materials.

Qualifications

The Manufacturer(s) will be able to provide sufficient production capacity and qualified personnel to meet the demands of the project. The Manufacturer(s) must be a well-established firm(s) that meets the requirements identified in the *Technical Specifications*.

2.7 Geosynthetic Installer

Responsibilities

The Geosynthetic Installer is responsible for field handling, storage, placement, seaming, ballasting or anchoring against wind uplift, and other aspects of the geosynthetic material installation. The Geosynthetic Installer may also be responsible for specialized construction tasks (i.e., including construction of anchor trenches for the geosynthetic materials).

Qualifications

The Geosynthetic Installer will be trained and qualified to install the geosynthetic materials of the type specified for this project. The Geosynthetic Installer shall meet the qualification requirements identified in the *Technical Specifications*.

2.8 CQA Consultant

Responsibilities

The CQA Consultant is a party, independent from the Owner, Contractor, Manufacturer, and Geosynthetic Installer, who is responsible for observing, testing, and documenting activities related to the CQC and CQA of the earthwork, piping, and geosynthetic components used in the construction of the Project as required by this CQA Plan and the *Technical Specifications*. The CQA Consultant will also be responsible for issuing a CQA report at the completion of the Project construction, which documents construction and associated CQA activities. The CQA report will be signed and sealed by the CQA Engineer who will be a Professional Engineer registered in the State of Utah.

Qualifications

The CQA Consultant shall be a well-established firm specializing in geotechnical and geosynthetic engineering that possess the equipment, personnel, and licenses necessary to conduct the geotechnical and geosynthetic tests required by the project plans and *Technical Specifications*. The CQA Consultant will provide qualified staff for the project, as necessary, which will include, at a minimum, a CQA Engineer and a CQA Site Manager. The CQA Engineer will be a professionally licensed engineer as required by State of Utah regulations.

The CQA Consultant will be experienced with earthwork and installation of geosynthetic materials similar to those materials used in construction of the Project. The CQA Consultant will be experienced in the preparation of CQA documentation including CQA Plans, field documentation, field testing procedures, laboratory testing procedures, construction specifications, construction drawings, and CQA reports.

The CQA Site Manager will be specifically familiar with the construction of earthworks, piping, and geosynthetic lining systems. The CQA Site Manager will be trained by the CQA Consultant in the duties as CQA Site Manager.

2.9 Surveyor

Responsibilities

The Surveyor is a party, independent from the Contractor, Manufacturer, and Geosynthetic Installer, that is responsible for surveying, documenting, and verifying the location of all significant components of the Work. The Surveyor's work is coordinated and employed by the Contractor. The Surveyor is responsible for issuing *Record Drawings* of the construction.

Qualifications

The Surveyor will be a well-established surveying company with at least 3 years of surveying experience in the State of Utah. The Surveyor will be a licensed professional as required by the State of Utah regulations. The Surveyor shall be fully equipped and experienced in the use of total stations and the recent version of AutoCAD. All surveying will be performed under the direct supervision of the Contractor.

2.10 CQA Laboratory

Responsibilities

The CQA Laboratory is a party, independent from the Contractor, Manufacturer, and Geosynthetic Installer, that is responsible for conducting tests in accordance with ASTM and other applicable test standards on samples of geosynthetic materials and soil in either an onsite or offsite laboratory.

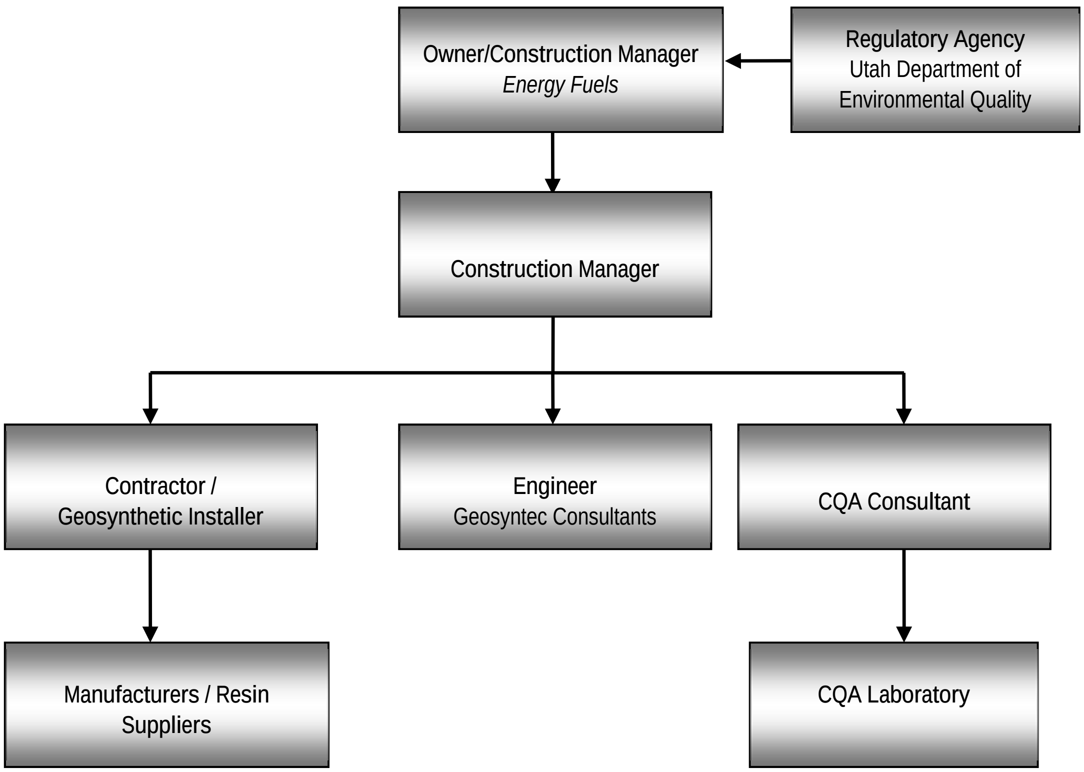
Qualifications

The CQA Laboratory will have experience in testing soils and geosynthetic materials and will be familiar with ASTM and other applicable test standards. The CQA Laboratory will be capable of providing test results within a maximum of seven days of receipt of samples and will maintain that capability throughout the duration of earthworks construction and geosynthetic materials installation. The CQA Laboratory will also be capable of transmitting geosynthetic destructive test results within 24 hours of receipt of samples and will maintain that capability throughout the duration of geosynthetic material installation.

2.11 Lines of Communication

The following organization chart indicates the lines of communication and authority related to this project.

Project Organization Chart
Energy Fuels
White Mesa Mill Cell 4B



2.12 Deficiency Identification and Rectification

If a defect is discovered in the work, the CQA Engineer will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Engineer will determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the CQA Engineer deems appropriate.

After evaluating the extent and nature of a defect, the CQA Engineer will notify the Construction Manager and schedule appropriate re-tests when the work deficiency is corrected by the Contractor.

The Contractor will correct the deficiency to the satisfaction of the CQA Engineer. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Engineer will develop and present to the Design Engineer suggested solutions for approval. Major modification to the *Construction Drawings*, *Technical Specifications*, or this CQA Plan must be provided to the regulatory agency for review prior to implementation.

Defect corrections will be monitored and documented by CQA personnel prior to subsequent work by the Contractor in the area of the deficiency.

3. CQA CONSULTANT'S PERSONNEL AND DUTIES

3.1 Overview

The CQA Engineer will provide supervision within the scope of work of the CQA Consultant. The scope of work for the CQA Consultant includes monitoring of construction activities including the following:

- earthwork;
- subgrade preparation;
- installation of GCL;
- installation of geomembrane;
- installation of geonet;
- installation of drainage aggregate;
- installation of piping; and
- installation of geotextile.

Duties of CQA personnel are discussed in the remainder of this section.

3.2 CQA Personnel

The CQA Consultant's personnel will include:

- the CQA Engineer, who works from the office of the CQA Consultant and who conducts periodic visits to the site as required; and
- the CQA Site Manager, who is located at the site.

3.3 CQA Engineer

The CQA Engineer shall supervise and be responsible for monitoring and CQA activities relating to the construction of the earthworks, piping, and installation of the geosynthetic materials of the Project. Specifically, the CQA Engineer:

- reviews the project design, this CQA Plan, *Construction Drawings*, and *Technical Specifications*;

- reviews other site-specific documentation; unless otherwise agreed, such reviews are for familiarization and for evaluation of constructability only, and hence the CQA Engineer and the CQA Consultant assume no responsibility for the liner system design;
- reviews and approves the Geosynthetic Installer's Quality Control (QC) Plan;
- attends Pre-Construction Meetings as needed;
- administers the CQA program (i.e., provides supervision of and manages onsite CQA personnel, reviews field reports, and provides engineering review of CQA related activities);
- provides quality control of CQA documentation and conducts site visits;
- reviews the *Record Drawings*; and
- with the CQA Site Manager, prepares the CQA report documenting that the project was constructed in accordance with the Construction Documents.

3.4 CQA Site Manager

The CQA Site Manager:

- acts as the onsite representative of the CQA Consultant;
- attends CQA-related meetings (e.g., pre-construction, daily, weekly (or designates a representative to attend the meetings));
- oversees the ongoing preparation of the *Record Drawings*;
- reviews test results provided by Contractor;
- assigns locations for testing and sampling;
- oversees the collection and shipping of laboratory test samples;
- reviews results of laboratory testing and makes appropriate recommendations;
- reviews the calibration and condition of onsite CQA equipment;
- prepares a daily summary report for the project;
- reviews the Manufacturer's Quality Control (MQC) documentation;
- reviews the Geosynthetic Installer's personnel Qualifications for conformance with those pre-approved for work on site;

- notes onsite activities in daily field reports and reports to the CQA Engineer and Construction Manager;
- reports unresolved deviations from the CQA Plan, *Construction Drawings*, and *Technical Specifications* to the Construction Manager; and
- assists with the preparation of the CQA report.

4. SITE AND PROJECT CONTROL

4.1 Project Coordination Meetings

Meetings of key project personnel are necessary to assure a high degree of quality during installation and to promote clear, open channels of communication. Therefore, Project Coordination Meetings are an essential element in the success of the project. Several types of Project Coordination Meetings are described below, including: (i) pre-construction meetings; (ii) progress meetings; and (iii) problem or work deficiency meetings.

4.1.1 Pre-Construction Meeting

A Pre-Construction Meeting will be held at the site prior to construction of the Project. At a minimum, the Pre-Construction Meeting will be attended by the Contractor, the Geosynthetic Installer's Superintendent, the CQA Consultant, and the Construction Manager.

Specific items for discussion at the Pre-Construction Meeting include the following:

- appropriate modifications or clarifications to the CQA Plan;
- the *Construction Drawings* and *Technical Specifications*;
- the responsibilities of each party;
- lines of authority and communication;
- methods for documenting and reporting, and for distributing documents and reports;
- acceptance and rejection criteria;
- protocols for testing;
- protocols for handling deficiencies, repairs, and re-testing;
- the time schedule for all operations;
- procedures for packaging and storing archive samples;
- panel layout and numbering systems for panels and seams;
- seaming procedures;
- repair procedures; and
- soil stockpiling locations.

The Construction Manager will conduct a site tour to observe the current site conditions and to review construction material and equipment storage locations. A person in attendance at the meeting will be appointed by the Construction Manager to record the discussions and decisions of the meeting in the form of meeting minutes. Copies of the meeting minutes will be distributed to all attendees.

4.1.2 Progress Meetings

Progress meetings will be held between the CQA Site Manager, the Contractor, Construction Manager, and other concerned parties participating in the construction of the project. This meeting will include discussions on the current progress of the project, planned activities for the next week, and revisions to the work plan or schedule. The meeting will be documented in meeting minutes prepared by a person designated by the Construction Manager at the beginning of the meeting. Within two working days of the meeting, draft minutes will be transmitted to representatives of parties in attendance for review and comment. Corrections or comments to the draft minutes shall be made within two working days of receipt of the draft minutes to be incorporated in the final meeting minutes.

4.1.3 Problem or Work Deficiency Meeting

A special meeting will be held when and if a problem or deficiency is present or likely to occur. The meeting will be attended by the Contractor, the Construction Manager, the CQA Site Manager, and other parties as appropriate. If the problem requires a design modification, the Design Engineer should either be present at, consulted prior to, or notified immediately upon conclusion of this meeting. The purpose of the work deficiency meeting is to define and resolve the problem or work deficiency as follows:

- define and discuss the problem or deficiency;
- review alternative solutions;
- select a suitable solution agreeable to all parties; and
- implement an action plan to resolve the problem or deficiency.

The Construction Manager will appoint one attendee to record the discussions and decisions of the meeting. The meeting record will be documented in the form of meeting minutes and copies will be distributed to all affected parties. A copy of the minutes will be retained in facility records.

5. DOCUMENTATION

5.1 Overview

An effective CQA Plan depends largely on recognition of all construction activities that should be monitored and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The CQA Consultant will document that quality assurance requirements have been addressed and satisfied.

The CQA Site Manager will provide the Construction Manager with signed descriptive remarks, data sheets, and logs to verify that monitoring activities have been carried out. The CQA Site Manager will also maintain, at the job site, a complete file of *Construction Drawings* and *Technical Specifications*, a CQA Plan, checklists, test procedures, daily logs, and other pertinent documents.

5.2 Daily Recordkeeping

Preparation of daily CQA documentation will consist of daily field reports prepared by the CQA Site Manager which may include CQA monitoring logs and testing data sheets. This information may be regularly submitted to and reviewed by the Construction Manager. Daily field reports will include documentation of the observed activities during each day of activity. The daily field reports may include monitoring logs and testing data sheets. At a minimum, these logs and data sheets will include the following information:

- the date, project name, location, and other identification;
- a summary of the weather conditions;
- a summary of locations where construction is occurring;
- equipment and personnel on the project;
- a summary of meetings held and attendees;
- a description of materials used and references of results of testing and documentation;
- identification of deficient work and materials;
- results of re-testing corrected "deficient work;"
- an identifying sheet number for cross referencing and document control;
- descriptions and locations of construction monitored;

- type of construction and monitoring performed;
- description of construction procedures and procedures used to evaluate construction;
- a summary of test data and results;
- calibrations or re-calibrations of test equipment and actions taken as a result of re-calibration;
- decisions made regarding acceptance of units of work or corrective actions to be taken in instances of substandard testing results;
- a discussion of agreements made between the interested parties which may affect the work; and
- signature of the respective CQA Site Manager.

5.3 Construction Problems and Resolution Data Sheets

Construction Problems and Resolution Data Sheets, to be submitted with the daily field reports prepared by the CQA Site Manager, describing special construction situations, will be cross-referenced with daily field reports, specific observation logs, and testing data sheets and will include the following information, where available:

- an identifying sheet number for cross-referencing and document control;
- a detailed description of the situation or deficiency;
- the location and probable cause of the situation or deficiency;
- how and when the situation or deficiency was found or located;
- documentation of the response to the situation or deficiency;
- final results of responses;
- measures taken to prevent a similar situation from occurring in the future; and
- signature of the CQA Site Manager and a signature indicating concurrence by the Construction Manager.

The Construction Manager will be made aware of significant recurring nonconformance with the *Construction Drawings*, *Technical Specifications*, or CQA Plan. The cause of the nonconformance will be determined and appropriate changes in procedures or specifications will be recommended. These changes will be submitted to the Construction Manager for approval. When this type of evaluation is made, the results will be documented and any revision to procedures or specifications will be approved by the Contractor and Design Engineer.

A summary of supporting data sheets, along with final testing results and the CQA Engineer's approval of the work, will be required upon completion of construction.

5.4 Photographic Documentation

Photographs will be taken and documented in order to serve as a pictorial record of work progress, problems, and mitigation activities. These records will be presented to the Construction Manager upon completion of the project. Photographic reporting data sheets, where used, will be cross-referenced with observation and testing data sheet(s), or Construction Problem and Resolution Data Sheet(s).

5.5 Design or Specifications Changes

Design or specifications changes may be required during construction. In such cases, the CQA Site Manager will notify the Design Engineer. Design or specification changes will be made with the written agreement of the Design Engineer and will take the form of an addendum to the *Construction Drawings* and *Technical Specifications*.

5.6 CQA Report

At the completion of the Project, the CQA Consultant will submit to the Owner a CQA report signed and sealed by a Professional Engineer licensed in the State of Utah. The CQA report will acknowledge: (i) that the work has been performed in compliance with the *Construction Drawings* and *Technical Specifications*; (ii) physical sampling and testing has been conducted at the appropriate frequencies; and (iii) that the summary document provides the necessary supporting information. At a minimum, this report will include:

- MQC documentation;
- a summary report describing the CQA activities and indicating compliance with the *Construction Drawings* and *Technical Specifications* which is signed and sealed by the CQA Engineer;
- a summary of CQA/CQC testing, including failures, corrective measures, and retest results;
- Contractor and Installer personnel resumes and qualifications as necessary;

- documentation that the geomembrane trial seams were performed in accordance with the CQA Plan and *Technical Specifications*;
- documentation that field seams were non-destructively tested using a method in accordance with the applicable test standards;
- documentation that nondestructive testing was monitored by the CQA Site Manager, that the CQA Site Manager informed the Geosynthetic Installer of any required repairs, and that the CQA Site Manager monitored the seaming and patching operations for uniformity and completeness;
- records of sample locations, the name of the individual conducting the tests, and the results of tests;
- *Record Drawings* as provided by the Surveyor; and
- daily field reports.

The *Record Drawings* will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., plan dimensions and appropriate elevations). *Record Drawings* and required base maps will be prepared by a qualified Professional Land Surveyor registered in the State of Utah. These documents will be reviewed by the CQA Consultant and included as part of the CQA Report.

6. WELL ABANDONMENT

6.1 Introduction

This section of the CQA Plan outlines the CQA activities to be performed for well abandonment. The CQA Site Manager will review and become familiar with the *Construction Documents* and any approved addenda or changes that pertain to work completed under this section.

The CQA Site Manager will monitor well abandonment operations. The CQA Engineer will review the contractor's submittals pertaining to CQA and provide recommendations to the Design Engineer. Monitored abandonment activities will be documented, as will deviations from the *Construction Drawings* and the *Technical Specifications*. Any non-conformance identified by the CQA Site Manager will be reported to the Construction Manager.

6.2 CQA Monitoring Activities

6.2.1 Materials

CQA activities provided for storing and handling of materials shall meet the requirements set forth in Section 02070 of the *Technical Specifications*.

6.2.2 Well Abandonment

The wells to be abandoned are indicated on the *Drawings*. Well abandonment shall be observed by the CQA Site Manager. Observed well abandonment activities shall be documented in daily field reports. The CQA Site Manager shall keep a detailed log for the abandoned well, including drilling procedure, total depth of abandonment, depth to groundwater (if applicable), final depth of boring, and well destruction details, including the depth of placement and quantities of all well abandonment materials.

6.2.3 Deficiencies

If a defect is discovered in the well abandonment, the CQA Site Manager will evaluate the extent and nature of the defect. The CQA Consultant will determine the extent of the deficient area by observations, a review of records, or other means that the CQA Consultant deems appropriate.

6.2.4 Notification

After observing a defect, the CQA Consultant will notify the Construction Manager and schedule appropriate re-evaluation after the work deficiency is corrected by the Contractor.

6.2.5 Repairs and Re-testing

The Contractor will correct the deficiency to the satisfaction of the CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Design Engineer suggested solutions for approval.

7. EARTHWORK

7.1 Introduction

This section prescribes the CQA activities to be performed to monitor that earthwork is constructed in accordance with *Construction Drawings* and *Technical Specifications*. The earthwork construction procedures to be monitored by the CQA Site Manager, if required, shall include:

- vegetation removal;
- subgrade preparation;
- engineered fill placement, moisture conditioning, and compaction; and
- anchor trench excavation and backfill.

7.2 Earthwork Testing Activities

Testing of earthwork to be used for engineered fill will be performed for material conformance. The CQA Laboratory will perform the conformance testing and CQC testing. Soil testing will be conducted in accordance with the current versions of the corresponding ASTM test procedures. The test methods indicated in Tables 1A and 1B are those that will be used for this testing unless the test methods are updated or revised prior to construction. Revisions to the test methods will be reviewed and approved by the Design Engineer and the CQA Consultant prior to their usage.

7.2.1 Sample Frequency

The frequency of subgrade soil testing for material qualification and material conformance will conform to the minimum frequencies presented in Table 1A. The frequency of soil testing shall conform to the minimum frequencies presented in Table 1B. The actual frequency of testing required will be increased by the CQA Site Manager, as necessary, if variability of materials is noted at the site, during adverse conditions, or to isolate failing areas of the construction.

7.2.2 Sample Selection

Sampling locations will be selected by the CQA Site Manager. Conformance samples will be obtained from borrow pits or stockpiles of material. The Contractor must plan the work and make soil available for sampling in a timely and organized manner so that the test results can be obtained before the material is installed. The CQA Site Manager must document sample locations so that failing areas can be immediately isolated. The CQA Site Manager will follow standard sampling procedures to obtain representative samples of the proposed soil materials.

7.3 CQA Monitoring Activities

7.3.1 Vegetation Removal

The CQA Site Manager will monitor and document that vegetation is sufficiently cleared and grubbed in areas where engineered fill is to be placed. Vegetation removal shall be performed as described in the *Technical Specifications* and the *Construction Drawings*.

7.3.2 Topsoil Removal

The CQA Site Manager will monitor and document that topsoil is sufficiently excavated in areas where engineered fill is to be placed. Topsoil removal shall be performed as described in the *Technical Specifications* and the *Construction Drawings*.

7.3.3 Engineered Fill

During construction, the CQA Site Manager will monitor engineered fill placement and compaction to confirm it is consistent with the requirements specified in the *Technical Specifications* and the *Construction Drawings*. The CQA Site Manager will monitor, at a minimum, that:

- the fill material is free of debris and other undesirable materials and that particles are no larger than 6-inches in longest dimension;
- the fill is constructed to the lines and grades shown on the *Construction Drawings*; and
- fill compaction requirements are met as specified in the *Technical Specifications.*

7.3.4 Subgrade Soil

During construction, the CQA Site Manager will monitor the subgrade soil placement and compaction methods are consistent with the requirements specified in the *Technical Specifications* and the *Construction Drawings*. The CQA Site Manager will monitor, at a minimum, that:

- the subgrade soil is free of protrusions larger than 0.7-inches and particles are to be no larger than 3-inches in longest dimension;
- the subgrade soil is constructed to the lines and grades shown on the *Construction Drawings*; and
- compaction requirements are met as specified in the *Technical Specifications.*

7.3.5 Fine Grading

The CQA Site Manager shall monitor and document that site re-grading performed meets the requirements of the *Technical Specifications* and the *Construction Drawings*. At a minimum, the CQA Site Manager shall monitor that:

- the subgrade surface is free of sharp rocks, debris, and other undesirable materials;
- the subgrade surface is smooth and uniform; and
- the subgrade surface meets the lines and grades shown on the *Construction Drawings*.

7.3.6 Anchor Trench Construction

During construction, the CQA Site Manager will monitor the anchor trench excavation and backfill methods are consistent with the requirements specified in the *Technical Specifications* and the *Construction Drawings*. The CQA Site Manager will monitor, at a minimum, that:

- the anchor trench is free of debris and other undesirable materials;
- the anchor trench is constructed to the lines and grades shown on the *Construction Drawings*; and
- compaction requirements are met, through visual observations, as specified in the *Technical Specifications.*

7.4 Deficiencies

If a defect is discovered in the earthwork product, the CQA Site Manager will immediately determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Consultant will determine the extent of the defective area by additional tests, observations, a review of records, or other means that the CQA Consultant deems appropriate. If the defect is related to adverse site conditions, such as overly wet soils or non-conforming particle sizes, the CQA Site Manager will define the limits and nature of the defect.

7.4.1 Notification

After evaluating the extent and nature of a defect, the CQA Consultant will notify the Construction Manager and Contractor and schedule appropriate re-evaluation when the work deficiency is to be corrected.

7.4.2 Repairs and Re-Testing

The Contractor will correct deficiencies to the satisfaction of the CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Construction Manager suggested solutions for his approval.

Re-evaluations by the CQA Site Manager shall continue until it is verified that defects have been corrected before any additional work is performed by the Contractor in the area of the deficiency.

8. DRAINAGE AGGREGATE

8.1 Introduction

This section prescribes the CQA activities to be performed to monitor that drainage aggregates are constructed in accordance with *Construction Drawings* and *Technical Specifications*. The drainage aggregates construction procedures to be monitored by the CQA Site Manager include drainage aggregate placement.

8.2 Testing Activities

Aggregate testing will be performed for material qualification and material conformance. These two stages of testing are defined as follows:

- Material qualification tests are used to evaluate the conformance of a proposed aggregate source with the *Technical Specifications* for qualification of the source prior to construction.
- Aggregate conformance testing is used to evaluate the conformance of a particular batch of aggregate from a qualified source to the *Technical Specifications* prior to installation of the aggregate.

The Contractor will be responsible for submitting material qualification test results to the Construction Manager and to the CQA Consultant for review. The CQA Laboratory will perform the conformance testing and CQC testing. Aggregate testing will be conducted in accordance with the current versions of the corresponding ASTM test procedures. The test methods indicated in Tables 2A and 2B are those that will be used for this testing unless the test methods are updated or revised prior to construction. Revisions to the test methods will be reviewed and approved by the Design Engineer and the CQA Consultant prior to their usage.

8.2.1 Sample Frequency

The frequency of aggregate testing for material qualification and material conformance will conform to the minimum frequencies presented in Table 2A. The frequency of aggregate testing shall conform to the minimum frequencies presented in Table 2B. The actual frequency of testing required will be increased by the CQA Site Manager, as necessary, if variability of materials is noted at the site, during adverse conditions, or to isolate failing areas of the construction.

8.2.2 Sample Selection

With the exception of qualification samples, sampling locations will be selected by the CQA Site Manager. Conformance samples will be obtained from borrow pits or stockpiles of material. The Contractor must plan the work and make aggregate available for sampling in a timely and organized manner so that the test results can be obtained before the material is installed. The CQA Site Manager must document sample locations so that failing areas can be immediately isolated. The CQA Site Manager will follow standard sampling procedures to obtain representative samples of the proposed aggregate materials.

8.3 CQA Monitoring Activities

8.3.1 Drainage Aggregate

The CQA Site Manager will monitor and document the installation of the drainage aggregates. In general, monitoring of the installation of drainage aggregate includes the following activities:

- reviewing documentation of the material qualification test results provided by the Contractor;
- sampling and testing for conformance of the materials to the *Technical Specifications*;
- documenting that the drainage aggregates are installed using the specified equipment and procedures;
- documenting that the drainage aggregates are constructed to the lines and grades shown on the *Construction Drawings*; and
- monitoring that the construction activities do not cause damage to underlying geosynthetic materials.

8.4 Deficiencies

If a defect is discovered in the drainage aggregates, the CQA Site Manager will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Consultant will determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the CQA Consultant deems appropriate.

8.4.1 Notification

After evaluating the extent and nature of a defect, the CQA Consultant will notify the Construction Manager and Contractor and schedule appropriate re-tests when the work deficiency is to be corrected.

8.4.2 Repairs and Re-testing

The Contractor will correct the deficiency to the satisfaction of the CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Construction Manager suggested solutions for approval.

Re-tests recommended by the CQA Site Manager shall continue until it is verified that the defect has been corrected before any additional work is performed by the Contractor in the area of the deficiency. The CQA Site Manager will also verify that installation requirements are met and that submittals are provided.

9. POLYVINYL CHLORIDE (PVC) PIPE AND STRIP COMPOSITE

9.1 Material Requirements

PVC pipe, fittings, and strip composite must conform to the requirements of the *Technical Specifications*. The CQA Consultant will document that the PVC pipe, fittings, and strip composite meet those requirements.

9.2 Manufacturer

9.2.1 Submittals

Prior to the installation of PVC pipe and strip composite, the Manufacturer will provide to the CQA Consultant:

- a properties' sheet including, at a minimum, all specified properties, measured using test methods indicated in the *Technical Specifications*, or equivalent; and

The CQA Consultant will document that:

- the property values certified by the Manufacturer meet the *Technical Specifications*; and
- the measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

9.3 Handling and Laying

Care will be taken during transportation of the pipe such that it will not be cut, kinked, or otherwise damaged. Ropes, fabric, or rubber-protected slings and straps will be used when handling pipes. Chains, cables, or hooks inserted into the pipe ends will not be used. Two slings spread apart will be used for lifting each length of pipe. Pipe or fittings will not be dropped onto rocky or unprepared ground.

Pipes will be handled and stored in accordance with the Manufacturer's recommendation. The handling of joined pipe will be in such a manner that the pipe is not damaged by dragging it over sharp and cutting objects. Slings for handling the pipe will not be positioned at joints. Sections of the pipes with deep cuts and gouges will be removed and the ends of the pipe rejoined.

9.4 Perforations

The CQA Site Manager shall monitor and document that the perforations of the PVC pipe conform to the requirements of the *Construction Drawings* and the *Technical Specifications*.

9.5 Joints

The CQA Monitor shall monitor and document that pipe and fittings are joined by the methods indicated in the *Technical Specifications*.

9.6 Strip Composite

The CQA Site Monitor shall monitor and document that the strip composite and sandbags meet and are installed in accordance with the requirements outlined on the drawings and in the *Technical Specifications.*

10. GEOMEMBRANE

10.1 General

This section discusses and outlines the CQA activities to be performed for high density polyethylene (HDPE) smooth, textured, and Drain Liner™ geomembrane installation. The CQA Site Manager will review the *Construction Drawings*, *Technical Specifications,* and any approved Addenda regarding this material.

10.2 Geomembrane Material Conformance

10.2.1 Introduction

The CQA Site Manager will document that the geomembrane delivered to the site meets the requirements of the *Technical Specifications* prior to installation. The CQA Site Manager will:

- review the manufacturer's submittals for compliance with the *Technical Specifications*;
- document the delivery and proper storage of geomembrane rolls; and
- conduct conformance testing of the rolls before the geomembrane is installed.

The following sections describe the CQA activities required to verify the conformance of geomembrane.

10.2.2 Review of Quality Control

10.2.2.1 Material Properties Certification

The Manufacturer will provide the Construction Manager and the CQA Consultant with the following:

- property data sheets, including, at a minimum, all specified properties, measured using test methods indicated in the *Technical Specifications*, or equivalent; and
- sampling procedures and results of testing.

The CQA Consultant will document that:

- the property values certified by the Manufacturer meet all of the requirements of the *Technical Specifications*; and
- the measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

10.2.2.2 Geomembrane Roll MQC Certification

Prior to shipment, the Manufacturer will provide the Construction Manager and the CQA Consultant with MQC certificates for every roll of geomembrane provided. The MQC certificates will be signed by a responsible party employed by the Geomembrane Manufacturer, such as the production manager. The MQC certificates shall include:

- roll numbers and identification; and
- results of MQC tests; as a minimum, results will be given for thickness, specific gravity, carbon black content, carbon black dispersion, tensile properties, and puncture resistance evaluated in accordance with the methods indicated in the *Technical Specifications* or equivalent methods approved by the Construction Manager.

The CQA Consultant will document that:

- that MQC certificates have been provided at the specified frequency, and that the certificates identify the rolls related to the roll represented by the test results; and
- review the MQC certificates and monitor that the certified roll properties meet the specifications.

10.2.3 Conformance Testing

The CQA Consultant shall obtain conformance samples (at the manufacturing facility or site) at the specified frequency and forward them to the Geosynthetics CQA Laboratory for testing to monitor conformance to both the *Technical Specifications* and the list of properties certified by the Manufacturer. The test procedures will be as indicated in Table 3. Where optional procedures are noted in the test method, the requirements of the *Technical Specifications* will prevail.

Samples will be taken across the width of the roll and will not include the first linear 3 feet of material. Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Consultant will mark the machine direction on the samples with an arrow along with the date and roll number. The required minimum sampling frequencies are provided in Table 3.

The CQA Consultant will examine results from laboratory conformance testing and will report any non-conformance to the Construction Manager and the Geosynthetic Installer. The procedures prescribed in the *Technical Specifications* will be followed in the event of a failing conformance test.

10.3 Delivery

10.3.1 Transportation and Handling

The CQA Consultant will document that the transportation and handling does not pose a risk of damage to the geomembrane.

Upon delivery of the rolls of geomembrane, the CQA Site Manager will document that the rolls are unloaded and stored on site as required by the *Technical Specifications*. Damage caused by unloading will be documented by the CQA Site Manager and the damaged material shall not be installed.

10.3.2 Storage

The Geosynthetic Installer will be responsible for the storage of the geomembrane on site. The Contractor will provide storage space in a location (or several locations) such that onsite transportation and handling are optimized, if possible, to limit potential damage.

The CQA Site Manager will document that storage of the geomembrane provides adequate protection against sources of damage.

10.4 Geomembrane Installation

10.4.1 Introduction

The CQA Site Manager will document that the geomembrane installation is carried out in accordance with the *Construction Drawings, Technical Specifications,* and Manufacturer's recommendations.

10.4.2 Earthwork[1]

10.4.2.1 Surface Preparation

The CQA Site Manager will document that:

- the prepared subgrade meets the requirements of the *Technical Specifications* and has been approved; and
- placement of the overlying materials does not damage, create large wrinkles, or induce excessive tensile stress in any underlying geosynthetic materials.

The Geosynthetic Installer will certify in writing that the surface on which the geosynthetics will be installed is acceptable. The Certificate of Acceptance, as presented in the *Technical Specifications*, will be signed by the Geosynthetic Installer and given to the CQA Site Manager prior to commencement of geosynthetics installation in the area under consideration.

After the subgrade has been accepted by the Geosynthetic Installer, it will be the Geosynthetic Installer's responsibility to indicate to the Construction Manager any change in the subgrade soil condition that may require repair work. If the CQA Site Manager concurs with the Geosynthetic Installer, then the CQA Site Manager shall monitor and document that the subgrade soil is repaired before geosynthetic installation begins.

At any time before and during the geomembrane installation, the CQA Site Manager will indicate to the Construction Manager locations that may not provide adequate support to the geomembrane.

10.4.2.2 Geosynthetic Termination

The CQA Site Manager will document that the geosynthetic terminations (Anchor Trench) have been constructed in accordance with the *Construction Drawings*. Backfilling above the terminations will be conducted in accordance with the *Technical Specifications*.

10.4.3 Geomembrane Placement

10.4.3.1 Panel Identification

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[1] For Option A, geomembrane will be installed over subgrade; for Option B, geomembrane will be installed over GCL

A field panel is the unit area of geomembrane which is to be seamed in the field, i.e., a field panel is a roll or a portion of roll cut in the field. It will be the responsibility of the CQA Site Manager to document that each field panel is given an "identification code" (number or letter-number) consistent with the Panel Layout Drawing. This identification code will be agreed upon by the Construction Manager, Geosynthetic Installer and CQA Site Manager. This field panel identification code will be as simple and logical as possible. Roll numbers established in the manufacturing plant must be traceable to the field panel identification code.

The CQA Site Manager will establish documentation showing correspondence between roll numbers and field panel identification codes. The field panel identification code will be used for all CQA records.

10.4.3.2 Field Panel Placement

Location

The CQA Site Manager will document that field panels are installed at the location indicated in the Geosynthetic Installer's Panel Layout Drawing, as approved or modified by the Construction Manager.

Installation Schedule

Field panels may be installed using one of the following schedules:

- all field panels are placed prior to field seaming in order to protect the subgrade from erosion by rain;
- field panels are placed one at a time and each field panel is seamed after its placement (in order to minimize the number of unseamed field panels exposed to wind); and
- any combination of the above.

If a decision is reached to place all field panels prior to field seaming, it is usually beneficial to begin at the high point area and proceed toward the low point with "shingle" overlaps to facilitate drainage in the event of precipitation. It is also usually beneficial to proceed in the direction of prevailing winds. Accordingly, an early decision regarding installation scheduling should be made if and only if weather conditions can be predicted with reasonable certainty. Otherwise, scheduling decisions must be made during installation, in accordance with varying conditions. In any event, the Geosynthetic Installer is fully responsible for the decision made regarding placement procedures.

The CQA Site Manager will evaluate every change in the schedule proposed by the Geosynthetic Installer and advise the Construction Manager on the acceptability of that change. The CQA Site Manager will document that the condition of the subgrade soil has not changed detrimentally during installation.

The CQA Site Manager will record the identification code, location, and date of installation of each field panel.

Weather Conditions

Geomembrane placement will not proceed unless otherwise authorized when the ambient temperature is below 32°F or above 122°F. In addition, wind speeds and direction will be monitored for potential impact to geosynthetic installation. Geomembrane placement will not be performed during any precipitation, in the presence of excessive moisture (e.g., fog, dew), or in an area of ponded water.

The CQA Site Manager will document that the above conditions are fulfilled. Additionally, the CQA Site Manager will document that the subgrade soil has not been damaged by weather conditions. The Geosynthetics Installer will inform the Construction Manager if the above conditions are not fulfilled.

Method of Placement

The CQA Site Manager will document the following:

- equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons or other means;
- the surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement;
- geosynthetics are oriented in accordance with the requirements of the *Technical Specifications*;
- excessive dust and/or dirt is not within the Drain Liner™ studs which could result in clogging and/or damage to the adjacent materials;

- geosynthetic elements immediately underlying the geomembrane are clean and free of debris;
- personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane;
- the method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil;
- the method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels); and
- adequate temporary loading or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind (in case of high winds, continuous loading, e.g., by adjacent sand bags, is recommended along edges of panels to minimize risk of wind flow under the panels).

The CQA Site Manager will inform the Construction Manager if the above conditions are not fulfilled.

Damaged panels or portions of damaged panels that have been rejected will be marked and their removal from the work area recorded by the CQA Site Manager. Repairs will be made in accordance with procedures described in Section 9.4.5.

10.4.4 Field Seaming

This section details CQA procedures to document that seams are properly constructed and tested in accordance with the Manufacturer's specifications and industry standards.

10.4.4.1 Requirements of Personnel

All personnel performing seaming operations will be qualified by experience or by successfully passing seaming tests, as outlined in the *Technical Specifications*. The most experienced seamer, the "master seamer", will provide direct supervision over less experienced seamers.

The Geosynthetic Installer will provide the Construction Manager and the CQA Consultant with a list of proposed seaming personnel and their experience records. These documents will be reviewed by the Construction Manager and the Geosynthetics CQA Consultant.

10.4.4.2 Seaming Equipment and Products

Approved processes for field seaming are fillet extrusion welding and double-track fusion welding.

Fillet Extrusion Process

The fillet extrusion-welding apparatus will be equipped with gauges giving the temperature in the apparatus.

The Geosynthetic Installer will provide documentation regarding the extrusion welding rod to the CQA Site Manager, and will certify that the extrusion welding rod is compatible with the *Technical Specification*, and in any event, is comprised of the same resin as the geomembrane.

The CQA Site Manager will log apparatus temperatures, ambient temperatures, and geomembrane surface temperatures at appropriate intervals.

The CQA Site Manager will document that:

- the Geosynthetic Installer maintains, on site, the number of spare operable seaming apparatus decided at the Pre-construction Meeting;
- equipment used for seaming is not likely to damage the geomembrane;
- the extruder is purged prior to beginning a seam until all heat-degraded extrudate has been removed from the barrel;
- the electric generator is placed on a smooth base such that no damage occurs to the geomembrane;
- a smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and
- the geomembrane is protected from damage in heavily trafficked areas.

Fusion Process

The fusion-welding apparatus must be automated vehicular-mounted devices. The fusion-welding apparatus will be equipped with gauges giving the applicable temperatures and pressures.

The CQA Site Manager will log ambient, seaming apparatus, and geomembrane surface temperatures as well as seaming apparatus speeds.

The CQA Site Manager will also document that:

- the Geosynthetic Installer maintains on site the number of spare operable seaming apparatus decided at the Pre-construction Meeting;
- equipment used for seaming is not likely to damage the geomembrane;
- for cross seams, the edge of the cross seam is ground to a smooth incline (top and bottom) prior to welding;
- the electric generator is placed on a smooth cushioning base such that no damage occurs to the geomembrane from ground pressure or fuel leaks;
- a smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and
- the geomembrane is protected from damage in heavily trafficked areas.

10.4.4.3 Seam Preparation

The CQA Site Manager will document that:

- prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris, and foreign material;
- horizontal seams are not present on slopes greater than 10H:1V;
- Drain Liner™ studs are removed and grind depth does not exceed 10 percent of the core geomembrane thickness; and
- seams are aligned with the fewest possible number of wrinkles and "fishmouths."

10.4.4.4 Weather Conditions for Seaming

The normally required weather conditions for seaming are as follows unless authorized in writing by the Design Engineer:

- seaming will only be approved between ambient temperatures of 32°F and 122°F.

If the Geosynthetic Installer wishes to use methods that may allow seaming at ambient temperatures below 32°F or above 122°F, the Geosynthetic Installer will demonstrate and certify that such methods produce seams which are entirely equivalent to seams produced within acceptable temperature, and that the overall quality of the geomembrane is not adversely affected.

The CQA Site Manager will document that these seaming conditions are fulfilled and will advise the Geosynthetics Installer if they are not.

10.4.4.5 Overlapping and Temporary Bonding

The CQA Site Manager will document that:

- the panels of geomembrane have a finished overlap of a minimum of 3 inches for both extrusion and fusion welding;
- no solvent or adhesive bonding materials are used; and
- the procedures utilized to temporarily bond adjacent panels together does not damage the geomembrane.

The CQA Site Manager will log appropriate temperatures and conditions, and will log and report non-compliances to the Construction Manager.

10.4.4.6 Trial Seams

Trial seams shall be prepared with the procedures and dimensions as indicated in the *Technical Specifications*. The CQA Site Manager will observe trial seam procedures and will document the results of trial seams on trial seam logs. Each trial seam samples will be assigned a number. The CQA Site Manager, will log the date, time, machine temperature(s), seaming unit identification, name of the seamer, and pass or fail description for each trial seam sample tested.

Separate trial seaming logs shall be maintained for fusion welded and extrusion welded trial seams.

10.4.4.7 General Seaming Procedure

Unless otherwise specified, the general production seaming procedure used by the Geosynthetic Installer will be as follows:

- fusion-welded seams are continuous, commencing at one end to the seam and ending at the opposite end;
- cleaning, overlap, and shingling requirements shall be maintained;

- if seaming operations are carried out at night, adequate illumination will be provided at the Geosynthetic Installer's expense; and
- seaming will extend to the outside edge of panels to be placed in the anchor trench.

The CQA Site Manager shall document geomembrane seaming operations on seaming logs. Seaming logs shall include, at a minimum:

- seam identifications (typically associated with panels being joined);
- seam starting time and date;
- seam ending time and date;
- seam length;
- identification of person performing seam; and
- identification of seaming equipment.

Separate logs shall be maintained for fusion and extrusion welded seams. In addition, the CQA Site Manager shall monitor during seaming that:

- fusion-welded seams are continuous, commencing at one end of the seam and ending at the opposite end; and
- cleaning, overlap, and shingling requirements are maintained.

10.4.4.8 Nondestructive Seam Continuity Testing

Concept

The Geosynthetic Installer will non-destructively test field seams over their length using a vacuum test unit, air pressure test (for double fusion seams only), or other method approved by the Construction Manager. The purpose of nondestructive tests is to check the continuity of seams. It does not provide information on seam strength. Continuity testing will be carried out as the seaming work progresses, not at the completion of field seaming.

The CQA Site Manager will:

- observe continuity testing;

- record location, date, name of person conducting the test, and the results of tests; and
- inform the Geosynthetic Installer of required repairs.

The Geosynthetic Installer will complete any required repairs in accordance with Section 10.4.5.

The CQA Site Manager will:

- observe the repair and re-testing of the repair;
- mark on the geomembrane that the repair has been made; and
- document the results.

The following procedures will apply to locations where seams cannot be non-destructively tested:

All such seams will be cap-stripped with the same geomembrane.

- If the seam is accessible to testing equipment prior to final installation, the seam will be non-destructively tested prior to final installation.
- If the seam cannot be tested prior to final installation, the seaming and cap-stripping operations will be observed by the CQA Site Manager and Geosynthetic Installer for uniformity and completeness.

The seam number, date of observation, name of tester, and outcome of the test or observation will be recorded by the CQA Site Manager.

Vacuum Testing

Vacuum testing shall be performed utilizing the equipment and procedures specified in the Technical Specifications. The CQA Site Manager shall observe the vacuum testing procedures and document that they are performed in accordance with the *Technical Specifications*. The result of vacuum testing shall be recorded on the CQA seaming logs. Results shall include, at a minimum, the personnel performing the vacuum test and the result of the test (pass or fail), and the test date. Seams failing the vacuum test shall be repaired in accordance with the procedures listed in the *Technical Specifications*. The CQA Site Manager shall document seam repairs in the seaming logs.

Air Pressure Testing

Air channel pressure testing shall be performed on double-track seams created with a fusion welding device, utilizing the equipment and procedures specified in the *Technical Specifications*. The CQA Site Manager shall observe the air pressure testing procedures and document that they are performed in accordance with the *Technical Specifications*. The result of air channel pressure testing shall be recorded on the CQA seaming logs. Results shall include, at a minimum, personnel performing the air pressure test, the starting air pressure and time, the final air pressure and time, the drop in psi during the test, and the result of the test (pass or fail). Seams failing the air pressure test shall be repaired in accordance with the procedures listed in the *Technical Specifications*. The CQA Site Manager shall document seam repairs in the seaming logs.

10.4.4.9 Destructive Testing

Concept

Destructive seam testing will be performed on site and at the independent CQA laboratory in accordance with the *Construction Drawings* and the *Technical Specifications*. Destructive seam tests will be performed at selected locations. The purpose of these tests is to evaluate seam strength. Seam strength testing will be done as the seaming work progresses, not at the completion of all field seaming.

Location and Frequency

The CQA Site Manager will select locations where seam samples will be cut out for laboratory testing. Those locations will be established as follows.

- The frequency of geomembrane seam testing is a minimum of one destructive sample per 500 feet of weld. If after a total of 50 samples have been tested and no more than one sample has failed, the frequency can be increased to one per 1,000 feet.
- A minimum of one test per seaming machine over the duration of the project.
- Additional test locations may be selected during seaming at the CQA Site Manager's discretion. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding.

The Geosynthetic Installer will not be informed in advance of the locations where the seam samples will be taken.

Sampling Procedure

Samples will be marked by the CQA Site Manager following the procedures listed in the *Technical Specifications*. Preliminary samples will be taken from either side of the marked sample and tested before obtaining the full sample per the requirements of the *Technical Specifications*. Samples shall be obtained by the Geosynthetic Installer. Samples shall be obtained as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material. The CQA Site Manager will:

- observe sample cutting and monitor that corners are rounded;
- assign a number to each sample, and mark it accordingly;
- record sample location on the Panel Layout Drawing; and
- record reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).

Holes in the geomembrane resulting from destructive seam sampling will be immediately repaired in accordance with repair procedures described in Section 10.4.5. The continuity of the new seams in the repaired area will be tested in accordance with Section 10.4.4.8.

Size and Distribution of Samples

The destructive sample will be 12 inches (0.3 meters) wide by 42 inches (1.1 meters) long with the seam centered lengthwise. The sample will be cut into three parts and distributed as follows:

- one portion, measuring 12 inches by 12 inches (30 centimeters (cm) by 30 cm), to the Geosynthetic Installer for field testing;
- one portion, measuring 12 inches by 18 inches (30 cm by 45 cm), for CQA Laboratory testing; and
- one portion, measuring 12 inches by 12 inches (30 cm by 30 cm), to the Construction Manager for archive storage.

Final evaluation of the destructive sample sizes and distribution will be made at the Pre-Construction Meeting.

Field Testing

Field testing will be performed by the Geosynthetic Installer using a gauged tensiometer. Prior to field testing the Geosynthetic Installer shall submit a calibration certificate for gauge tensiometer to the CQA Consultant for review. Calibration must have been performed within one year of use on the current project. The destructive sample shall be tested according to the requirements of the *Technical Specifications*. The specimens shall not fail in the seam and shall meet the strength requirements outlined in the *Technical Specifications*. If any field test specimen fails, then the procedures outlined in *Procedures for Destructive Test Failures* of this section will be followed.

The CQA Site Manager will witness field tests and mark samples and portions with their number. The CQA Site Manager will also document the date and time, ambient temperature, number of seaming unit, name of seamer, welding apparatus temperatures and pressures, and pass or fail description.

CQA Laboratory Testing

Destructive test samples will be packaged and shipped, if necessary, under the responsibility of the CQA Site Manager in a manner that will not damage the test sample. The Construction Manager will be responsible for storing the archive samples. This procedure will be outlined at the Pre-construction Meeting. Samples will be tested by the CQA Laboratory. The CQA Laboratory will be selected by the CQA Consultant with the concurrence of the Design Engineer.

Testing will include “Bonded Seam Strength” and “Peel Adhesion.” The minimum acceptable values to be obtained in these tests are given in the *Technical Specifications*. At least five specimens will be tested for each test method. Specimens will be selected alternately, by test, from the samples (i.e., peel, shear, peel, shear, and so on). A passing test will meet the minimum required values in at least four out of five specimens.

The CQA Laboratory will provide test results no more than 24 hours after they receive the samples. The CQA Consultant will review laboratory test results as soon as they become available, and make appropriate recommendations to the Construction Manager.

Geosynthetic Installer's Laboratory Testing

The Geosynthetic Installer's laboratory test results will be presented to the Construction Manager and the CQA Consultant for comments.

Procedures for Destructive Test Failure

The following procedures will apply whenever a sample fails a destructive test, whether that test conducted by the CQA Laboratory, the Geosynthetic Installer's laboratory, or by gauged tensiometer in the field. The Geosynthetic Installer has two options:

- The Geosynthetic Installer can reconstruct the seam between two passed test locations.
- The Geosynthetic Installer can trace the welding path to an intermediate location at 10 feet (3 meters) minimum from the point of the failed test in each direction and take a small sample for an additional field test at each location. If these additional samples pass the test, then full laboratory samples are taken. If these laboratory samples pass the tests, then the seam is reconstructed between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

Acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken. Repairs will be made in accordance with Section 10.4.5.

The CQA Site Manager will document actions taken in conjunction with destructive test failures.

10.4.5 Defects and Repairs

This section prescribes CQA activities to document that defects, tears, rips, punctures, damage, or failing seams shall be repaired.

10.4.5.1 Identification

Seams and non-seam areas of the geomembrane shall be examined by the CQA Site Manager for identification of defects, holes, blisters, undispersed raw materials and signs of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of examination.

10.4.5.2 Evaluation

Potentially flawed locations, both in seam and non-seam areas, shall be non-destructively tested using the methods described in Section 10.4.4.8 as appropriate. Each location that fails the nondestructive testing will be marked by the CQA Site Manager and repaired by the Geosynthetic Installer. Work will not proceed with any materials that will cover locations which have been repaired until laboratory test results with passing values are available.

10.4.5.3 Repair Procedures

Portions of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, will be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure will be at the discretion of the CQA Consultant with input from the Construction Manager and Geosynthetic Installer. The procedures available include:

- patching, used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter;
- grinding and re-welding, used to repair small sections of extruded seams;
- spot welding or seaming, used to repair small tears, pinholes, or other minor, localized flaws;
- capping, used to repair large lengths of failed seams; and
- removing a bad seam and replacing with a strip of new material welded into place (used with large lengths of fusion seams).

In addition, the following provisions will be satisfied:

- surfaces of the geomembrane which are to be repaired will be abraded no more than 20 minutes prior to the repair;
- surfaces must be clean and dry at the time of the repair;
- all seaming equipment used in repairing procedures must be approved;
- the repair procedures, materials, and techniques will be approved in advance by the CQA Consultant with input from the Design Engineer and Geosynthetic Installer;

- patches or caps will extend at least 6 inches (150 millimeters (mm)) beyond the edge of the defect, and all corners of patches will be rounded with a radius of at least 3 inches (75 mm);
- cuts and holes to be patched shall have rounded corners; and
- the geomembrane below large caps should be appropriately cut to avoid water or gas collection between the two sheets.

10.4.5.4 Verification of Repairs

The CQA Site Manager shall monitor and document repairs. Records of repairs shall be maintained on repair logs. Repair logs shall include, at a minimum:

- panel containing repair and approximate location on panel;
- approximate dimensions of repair;
- repair type, i.e. fusion weld or extrusion weld
- date of repair;
- seamer making the repair; and
- results of repair non-destructive testing (pass or fail).

Each repair will be non-destructively tested using the methods described herein, as appropriate. Repairs that pass the non-destructive test will be taken as an indication of an adequate repair. Large caps may be of sufficient extent to require destructive test sampling, per the requirements of the *Technical Specifications*. Failed tests shall be redone and re-tested until passing test results are observed.

10.4.5.5 Large Wrinkles

When seaming of the geomembrane is completed (or when seaming of a large area of the geomembrane liner is completed) and prior to placing overlying materials, the CQA Site Manager will observe the geomembrane wrinkles. The CQA Site Manager will indicate to the Geosynthetic Installer which wrinkles should be cut and re-seamed. The seam thus produced will be tested like any other seam.

10.4.6 Lining System Acceptance

The Geosynthetic Installer and the Manufacturer(s) will retain all responsibility for the geosynthetic materials in the liner system until acceptance by the Construction Manager.

The geosynthetic liner system will be accepted by the Construction Manager when:

- the installation is finished;
- verification of the adequacy of all seams and repairs, including associated testing, is complete;
- all documentation of installation is completed including the CQA Engineer's acceptance report and appropriate warranties; and
- CQA report, including "as built" drawing(s), sealed by a registered professional engineer has been received by the Construction Manager.

The CQA Site Manager will document that installation proceeded in accordance with the *Technical Specifications* for the project.

11. GEOTEXTILE

11.1 Introduction

This section of the CQA Plan outlines the CQA activities to be performed for the geotextile installation. The CQA Consultant will review the *Construction Drawings*, and the *Technical Specifications*, and any approved addenda or changes.

11.2 Manufacturing

The Manufacturer will provide the Construction Manager with a list of guaranteed "minimum average roll value" properties (defined as the mean less two standard deviations), for each type of geotextile to be delivered. The Manufacturer will also provide the Construction Manager with a written quality control certification signed by a responsible party employed by the Manufacturer that the materials actually delivered have property "minimum average roll values" which meet or exceed all property values guaranteed for that type of geotextile.

The quality control certificates will include:

- roll identification numbers; and
- results of MQC testing.

The Manufacturer will provide, as a minimum, test results for the following:

- mass per unit area;
- grab strength;
- tear strength;
- puncture strength;
- permittivity; and
- apparent opening size.

MQC tests shall be performed at the frequency listed in the *Technical Specifications*. CQA tests on geotextile produced for the project shall be performed according to the test methods specified and frequencies presented in Table 4.

The CQA Consultant will examine Manufacturer certifications to evaluate that the property values listed on the certifications meet or exceed those specified for the particular type of geotextile and the measurements of properties by the Manufacturer are properly documented, test methods acceptable and the certificates have been provided at the specified frequency properly identifying the rolls related to testing. Deviations will be reported to the Construction Manager.

11.3 Labeling

The Manufacturer will identify all rolls of geotextile with the following:

- manufacturer's name;
- product identification;
- lot number;
- roll number; and
- roll dimensions.

The CQA Site Manager will examine rolls upon delivery and deviation from the above requirements will be reported to the Construction Manager.

11.4 Shipment and Storage

During shipment and storage, the geotextile will be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions. To that effect, geotextile rolls will be shipped and stored in relatively opaque and watertight wrappings.

Protective wrappings will be removed less than one hour prior to unrolling the geotextile. After the wrapping has been removed, a nonwoven geotextile will not be exposed to sunlight for more than 15 days, except for UV protection geotextile, unless otherwise specified and guaranteed by the Manufacturer.

The CQA Site Manager will observe rolls upon delivery at the site and deviation from the above requirements will be reported to the Geosynthetic Installer.

11.5 Conformance Testing

11.5.1 Tests

The CQA Consultant will sample the geotextile either during production at the manufacturing facility or after delivery to the construction site. The samples will be forwarded to the Geosynthetics CQA Laboratory for testing to assess conformance with the *Technical Specifications*. The test methods and minimum testing frequencies are indicated in Table 4.

11.5.2 Sampling Procedures

Samples will be taken across the width of the roll and will not include the first 3 feet. Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Consultant will mark the machine direction on the samples with an arrow.

Unless otherwise specified, samples will be taken at a rate as indicated in Table 4 for geotextiles.

11.5.3 Test Results

The CQA Consultant will examine results from laboratory conformance testing and will report non-conformance with the *Technical Specifications* and this CQA Plan to the Construction Manager.

11.5.4 Conformance Sample Failure

The following procedure will apply whenever a sample fails a conformance test that is conducted by the CQA Laboratory:

- The Manufacturer will replace every roll of geotextile that is in nonconformance with the *Technical Specifications* with a roll(s) that meets *Technical Specifications*; or
- The Geosynthetic Installer will remove conformance samples for testing by the CQA Laboratory from the closest numerical rolls on both sides of the failed roll. These two samples must conform to the *Technical Specifications*. If either of these samples fail, the numerically closest rolls on the side of the failed sample will be tested by the CQA Laboratory. These samples must conform to the *Technical Specifications*. If any of these samples fail, every roll of geotextile on site from this lot and every subsequently delivered roll that is from the same lot must be tested by the CQA Laboratory for conformance to the *Technical Specifications*. This additional conformance testing will be at the expense of the Manufacturer.

The CQA Site Manager will document actions taken in conjunction with conformance test failures.

11.6 Handling and Placement

The Geosynthetic Installer will handle all geotextiles in such a manner as to document they are not damaged in any way, and the following will be complied with:

- In the presence of wind, all geotextiles will be weighted with sandbags or the equivalent. Such sandbags will be installed during placement and will remain until replaced with earth cover material.
- Geotextiles will be cut using an approved geotextile cutter only. If in place, special care must be taken to protect other materials from damage, which could be caused by the cutting of the geotextiles.
- The Geosynthetic Installer will take all necessary precautions to prevent damage to underlying layers during placement of the geotextile.
- During placement of geotextiles, care will be taken not to entrap in the geotextile stones, excessive dust, or moisture that could damage the geotextile, generate clogging of drains or filters, or hamper subsequent seaming.
- A visual examination of the geotextile will be carried out over the entire surface, after installation, to document that no potentially harmful foreign objects, such as needles, are present.

The CQA Site Manager will note non-compliance and report it to the Construction Manager.

11.7 Seams and Overlaps

Geotextiles will be continuously sewn. No horizontal seams will be allowed on side slopes (i.e. seams will be along, not across, the slope), except as part of a patch.

Seams will be sewn using polymeric thread with chemical and ultraviolet resistance properties equal to or exceeding those of the geotextile.

11.8 Repair

Holes or tears in the geotextile will be repaired as follows:

- On slopes: A patch made from the same geotextile will be double seamed into place. Should a tear exceed 10 percent of the width of the roll, that roll will be removed from the slope and replaced.
- Non-slopes: A patch made from the same geotextile will be spot-seamed in place with a minimum of 6 inches (0.60 meters) overlap in all directions.

Care will be taken to remove any soil or other material that may have penetrated the torn geotextile.

The CQA Site Manager will observe any repair, note any non-compliance with the above requirements and report them to the Construction Manager.

11.9 Placement of Soil or Aggregate Materials

The Contractor will place all soil or aggregate materials located on top of a geotextile, in such a manner as to document:

- no damage of the geotextile;
- minimal slippage of the geotextile on underlying layers; and
- no excess tensile stresses in the geotextile.

Non-compliance will be noted by the CQA Site Manager and reported to the Construction Manager.

12. GEOSYNTHETIC CLAY LINER (GCL)

12.1 Introduction

This section of the CQA Plan outlines the CQA activities to be performed for the GCL installation. The CQA Consultant will review the *Construction Drawings*, *Technical Specifications*, and approved addenda or changes.

12.2 Manufacturing

The Manufacturer will provide the Construction Manager with a list of guaranteed "minimum average roll value" properties (defined as the mean less two standard deviations), for the GCL to be delivered. The Manufacturer will also provide the Construction Manager with a written quality control certification signed by a responsible party employed by the Manufacturer that the materials actually delivered have property "minimum average roll values" which meet or exceed all property values guaranteed for that GCL.

The quality control certificates will include:

- roll identification numbers; and
- results of quality control testing.

The Manufacturer will provide, as a minimum, test results for the following:

- mass per unit area (bentonite content); and
- index flux.

Quality control tests must be performed, in accordance with the test methods specified in Table 5, on GCL produced for the project.

The CQA Consultant will examine Manufacturer certifications to verify that the property values listed on the certifications meet or exceed those specified for the GCL and the measurements of properties by the Manufacturer are properly documented, test methods acceptable and the certificates have been provided at the specified frequency properly identifying the rolls related to testing. Deviations will be reported to the Construction Manager.

12.3 Labeling

The Manufacturer will identify all rolls of GCL with the following:

- manufacturer's name;
- product identification;
- lot number;
- roll number; and
- roll dimensions.

The CQA Site Manager will examine rolls upon delivery and deviation from the above requirements will be reported to the Construction Manager.

12.4 Shipment and Storage

During shipment and storage, the GCL will be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, and cutting or any other damaging or deleterious conditions. To that effect, GCL rolls will be shipped and stored in relatively opaque and watertight wrappings.

The CQA Site Manager will observe rolls upon delivery at the site and any deviation from the above requirements will be reported to the Construction Manager.

12.5 Conformance Testing

12.5.1 Tests

The CQA Consultant will sample the GCL either during production at the manufacturing facility or after delivery to the construction site. The samples will be forwarded to the Geosynthetics CQA Laboratory for testing to assess conformance with the *Technical Specifications*. The test methods and minimum testing frequencies are indicated in Table 5.

Samples will be taken across the width of the roll and will not include the first 3 ft if the sample is cut on site. Unless otherwise specified, samples will be 3 ft long by the roll width. The CQA Consultant will mark the machine direction with an arrow and the manufacturer's roll number on each sample.

During GCL installation, the CQA Site Manager will deploy a small container to collect water as it is being applied to the surface of the GCL. The depth of water within the container will be measured and compared to the requirements outlined in the Technical Specifications. In addition, the CQA Site Manager will collect 6 inch square samples of the hydrated GCL for testing of moisture content. Samples will be collected once the overlying secondary geomembrane is in place and taken from within a destructive sample location. The test methods and minimum testing frequencies are indicated in Table 5.

The CQA Site Manager will examine results from laboratory conformance testing and will report non-conformance to the Construction Manager.

12.5.2 Conformance Sample Failure

The following procedure will apply whenever a sample fails a conformance test that is conducted by the CQA Laboratory:

- The Manufacturer will replace every roll of GCL that is in nonconformance with the *Technical Specifications* with a roll(s) that meets *Technical Specifications*; or
- The Geosynthetic Installer will remove conformance samples for testing by the CQA Laboratory from the closest numerical rolls on both sides of the failed roll. These two samples must conform to the *Technical Specifications*. If either of these samples fail, the numerically closest rolls on the side of the failed sample will be tested by the CQA Laboratory. These samples must conform to the *Technical Specifications*. If any of these samples fail, every roll of GCL on site from this lot and every subsequently delivered roll that is from the same lot must be tested by the CQA Laboratory for conformance to the *Technical Specifications*. This additional conformance testing will be at the expense of the Manufacturer.

The CQA Site Manager will document actions taken in conjunction with conformance test failures.

12.6 GCL Delivery and Storage

Upon delivery to the site, the CQA Site Manager will check the GCL rolls for defects (e.g., tears, holes) and for damage. The CQA Site Manager will report to the Construction Manager and the Geosynthetics Installer:

- any rolls, or portions thereof, which should be rejected and removed from the site because they have severe flaws; and
- any rolls which include minor repairable flaws.

The GCL rolls delivered to the site will be checked by the CQA Site Manager to document that the roll numbers correspond to those on the approved Manufacturer's quality control certificate of compliance.

12.6.1 Earthwork[2]

12.6.1.1 Surface Preparation

The CQA Site Manager will document that:

- the prepared subgrade meets the requirements of the *Technical Specifications* and has been approved; and
- placement of the overlying materials does not damage, create large wrinkles, or induce excessive tensile stress in any underlying geosynthetic materials.

The Geosynthetic Installer will certify in writing that the surface on which the geosynthetics will be installed is acceptable. The Certificate of Acceptance, as presented in the *Technical Specifications*, will be signed by the Geosynthetic Installer and given to the CQA Site Manager prior to commencement of geosynthetics installation in the area under consideration.

After the subgrade has been accepted by the Geosynthetic Installer, it will be the Geosynthetic Installer's responsibility to indicate to the Construction Manager any change in the subgrade soil condition that may require repair work. If the CQA Site Manager concurs with the Geosynthetic Installer, then the CQA Site Manager shall monitor and document that the subgrade soil is repaired before geosynthetic installation begins.

At any time before and during the geomembrane installation, the CQA Site Manager will indicate to the Construction Manager locations that may not provide adequate support to the geomembrane.

12.7 GCL Installation

[2] For Option A, geomembrane will be installed over subgrade and no GCL will be installed; for Option B, GCL will be installed over subgrade

The CQA Site Manager will monitor and document that the GCL is installed in accordance with the *Drawings* and the *Technical Specifications*. The Geosynthetics Installer shall provide the CQA Site Manager a certificate of subgrade acceptance prior to the installation of the GCL as outlined in the *Technical Specifications*. The GCL installation activities to be monitored and documented by the CQA Site Manager include:

- monitoring that the GCL rolls are stored and handled in a manner which does not result in any damage to the GCL;
- monitoring that the GCL is not exposed to UV radiation for extended periods of time without prior approval;
- monitoring that the GCL are seamed in accordance with the *Technical Specifications* and the Manufacturer's recommendations;
- monitoring and documenting that the GCL is installed on an approved subgrade, free of debris, protrusions, or uneven surfaces;
- monitoring that the subgrade surface is moist to within a minimum of 1 inch from the subgrade surface;
- monitoring that the GCL is hydrated prior to installation of the overlying geomembrane; and
- monitoring that any damage to the GCL is repaired as outlined in the *Technical Specifications*.

The CQA Site Manager will note non-compliance and report it to the Construction Manager.

13. GEONET

13.1 Introduction

This section of the CQA Plan outlines the CQA activities to be performed for the geonet installation. The CQA Consultant will review the *Construction Drawings*, *Technical Specifications*, and any approved addenda or changes.

13.2 Manufacturing

The Manufacturer will provide the CQA Consultant with a list of certified "minimum average roll value" properties for the type of geonet to be delivered. The Manufacturer will also provide the CQA Consultant with a written certification signed by a responsible representative of the Manufacturer that the geonet actually delivered have "minimum average roll values" properties which meet or exceed all certified property values for that type of geonet.

The CQA Consultant will examine the Manufacturers' certifications to document that the property values listed on the certifications meet or exceed those specified for the particular type of geonet. Deviations will be reported to the Construction Manager.

13.3 Labeling

The Manufacturer will identify all rolls of geonet with the following:

- Manufacturer's name;
- product identification;
- lot number;
- roll number; and
- roll dimensions.

The CQA Site Manager will examine rolls upon delivery and deviation from the above requirements will be reported to the Construction Manager.

13.4 Shipment and Storage

During shipment and storage, the geonet will be protected from mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions. The CQA Site Manager will observe rolls upon delivery to the site and deviation from the above requirements will be reported to the Construction Manager. Damaged rolls will be rejected and replaced.

The CQA Site Manager will observe that geonet is free of dirt and dust just before installation. The CQA Site Manager will report the outcome of this observation to the Construction Manager, and if the geonet is judged dirty or dusty, they will be cleaned by the Geosynthetic Installer prior to installation.

13.5 Conformance Testing

13.5.1 Tests

The geonet material will be tested for transmissivity (ASTM D 4716) and for thickness (ASTM D 5199) at the frequencies presented in Table 6.

13.5.2 Sampling Procedures

The CQA Consultant will sample the geonet either during production at the manufacturing facility or after delivery to the construction site. The samples will be forwarded to the Geosynthetics CQA Laboratory for testing to assess conformance with the *Technical Specifications*.

Samples will be taken across the width of the roll and will not include the first 3 linear feet. Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Consultant will mark the machine direction on the samples with an arrow.

13.5.3 Test Results

The CQA Consultant will examine results from laboratory conformance testing and compare results to the *Technical Specifications*. The criteria used to evaluate acceptability are presented in the *Technical Specifications*. The CQA Consultant will report any nonconformance to the Construction Manager.

13.5.4 Conformance Test Failure

The following procedure will apply whenever a sample fails a conformance test that is conducted by the CQA Laboratory:

- The Manufacturer will replace every roll of geonet that is in nonconformance with the *Technical Specifications* with a roll that meets specifications; or

- The Geosynthetic Installer will remove conformance samples for testing by the CQA Laboratory from the closest numerical rolls on both sides of the failed roll. These two samples must conform to the *Technical Specifications*. If either of these samples fail, the numerically closest rolls on the side of the failed sample that is not tested, will be tested by the CQA Laboratory. These samples must conform to the *Technical Specifications*. If any of these samples fail, every roll of geonet on site from this lot and every subsequently delivered roll that is from the same lot must be tested by the CQA Laboratory for conformance to the *Technical Specifications*.

The CQA Site Manager will document actions taken in conjunction with conformance test failures.

13.6 Handling and Placement

The Geosynthetic Installer will handle all geonet in such a manner as to document they are not damaged in any way. The Geosynthetic Installer will comply with the following:

- If in place, special care must be taken to protect other materials from damage, which could be caused by the cutting of the geonet.
- The Geosynthetic Installer will take any necessary precautions to prevent damage to underlying layers during placement of the geonet.
- During placement of geonet, care will be taken to prevent entrapment of dirt or excessive dust that could cause clogging of the drainage system, or stones that could damage the adjacent geomembrane. If dirt or excessive dust is entrapped in the geonet, it should be cleaned prior to placement of the next material on top of it. In this regard, care should be taken with the handling or sandbags, to prevent rupture or damage of the sandbag.
- A visual examination of the geonet will be carried out over the entire surface, after installation to document that no potentially harmful foreign objects are present.

The CQA Site Manager will note noncompliance and report it to the Construction Manager.

13.7 Geonet Seams and Overlaps

Adjacent geonet panels will be joined in accordance with *Construction Drawings* and *Technical Specifications*. As a minimum, the adjacent rolls will be overlapped by at least 4 inches and secured by tying, in accordance with the *Technical Specifications*.

The CQA Site Manager will note any noncompliance and report it to the Construction Manager.

13.8 Repair

Holes or tears in the geonet will be repaired by placing a patch extending 2 feet beyond edges of the hole or tear. The patch will be secured by tying with approved tying devices every 6 inches If the hole or tear width across the roll is more than 50 percent of the width of the roll, the damaged area will be cut out and the two portions of the geonet will be joined in accordance with Section 13.7.

The CQA Site Manager will observe repairs, note non-compliances with the above requirements and report them to the Construction Manager.

14. CONCRETE SPILLWAY

14.1 Introduction

This section prescribes the CQA activities to be performed to monitor that the concrete spillway is constructed in accordance with *Construction Drawings* and *Technical Specifications*. The concrete spillway construction procedures to be monitored by the CQA Site Manager, if required, shall include:

- subgrade preparation;
- liner system and cushion geotextile installation;
- welded wire reinforcement installation; and
- concrete placement and finishing.

14.2 CQA Monitoring Activities

14.2.1 Subgrade Preparation

The CQA Site Manager will monitor and document that the subgrade is prepared in accordance with the *Technical Specifications* and the *Construction Drawings*.

14.2.2 Liner System and Cushion Geotextile Installation

The CQA Site Manager shall monitor and document that the liner system components, along with the anchor trench and cushion geotextile, are installed in accordance with the requirements of the *Technical Specifications* and the *Construction Drawings*.

14.2.3 Welded Wire Reinforcement Installation

The CQA Site Manager shall monitor and document that the welded wire fabric reinforcement is installed in accordance with the requirements of the *Technical Specifications* and the *Construction Drawings*.

14.2.4 Concrete Installation

The CQA Site Manager shall test, monitor, and document that the concrete is installed in accordance with the requirements of the *Technical Specifications* and the *Construction Drawings*. At a minimum, the CQA Site Manager shall review the concrete tickets prior to installing the concrete to monitor that the concrete meets the requirements outlined in the *Technical Specifications*.

14.2.5 Conformance Testing

The Contractor shall facilitate the CQA Site Manager in the collection of samples required for testing. Compression test specimens shall be prepared by the CQA Site Manager by the following method:

- compression test cylinders from fresh concrete in accordance with ASTM C 172 and C 31.

Compression testing shall be completed on one cylinder at 7 days, one cylinder at 14 days, and two (2) cylinders at the 28 day strength. The CQA Consultant will examine results from laboratory conformance testing and will report any non-conformance with the requirements outlined in the *Technical Specifications* to the Construction Manager.

14.3 Deficiencies

If a defect is discovered in the concrete spillway, the CQA Site Manager will immediately determine the extent and nature of the defect. The CQA Site Manager will determine the extent of the defective area by additional observations, a review of records, or other means that the CQA Site Manager deems appropriate.

14.3.1 Notification

After evaluating the extent and nature of a defect, the CQA Site Manager will notify the Construction Manager and Contractor and schedule appropriate re-evaluation when the work deficiency is to be corrected.

14.3.2 Repairs

The Contractor will correct deficiencies to the satisfaction of the CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Construction Manager suggested solutions for his approval.

Re-evaluations by the CQA Site Manager shall continue until the defects have been corrected before any additional work is performed by the Contractor in the area of the deficiency.

15. SURVEYING

15.1 Survey Control

Survey control will be performed by the Surveyor as needed. A permanent benchmark will be established for the site(s) in a location convenient for daily tie--in. The vertical and horizontal control for this benchmark will be established within normal land surveying standards.

15.2 Precision and Accuracy

A wide variety of survey equipment is available for the surveying requirements for these projects. The survey instruments used for this work should be sufficiently precise and accurate to meet the needs of the projects.

15.3 Lines and Grades

The following structures will be surveyed to verify and document the lines and grades achieved during construction of the Project:

- geomembrane terminations; and
- centerlines of pipes.

15.4 Frequency and Spacing

A line of survey points no further than 100 feet apart must be taken at the top of pipes or other appurtenances to the liner.

15.5 Documentation

Field survey notes should be retained by the Land Surveyor. The findings from the field surveys should be documented on a set of Survey *Record Drawings*, which shall be provided to the Construction Manager in AutoCAD format or other suitable format as directed by the Construction Manager.

TABLE 1A

TEST PROCEDURES FOR THE EVALUATION OF EARTHWORK

TEST METHOD	DESCRIPTION	TEST STANDARD
Sieve Analysis	Particle Size Distribution	ASTM D 422
Modified Proctor	Moisture Density Relationship	ASTM D 1557

TABLE 1B

MINIMUM EARTHWORK TESTING FREQUENCIES

TEST	TEST METHOD	FILL
Sieve Analysis	ASTM D 422	1 per 20,000 CY or 1 per material type
Modified Proctor	ASTM D 1557	1 per 20,000 CY or 1 per material type
Nuclear Densometer – In-situ Moisture/Density	ASTM D 6938	1 per 500 yd^3

TABLE 2A

TEST PROCEDURES FOR THE EVALUATION OF AGGREGATE

TEST METHOD	DESCRIPTION	TEST STANDARD
Sieve Analysis	Particle Size Distribution of Fine and Coarse Aggregates	ASTM C 136
Hydraulic Conductivity (Rigid Wall Permeameter)	Permeability of Aggregates	ASTM D 2434
Insoluable Residue	Insoluable Residue in Carbonate Aggregates	ASTM D 3042

TABLE 2B

MINIMUM AGGREGATE TESTING FREQUENCIES FOR CONFORMANCE TESTING

TEST	TEST METHOD	DRAINAGE AGGREGATE
Sieve Analysis	ASTM C 136	1 per project
Hydraulic Conductivity	ASTM D 2434	1 per project
Insoluable Residue	Insoluable Residue in Carbonate Aggregates	1 per project

TABLE 3

GEOMEMBRANE CONFORMANCE TESTING REQUIREMENTS

TEST NAME	TEST METHOD	FREQUENCY[4]
Specific Gravity	ASTM D 792	200,000 ft^2
Thickness	ASTM D 5199 or ASTM D 5994	200,000 ft^2
Tensile Strength at Yield	ASTM D 6693	200,000 ft^2
Tensile Strength at Break	ASTM D 6693	200,000 ft^2
Elongation at Yield	ASTM D 6693	200,000 ft^2
Elongation at Break	ASTM D 6693	200,000 ft^2
Carbon Black Content	ASTM D 4218	200,000 ft^2
Carbon Black Dispersion	ASTM D 5596	200,000 ft^2
Interface Shear Strength[1,2,3]	ASTM D 5321	1 per project

Notes:
1. To be performed at normal stresses of 10, 20, and 40 psi between smooth geomembrane and Drain Liner™
2. To be performed at normal stresses of 10, 20, and 40 psi between smooth geomembrane and 300-mil geonet
3. To be performed at normal stresses of 100, 200, and 400 psf between textured geomembrane and nonwoven geotexile.
4. Frequency does not include material intended for splash pads.

TABLE 4

GEOTEXTILE CONFORMANCE TESTING REQUIREMENTS

TEST NAME	TEST METHOD	MINIMUM FREQUENCY
Mass per Unit Area	ASTM D 5261	1 test per 260,000 ft^2
Grab Strength	ASTM D 4632	1 test per 260,000 ft^2
Puncture Resistance	ASTM D 6241	1 test per 260,000 ft^2
Permittivity	ASTM D 4491	1 test per 260,000 ft^2
Apparent Opening Size	ASTM D 4751	1 test per 260,000 ft^2

Notes:
1. Nonwoven geotextile only.

TABLE 5

GCL CONFORMANCE TESTING REQUIREMENTS

TEST NAME	TEST METHOD	MINIMUM FREQUENCY
Mass per Unit Area	ASTM D 5993	1 test per 100,000 ft^2
Index Flux	ASTM D 5887	1 test per 400,000 ft^2
Bentonite Moisture Content – Post Field Hydration	ASTM D 2216	1 test per 4 secondary geomembrane destructive samples

Note: Hydraulic index flux testing shall be performed under an effective confining stress of 5 pounds per square inch.

TABLE 6

GEONET CONFORMANCE TESTING REQUIREMENTS

TEST NAME	TEST METHOD	MINIMUM FREQUENCY
Thickness	ASTM D 5199	1 test per 200,000 ft^2
Hydraulic Transmissivity	ASTM D 4716	1 test per 400,000 ft^2

Note: Transmissivity shall be measured using water at 68°F with a gradient of 0.1 under a confining pressure of 7,000 lb/ft^2. The geonet shall be placed in the testing device between 60-mil smooth geomembrane. Measurements are taken one hour after application of confining pressure.

APPENDIX C

Project Technical Specifications

Prepared for

Energy Fuels Resources (USA), Inc.
6425 S. Highway 191
P.O. Box 809
Blanding, UT 84511

TECHNICAL SPECIFICATIONS

CELLS 5A AND 5B

WHITE MESA MILL
BLANDING, UTAH

Prepared by

Geosyntec consultants

engineers | scientists | innovators

16644 West Bernardo Drive, Suite 301
San Diego, CA 92127

Project Number SC0634

June 2018

CERTIFICATION PAGE

TECHNICAL SPECIFICATIONS
CELLS 5A AND 5B CONSTRUCTION
ENERGY FUELS RESOURCES (USA), INC.
WHITE MESA MILL
BLANDING, UTAH

The Engineering material and data contained in these Technical Specifications were prepared under the supervision and direction of the undersigned, whose seal as a registered Professional Engineer is affixed below.

Gregory T. Corcoran, P.E.
Engineer of Record

TABLE OF CONTENTS

SECTION 01010

SUMMARY OF WORK

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Work consists of constructing Cells 5A and 5B under separate contracts and at separate times. Cell 5A will be constructed first, followed by Cell 5B in subsequent years. These Technical Specifications are to be used for both Projects.

B. The Work generally involves the excavation or soil and rock, placement and compaction of fill, preparation of subgrade, installation of geosynthetic liner system, and installation of associated piping and concrete.

C. These Technical Specifications consist of requirements related to both Option A – Triple Liner and Option B – Double Liner with Geosynthetic Clay Liner (GCL). Applicability of specifications, specifically GCL, is dependent on Option selected for construction. The Owner will direct the Contractor as to which liner system option will be constructed.

D. The Work will generally consist of:

1. Initial topographic survey;
2. Mass excavation and fill placement and compaction;
3. Subgrade preparation;
4. Anchor trench and leak detection system trench and sump excavation;
5. Installation of either (see Drawings, Option A or Option B for specific differences):
    a. Option A - 130-mil high density polyethylene (HDPE) tertiary Drain Liner™ geomembrane and textured 60-mil HDPE geomembrane in the sump side slope riser trench; or
    b. Option B - Geosynthetic clay liner (GCL).
6. Option A only - Installation of secondary leak detection system, cushion geotextile, drainage aggregate, and 4-inch and 18-inch polyvinyl chloride (PVC) pipe and fittings;
7. Installation of smooth 60-mil HDPE secondary geomembrane on the bottom of the Cell, 130-mil HDPE Drain Liner ™ geomembrane on the side slopes and 60-mil textured geomembrane on the sump side slope riser trench;
8. Installation of primary leak detection system, cushion geotextile, drainage aggregate, and 4-inch and 18-inch polyvinyl chloride (PVC) pipe and fittings;
9. Installation of 300-mil geonet on the bottom of the cell;
10. Installation of smooth 60-mil HDPE primary geomembrane and textured 60-mil HDPE geomembrane in the sump side slope riser trench;
11. Installation of 16 oz./SY nonwoven geotextile cushion;
12. Installation of slimes drain 4-inch and 18-inch PVC pipe and fittings;
13. Installation of drainage aggregate around slimes drain and within sump;
14. Installation of woven geotextile;

15. Installation of 60-mil HDPE geomembrane splash pads;
16. Backfill and compaction of anchor trenches;
17. Construction of concrete spillway and pipe support at the side slope riser termination; and
18. Installation of strip composite drainage layer, including sand bags.

1.02 CONTRACTOR'S RESPONSIBILITIES

A. Start, layout, construct, and complete the construction of the lining system (the Project) in accordance with the Technical Specifications, CQA Plan, and Drawings (Contract Documents).

B. Provide a competent site superintendent, capable of reading and understanding the Construction Documents, who shall receive instructions from the Construction Manager. Site superintendent shall have successfully completed projects of similar scope (excavation of soil and rock, fill placement and compaction, finish work to close tolerances to lines and grades, and geosynthetic liner installation).

C. Establish means, techniques, and procedures for constructing and otherwise executing the Work.

D. Establish and maintain proper Health and Safety practices for the duration of the Project.

E. Except as otherwise specified, furnish the following and pay the cost thereof:

1. Labor, superintendent, and products.
2. Construction supplies, equipment, tools, and machinery.
3. Electricity and other utilities required for construction.
4. Other facilities and services necessary to properly execute and complete the Work.
5. A Registered Land Surveyor, licensed in the State of Utah, to survey and layout the Work, and to certify as-built Record Drawings.

F. Pay cost of legally required sales, consumer, use taxes and governmental fees.

G. Perform Work in accordance with codes, ordinances, rules, regulations, orders, and other legal requirements of governmental bodies and public agencies bearing on performance of the Work.

H. Forward submittals and communications to the Construction Manager. Where applicable, the Construction Manager will coordinate submittals and communications with the representatives who will give approvals and directions through the Construction Manager.

I. Maintain order, safe practices, and proper conduct at all times among Contractor's employees. The Owner, and its authorized representative, may require that disciplinary action be taken against an employee of the Contractor for disorderly, improper, or unsafe conduct. Should an employee of the Contractor be dismissed from his duties for misconduct, incompetence, or unsafe practice, or combination thereof, that employee shall not be rehired for the duration of the Work.

J. Coordinate the Work with the utilities, private utilities, and/or other parties performing work on or adjacent to the Site. Eliminate or minimize delays in the Work and conflicts with those utilities or contractors. Coordinate activities with the Construction Manager. Schedule private utility and public utility work relying on survey points, lines, and grades established by the Contractor to occur immediately after those points, lines, and grades have been established.

K. Coordinate activities of the several trades, suppliers, and subcontractors, if any, performing the Work.

1.03 NOTIFICATION

A. The Contractor shall notify the Construction Manager in writing if he elects to subcontract, sublet, or reassign any portion of the Work. This shall be done at the time the bid is submitted. The written statement shall describe the portion of the Work to be performed by the Subcontractor and shall include an indication, by reference if desired by the Construction Manager, that the Subcontractor is particularly experienced and equipped to perform that portion of the Work. No portion of the Work shall be subcontracted, sublet, or reassigned without written permission of the Construction Manager. Consent to subcontract, sublet, or reassign any portion of the Work by the Construction Manager shall not be considered as a testimony of the Construction Manager as to the qualifications of the Subcontractor and shall not be construed to relieve the Contractor of any responsibilities for completion of the Work.

1.04 CONFORMANCE

A. Work shall conform to the Technical Specifications, Construction Quality Assurance (CQA) Plan, and Drawings that form a part of these Contract Documents.

B. Omissions from the Technical Specifications, CQA Plan, and Drawings or the misdescription of details of the Work which are necessary to carry out the intent of the Contract Documents, are customarily performed and shall not relieve the Contractor from performing such omitted or misdescribed details of the Work, but they shall be performed as if fully and correctly set forth and described in the Technical Specifications, CQA Plan, and Drawings.

1.05 DEFINITIONS

A. **OWNER** – The term Owner means Energy Fuels Resources (USA), Inc. for whom the Work is to be provided.

B. **CONSTRUCTION MANAGER** – The term Construction Manager means the firm responsible for project administration and project documentation control. All formal documents will be submitted to the Construction Manager for proper distribution and/or review. During the period of Work the Construction Manager will act as an authorized representative of the Owner.

C. **DESIGN ENGINEER** – The term Design Engineer means the firm responsible for the design and preparation of the Construction Documents. The Design Engineer is responsible for approving all design changes, modifications, or clarifications encountered during construction. The Design Engineer reports directly to the Owner.

D. **CQA CONSULTANT** – The term CQA Consultant refers to the firm responsible for CQA related monitoring and testing activities. The CQA Consultant's authorized personnel will include CQA Engineer-of-Record and CQA Site Manager. The CQA Consultant may also perform construction quality control (CQC) work as appropriate.

E. **CONTRACTOR** – The term Contractor means the firm that is responsible for the Work. The Contractor's responsibilities include the Work of any and all of the subcontractors and suppliers. The Contractor reports directly to the Construction Manager. All subcontractors report directly to the Contractor.

F. **SURVEYOR** – The term Surveyor means the firm that will perform the survey and provide as-built Record Drawings for the Work. The Surveyor shall be a Registered Land Surveyor, licensed to practice in the State of Utah. The Surveyor is employed by and reports directly to the Contractor.

G. **SITE** – The term Site refers to all approved staging areas, and all areas where the Work is to be performed, both public and private owned.

H. **WORK** – The term Work means the entire completed construction, or various separately identifiable parts thereof, required to be furnished under the Contract Documents. Work includes any and all labor, services, materials, equipment, tools, supplies, and facilities required by the Contract Documents and necessary for the completion of the project. Work is the result of performing services, furnishing labor, and furnishing and incorporating materials and equipment into the construction, all as required by the Contract Documents.

I. **DAY** – A calendar day on which weather and other conditions not under the control of the Contractor will permit construction operations to proceed for the major part of the day (greater than 4 hours) with the normal working force engaged in performing the controlling item or items of Work which would be in progress at that time.

J. **CONTRACT DOCUMENTS** – Contract Documents consist of the Technical Specifications, CQA Plan, and Drawings.

1.06 CONTRACT TIMES

A. The time stated for completion and substantial completion shall be in accordance with the Contract Times specified in the Agreement. No claims for damages shall be made by the Contractor for delays.

B. Contractor shall adhere to the schedule provided in the Contract. Unapproved extensions to the schedule will result in the Contractor paying liquidated damages in the amount of $4,000 per day to cover costs associated with Construction Management and construction oversight.

1.07 CONTRACTOR USE OF WORK SITE

A. Confine Site operations to areas permitted by law, ordinances, permits, and the Contract Documents. The Contractor shall ensure that all persons under his control (including Subcontractors and their workers and agents) are kept within the boundaries of the Site and shall be responsible for any acts of trespass or damage to property by persons who are under his control. Consider the safety of the Work, and that of people and property on and adjacent to work Site, when determining amount, location, movement, and use of materials and equipment on work Site.

B. The Contractor shall be responsible for protecting private and public property including pavements, drainage culverts, electricity, highway, telephone, and similar property and shall make good of, or pay for, all damage caused thereto. Control of erosion throughout the project is of prime importance and is the responsibility of the Contractor. The Contractor shall provide and maintain all necessary measures to control erosion during progress of the Work to the satisfaction of the Construction Manager and all applicable laws and regulations, and shall remove such measures and collected debris upon completion of the project. All provisions for erosion and sedimentation control apply equally to all areas of the Work.

C. The Contractor shall promptly notify the Construction Manager in writing of any subsurface or latent physical conditions at the Site that differ materially from those indicated or referred to in the Contract Documents. Construction Manager will promptly review those conditions and advise Owner in writing if further investigations or tests are necessary. If the Construction Manager finds that the results of such investigations or tests indicate that there are subsurface and latent physical conditions which differ materially from those intended in the Contract Documents, and which could not reasonably have been anticipated by Contractor, a Change Order shall be issued incorporating the necessary revisions.

D. At no time shall the Contractor interfere with operations of businesses on or in the vicinity of the Site. Should the Contractor need to work outside the regular working hours, the Contractor is required to submit a written request and obtain approval by the Construction Manager.

1.08 PRESERVATION OF SCIENTIFIC INFORMATION

A. Federal and State legislation provides for the protection, preservation, and collection of data having scientific, prehistoric, historical, or archaeological value (including relics and specimens) that might otherwise be lost due to alteration of the terrain as a result of any construction work. If evidence of such information is discovered during the course of the Work, the Contractor shall notify the Construction Manager immediately, giving the location and nature of the findings. Written confirmation shall be forwarded within two (2) working days.

B. The Contractor shall exercise care so as not to damage artifacts uncovered during excavation operations, and shall provide such cooperation and assistance as may be necessary to preserve the findings for removal or other disposition by the Construction Manager or Government agency.

C. Where appropriate, by reason of a discovery, the Construction Manager may order delays in the time of performance, or changes in the Work, or both. If such delays, or changes, or both, are ordered, the time of performance and contract price shall be adjusted in accordance with the applicable clauses of the Contract.

1.09 MEASUREMENT AND PAYMENT

A. Measurement for Work will be according to the work items listed in Section 01025 of these Specifications.

1.10 EXISTING UTILITIES

A. The Contractor shall be responsible for locating, uncovering, protecting, flagging, and identifying all existing utilities encountered while performing the Work. The Contractor shall request that Underground Service Alert (USA) locate and identify the existing utilities. The request shall be made 48 hours in advance.

B. Costs resulting from damage to utilities shall be borne by the Contractor. Costs of damage shall include repair and compensation for incidental costs resulting from the unscheduled loss of utility service to affected parties.

C. The Contractor shall immediately stop work and notify the Construction Manager of all utilities encountered and damaged. The Contractor shall also Survey the exact location of any utilities encountered during construction.

1.11 CONTRACTOR QUALIFICATIONS

A. The Contractor, and all subcontractors, shall be licensed at the time of bidding, and throughout the period of the Contract, by the State of Utah to do the type of work required under terms of these Contract Documents. By submitting a bid, the Contractor certifies that he is skilled, competent, and knowledgeable on the nature, extent and inherent conditions of the Work to be performed and has been regularly engaged in the general class and type of work called for in these Contract Documents and meets the qualifications required in these Specifications.

B. The Construction Manager shall disqualify a bidder that either cannot provide references, or if the references cannot substantiate the Contractor's qualifications.

C. By submission of a bid for this Project, the Contractor acknowledges that he is thoroughly familiar with the Site conditions.

D. Contractor shall provide a full-time, on-site superintendent that is qualified in this type of work. Site superintendent shall have successfully completed three projects of similar scope (excavation of soil and rock, fill placement and compaction, finish work to close tolerances to lines and grades, and geosynthetic liner installation).

1.12 INTERPRETATION OF TECHNICAL SPECIFICATIONS, CQA PLAN, AND DRAWINGS

A. Should it appear that the Work to be done or any matters relative thereto are not sufficiently detailed or explained in the Technical Specifications, CQA Plan, and/or Drawings, the Design Engineer will further explain or clarify, as may be necessary. In the event of any questions arising respecting the true meaning of the Contract Documents, the matter shall be referred to the Design Engineer, whose decision thereon shall be final.

1.13 HEALTH AND SAFETY

A. The Contractor shall be responsible for health and safety of its own crew, subcontractors, suppliers, and visitors. The Contractor shall adhere to the Contractor Safety Rules for the Site and all applicable Mine Safety and Health Administration (MSHA) rules.

1.14 GENERAL REQUIREMENTS

A. SURVEYING – The Surveyor shall be responsible for all surveying required to layout and control the Work. Surveying shall be conducted such that all applicable standards required by the State of Utah are met.

B. PERMITS – The Contractor shall be required to obtain permits in accordance with construction of the facility.

C. SEDIMENTATION, EROSION CONTROL, AND DEWATERING – Contractor shall comply with all laws, ordinances, and permits for controlling erosion, water pollution, and dust emissions resulting from construction activities; the Contractor shall be responsible for any fines imposed due to noncompliance. The Contractor shall perform work in accordance with the Storm Water Pollution Prevention Plan (SWPPP) provided by the Owner. The Contractor shall pump all water generated from dewatering into Cell 4A and 4B, as directed by the Construction Manager.

D. PROTECTION OF EXISTING SERVICES AND WELLS – The Contractor shall exercise care to avoid disturbing or damaging the existing monitor wells, settlement monuments, electrical poles and lines, permanent below-ground utilities, permanent drainage structures, and temporary utilities and structures. When the Work requires the Contractor to be near or to cross locations of known utilities, the Contractor shall carefully uncover, support, and protect these utilities and shall not cut, damage, or otherwise disturb them without prior authorization from the Construction Manager. All utilities or wells damaged by the Contractor shall be immediately repaired by the Contractor to the satisfaction of the Construction Manager at no additional cost.

E. BURNING – The use of open fires for any reason is prohibited.

F. TEMPORARY ROADS – The Contractor shall be responsible for constructing and maintaining all temporary roads and lay down areas that the Contractor may require in the execution of the Work.

G. CONSTRUCTION WATER – The Contractor shall obtain water from the Owner for construction and dust control. The Contractor shall not add substances (such as soap) to construction water.

H. COOPERATION – The Contractor shall cooperate with all other parties engaged in project-related activities to the greatest extent possible. Disputes or problems should be referred to the Construction Manager for resolution.

I. FAMILIARIZATION – The Contractor is responsible for becoming familiar with all aspects of the Work prior to performing the Work.

J. SAFEGUARDS – The Contractor shall provide and use all personnel safety equipment, barricades, guardrails, signs, lights, flares, and flagmen as required by MSHA, Occupational Safety and Health Administration (OSHA), state, or local codes and ordinances. No excavations deeper than 4 feet with side slopes steeper than 2:1 (horizontal:vertical) shall be made without the prior approval of the Design Engineer and the Construction Manager. When shoring is required, the design and inspection of such shoring shall be the Contractor's responsibility and shall be subject to the review of the Design Engineer and Construction Manager prior to use. No personnel shall work within or next to an excavation requiring shoring until such shoring has been installed, inspected, and approved by an engineer registered in the State of Utah. The Contractor shall be responsible for any fines imposed due to violation of any laws and regulations relating to the safety of the Contractor's personnel.

K. CLEAN-UP – The Contractor shall be responsible for general housekeeping during construction. Upon completion of the Work, the Contractor shall remove all of his equipment, facilities, construction materials, and trash. All disturbed surface areas shall be re-paved, re-vegetated, or otherwise put into the pre-existing condition before performing the Work, or a condition satisfactory to the Construction Manager.

L. SECURITY – The Contractor is responsible for the safety and condition of all of his tools and equipment.

M. ACCEPTANCE OF WORK – The Contractor shall retain ownership and responsibility for all Work until accepted by Construction Manager. Construction Manager will accept ownership and responsibility for the Work: (i) when all Work is completed; and (ii) after the Contractor has submitted all required documentation, including manufacturing quality control documentation and manufacturing certifications.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

NOT USED.

[END OF SECTION]

SECTION 01025

MEASUREMENT AND PAYMENT

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. This section covers measurement and payment criteria applicable to the Work performed under lump sum and unit price payment methods, and non-payment for rejected work.

1.02 RELATED SECTIONS

A. This section relates to all other sections of the contract.

1.03 AUTHORITY

A. Measurement methods delineated in the individual specification sections are intended to complement the criteria of this section. In the event of conflict, the requirements of the individual specification section shall govern.

B. A surveyor, licensed in the State of Utah, hired by the Contractor will take all measurements and compute quantities accordingly. All measurements, cross-sections, and quantities shall be stamped and certified by the licensed surveyor and submitted to the Construction Manager. The Construction Manager maintains the right to provide additional measurements and calculation of quantities to verify measurements and quantities submitted by the Contractor.

1.04 UNIT QUANTITIES SPECIFIED

A. Quantities and measurements indicated in the Bid Schedule are for bidding and contract purposes only. Quantities and measurements supplied or placed in the Work and verified by the Construction Manager shall determine payment. If the actual work requires more or fewer quantities than those quantities indicated, the Contractor shall provide the required quantities at the lump sum and unit prices contracted unless modified elsewhere in these Contract Documents.

B. Utah sales tax shall be included in each bid item as appropriate.

1.05 MEASUREMENT OF QUANTITIES

A. Measurement by Volume: Measurement shall be by the cubic dimension using mean lengths, widths, and heights or thickness, or by average end area method as measured by the surveyor. All measurement shall be the difference between the original ground surface and the design ("neat-line") dimensions and grades.

B. Measurement by Area: Measurement shall be by the square dimension using mean lengths and widths and/or radius as measured by the surveyor. All measurement shall be the difference between the original ground surface and the design ("neat-line") dimensions and grades.

C. Linear Measurement: Measurement shall be by the linear dimension, at the item centerline or mean chord. All measurement shall be the difference between the original ground surface and the design ("neat-line") dimensions and grades.

D. Stipulated Lump Sum Measurement: Items shall be measured as a percentage by weight, volume, area, or linear means or combination, as appropriate, of a completed item or unit of Work.

1.06 PAYMENT

A. Payment includes full compensation for all required labor, products, tools, equipment, transportation, services, and incidentals; erection, application, or installation of an item of the Work; and all overhead and profit. Final payment for Work governed by unit prices will be made on the basis of the actual measurements and quantities accepted by the Construction Manager multiplied by the unit price for Work which is incorporated in or made necessary by the Work.

B. A monthly progress payment schedule will be used to compensate the Contractor for the Work. The monthly amount to be paid to the Contractor is calculated as the percent of completed work for each bid item multiplied by the total anticipated work for that bid item minus a 10 percent retainer.

C. When the Contractor has completed all Work associated with completion of the project, the remaining 10 percent retainer of the contract amount will be paid to the Contractor after filing the Notice of Completion.

1.07 NON-PAYMENT FOR REJECTED PRODUCTS

A. Payment shall not be made for any of the following:

1. Products wasted or disposed of in a manner that is not acceptable.
2. Products determined as unacceptable before or after placement.
3. Products not completely unloaded from the transporting vehicle.
4. Products placed beyond the design lines, dimensions, grades, and levels of the required Work.
5. Products remaining on hand after completion of the Work.
6. Loading, hauling, and disposing of rejected Products.
7. Products rejected because of contamination (i.e. soil residues, fuel spills, solvents, etc.).

B. Excavation of loose soil and/or rock, caused by actions of the Contractor (e.g. overblasting), necessary to meet specifications for engineered fill placement.

1.08 BID ITEMS

A. The following bid items shall be used by the Owner and by the Contractor to bid the Work described in these bid documents.

BID ITEM	SECTION	DESCRIPTION	UNITS
1	01500	Construction Facilities	LS
2	01505	Mobilization / Demobilization	LS
3	02070	Well Abandonment	LS
4	02200	Soil Excavation	LS
5	02200	Rock Excavation	LS
6	02200	Engineered Fill	LS
7	02220	Subgrade Preparation	LS
8	02220	Anchor Trench	LF
9	02616	4-inch PVC Pipe and Fittings	LF
10	02616	18-inch PVC Pipe and Fittings	LF
11	02616	Strip Drain Composite	LF
12	02770	60-mil Smooth HDPE Geomembrane	SF
13	02770	60-mil Textured HDPE Geomembrane	SF
14	02770	130-mil HDPE Drain Liner™ Geomembrane	SF
15	02772	Geosynthetic Clay Liner	SF
16	02773	300-mil Geonet	SF
17	03400	Cast-In-Place Concrete	LS
18	01505	Performance Bond	LS

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

NOT USED.

[END OF SECTION]

SECTION 01300

SUBMITTALS

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. This section contains requirements for administrative and work-related submittals such as construction progress schedules, Shop Drawings, test results, operation and maintenance data, and other submittals required by Contract Documents.

B. Submit required materials to the Construction Manager for proper distribution and review in accordance with requirements of the Contract Documents**.**

1.02 CONSTRUCTION PROGRESS SCHEDULES

A. The Contractor shall prepare and submit two (2) copies of the baseline construction progress Schedule to the Construction Manager for review within five (5) days after the effective date of Contract.

B. Schedules shall be prepared in Microsoft Project/Primavera. The schedule shall include the following items.

1. A separate horizontal bar for each operation.
2. A horizontal time scale, which identifies the first workday of each week.
3. A scale with spacing to allow space for notations and future revisions.
4. Listings arranged in order of start for each item of the Work.

C. The Construction Progress Schedule for construction of the Work shall include the following items where applicable.

1. Submittals: dates for beginning and completion of each major element of construction and installation dates for major items. Elements shall include, but not be limited to, the following items which are applicable:

   a. Mobilization schedule.
   b. Demobilization schedule.
   c. Final site clean-up.
   d. Show projected percentage of completion for each item as of first day of each week.
   e. Show each individual Bid Item.

D. Schedule Revisions:

1. Bi-weekly to reflect changes in progress of Work.
2. Indicate progress of each activity at submittal date.
3. Show changes occurring since the previous schedule submittal. Changes shall include the following.
    a. Major changes in scope.
    b. Activities modified since previous submittal.
    c. Revised projections of progress and completion.
    d. Other identifiable changes.
4. Provide narrative report as needed to define:
    a. Problem areas, anticipated delays, and impact on schedule.
    b. Recommended corrective action and its effect.

1.03 CONSTRUCTION WORK SCHEDULE

A. The Contractor shall submit an updated 14-day work schedule at the beginning of each week by Monday morning at 8:00 a.m. The schedule shall address applicable line items from the construction project schedule with a refined level of detail for special activities.

1.04 SHOP DRAWINGS AND SAMPLES

A. Shop Drawings, product data, and samples shall be submitted as required in individual Sections of the Specifications.

B. The Contractor's Responsibilities:

1. Review Shop Drawings, product data, and samples prior to submittal.
2. Determine and verify:
    a. Field measurements.
    b. Field construction criteria.
    c. Catalog numbers and similar data.
    d. Conformance with Specifications.
3. Coordinate each submittal with requirements of the Work and Contract Documents.
4. Notify the Construction Manager in writing, at the time of the submittal, of deviations from requirements of Contract Documents.
5. Begin no fabrication or Work pertaining to required submittals until return of the submittals with appropriate approval.
6. Designate dates for submittal and receipt of reviewed Shop Drawings and samples in the construction progress schedule.

C. Submittals shall contain:

1. Date of submittal and dates of previous submittals.
2. Project title and number.
3. Contract identification.
4. Names of:
    a. The Contractor.
    b. Supplier.
    c. Manufacturer.
5. Summary of items contained in the submittal.
6. Identification of the product with identification numbers and the Drawing and Specification section numbers.
7. Clearly identified field dimensions.
8. Details required on the Drawings and in the Specifications.
9. Manufacturer, model number, dimensions, and clearances, where applicable.
10. Relation to adjacent or critical features of the Work or materials.
11. Applicable standards, such as ASTM or Federal Specification numbers.
12. Identification of deviations from Contract Documents.
13. Identification of revisions on re-submittals.
14. 8-inch by 3-inch blank space for the Contractor's and proper approval stamp.
15. The Contractor's stamp, signed, certifying review of the submittal, verification of the products, field measurements, field construction criteria, and coordination of information within the submittal with requirements of Work and Contract Documents.

D. Re-submittal Requirements:

1. Re-submittal is required when corrections or changes in submittals are required by the Construction Manager, Design Engineer, or CQA Consultant. Re-submittals are required until all comments by the Construction Manager, Design Engineer, or CQA Consultant is addressed and the submittal is approved.
2. Shop Drawings and Product Data:
    a. Revise initial drawings or data and resubmit as specified for initial submittal.
    b. Indicate changes made other than those requested by the Construction Manager, Design Engineer, or CQA Consultant.

E. Distribute reproductions of Shop Drawings and copies of product data which have been accepted by the Construction Manager to:

1. Job site file.
2. Record documents file.

F. Construction Manager's Duties:

1. Verify that review comments are technically correct and are consistent with technical and contractual requirements of the work.
2. Return submittals to the Contractor for distribution or re-submittal.

G. Design Engineer's Duties:

1. Review submittals promptly for compliance with contract documents and in accordance with the schedule.
2. Affix stamp and signature, and indicate either the requirements for re-submittal or no comments.
3. Return submittals to the Construction Manager.

H. CQA Consultant's Duties:

1. Review submittals promptly for compliance with contract documents and in accordance with the schedule.
2. Affix stamp and signature, and indicate either the requirements for re-submittal or no comments.
3. Return submittals to the Construction Manager.

1.05 TEST RESULTS AND CERTIFICATION

A. Results of tests conducted by the Contractor on materials or products shall be submitted for review.

B. Certification of products shall be submitted for review.

1.06 SUBMITTAL REQUIREMENTS

A. Provide complete copies of required submittals as follows.

1. Construction Work Schedule:
   a. Two copies of initial schedule (baseline schedule).
   b. Two copies of each revision.
2. Construction Progress Schedule:
   a. Two copies of initial schedule.
   b. Two copies of each revision.
3. Shop Drawings: Two copies.
4. Certification Test Results: Two copies.
5. Other Required Submittals:
   a. Two copies, if required, for review.
   b. Two copies, if required, for record.

B. Deliver the required copies of the submittals to the Construction Manager.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

NOT USED.

[END OF SECTION]

SECTION 01400

QUALITY CONTROL

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. Monitor quality control over suppliers, Manufacturers, products, services, Site conditions, and workmanship, to produce Work of specified quality.

B. Comply with Manufacturers' instructions, including each step in sequence.

C. Should Manufacturers' instructions conflict with Technical Specifications, request clarification from Design Engineer before proceeding.

D. Comply with specified standards as minimum quality for the Work except where more stringent tolerances, codes, or specified requirements indicate higher standards or more precise workmanship.

E. Perform Work by persons qualified to produce workmanship of specified quality.

1.02 TOLERANCES

A. Monitor tolerance control of installed products to produce acceptable Work. Do not permit tolerances to accumulate.

B. Comply with Manufacturers' tolerances. Should Manufacturers' tolerances conflict with Technical Specifications, request clarification from Design Engineer before proceeding.

C. Adjust products to appropriate dimensions; position before securing products in place.

1.03 REFERENCES

A. For products or workmanship specified by association, trade, or other consensus standards, complies with requirements of the standard, except when more rigid requirements are specified or are required by applicable codes.

B. Conform to reference standard by date of current issue on date of Notice to Proceed with construction, except where a specific date is established by code.

C. Obtain copies of standards where required by product Specification sections.

1.04 INSPECTING AND TESTING SERVICES

A. The CQA Consultant will perform construction quality assurance (CQA) inspections, tests, and other services specified in individual Sections of the Specification.

B. The Contractor shall cooperate with CQA Consultant; furnish samples of materials, design mix, equipment, tools, storage, safe access, and assistance by incidental labor as requested.

C. CQA testing or inspecting does not relieve Contractor, subcontractors, and suppliers from their requirements to perform quality control Work as indicated in the Technical Specifications.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

NOT USED.

[END OF SECTION]

SECTION 01500

CONSTRUCTION FACILITIES

PART 1 – GENERAL

1.01 SECTION INCLUDES

A. Construction facilities include furnishing of all equipment, materials, tools, accessories, incidentals, labor, and performing all work for the installation of equipment and for construction of facilities, including their maintenance, operation, and removal, if required, at the completion of the Work under the Contract.

1.02 DESCRIPTION OF WORK

A. Construction facilities include, but are not limited to, the following equipment, materials, facilities, areas, and services:

1. Parking Areas.
2. Temporary Roads.
3. Storage of Materials and Equipment.
4. Construction Equipment.
5. Temporary Sanitary Facilities.
6. Temporary Water.
7. First Aid Facilities.
8. Health and Safety.
9. Security.

B. Construct/install, maintain, and operate construction facilities in accordance with the applicable federal, state, and local laws, rules, and regulations, and the Contract Documents.

1.03 GENERAL REQUIREMENTS

A. Contractor is responsible for furnishing, installing, constructing, operating, maintaining, removing, and disposing of the construction facilities, as specified in this Section, and as required for the completion of the Work under the Contract.

B. Contractor shall maintain construction facilities in a clean, safe, and sanitary condition at all times until completion of the Work.

C. Contractor shall minimize land disturbances related to the construction facilities to the greatest extent possible and restore land, to the extent reasonable and practical, to its original contours by grading to provide positive drainage and by seeding the area to match with existing vegetation or as specified elsewhere.

1.04 TEMPORARY ROADS AND PARKING AREAS

A. Temporary roads and parking areas are existing roads that are improved or new roads constructed by Contractor for convenience of Contractor in the performance of the Work under the Contract.

B. Contractor shall coordinate construction with Construction Manager.

C. Construct and operate roads in accordance with all MSHA and other applicable standards.

D. If applicable, coordinate all road construction activities with local utilities, fire, and police departments.

E. Keep erosion to a minimum and maintain suitable grade and radii of curves to facilitate ease of movement of vehicles and equipment.

F. Furnish and install longitudinal and cross drainage facilities, including, but not limited to, ditches, structures, pipes and the like.

G. Clean equipment so that mud or dirt is not carried onto public roads. Clean up any mud or dirt transported by equipment on paved roads both on-site and off-site.

1.05 STORAGE OF MATERIALS AND EQUIPMENT

A. Make arrangements for material and equipment storage areas. Locations and configurations of approved facilities are subject to the acceptance of the Construction Manager.

B. Confine all operations, including storage of materials, to approved areas. Store materials in accordance with these Technical Specifications and the Construction Drawings.

C. Store construction materials and equipment within boundaries of designated areas. Storage of gasoline or similar fuels must conform to state and local regulations and be limited to the areas approved for this purpose by the Construction Manager.

1.06 CONSTRUCTION EQUIPMENT

A. Erect, equip, and maintain all construction equipment in accordance with all applicable statutes, laws, ordinances, rules, and regulations or other authority having jurisdiction.

B. Provide and maintain scaffolding, staging, hoists, barricades, and similar equipment required for performance of the Work. Provide hoists or similar equipment with operators and signals, as required.

C. Provide, maintain, and remove upon completion of the Work, all temporary rigging, scaffolding, hoisting equipment, debris boxes, barricades around openings and excavations, fences, ladders, and all other temporary work, as required for all Work hereunder.

D. Construction equipment and temporary work must conform to all the requirements of state, county, and local authorities, MSHA, and underwriters that pertain to operation, safety, and fire hazard. Furnish and install all items necessary for conformity with such requirements, whether or not called for under separate Sections of these Technical Specifications.

1.07 TEMPORARY SANITARY FACILITIES

A. Provide temporary sanitary facilities for use by all employees and persons engaged in the Work, including subcontractors, their employees and authorized visitors, and the Construction Manager.

B. Sanitary facilities include enclosed chemical toilets and washing facilities. These facilities must meet the requirements of local public health standards.

C. Locate sanitary facilities as approved by Construction Manager, and maintain in a sanitary condition during the entire course of the Work.

1.08 TEMPORARY WATER

A. Make all arrangements for water needs from the Owner.

B. Provide drinking water for all personnel at the site.

1.09 FIRST AID FACILITIES

A. Provide first aid equipment and supplies to serve all Contractor personnel at the Site.

1.10 HEALTH AND SAFETY

A. The Contractor shall submit a Site Health and Safety Plan for review a minimum of 7 days prior to mobilization.

B. Provide necessary monitoring equipment and personal protective equipment in accordance with Contractor prepared Site Health and Safety Plan.

1.11 SECURITY

A. Make all necessary provisions and be responsible for the security of the Work and the Site until final inspection and acceptance of the Work, unless otherwise directed by the Construction Manager.

1.12 SHUT-DOWN TIME OF SERVICE

A. Do not disconnect or shut down any part of the existing utilities and services, except by express written permission of Construction Manager.

1.13 MAINTENANCE

A. Maintain all construction facilities, utilities, temporary roads, and the like in good working condition as required by the Construction Manager during the term of the Work.

1.14 STATUS AT COMPLETION

A. Upon completion of the Work, or prior thereto, when so required by Construction Manager:

1. Repair damage to roads caused by or resulting from the Contractor's work or operations.
2. Remove and dispose of all construction facilities. Similarly, all areas utilized for temporary facilities shall be returned to near original, natural state, or as otherwise indicated or directed by the Construction Manager.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for Construction Facilities shall be lump sum (LS) and payment will be based on the unit price provided on the Bid Schedule.

B. The following are considered incidental to the Work:

1. Mobilization.
2. Temporary roadways and parking areas.
3. Temporary sanitary facilities.
4. Decontamination of equipment.
5. Security.
6. Demobilization.

[END OF SECTION]

SECTION 01505

MOBILIZATION / DEMOBILIZATION

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. Mobilization consists of preparatory work and operations, including but not limited to those necessary for the movement of personnel and project safety; including: adequate personnel, equipment necessary for full planned production to meet baseline schedule, supplies, and incidentals to the project Site; establishment of facilities necessary for work on the project; premiums on bond and insurance for the project and for other work and operations the Contractor must perform or costs the Contractor must incur before beginning work on the project, which are not covered in other bid items.

B. Demobilization consists of work and operations including, but not limited to, movement of personnel, equipment, supplies, and incidentals off-site.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section shall be lump sum (LS) and payment will be based on the unit price provided on the Bid Schedule.

B. The Contract Price for Mobilization/Demobilization shall include the provision for movement of equipment onto the job site; removal of all facilities and equipment at the completion of the project; permits; preparation of a Health and Safety Plan; all necessary safety measures; and all other related mobilization and demobilization costs. Price bid for mobilization shall not exceed 10 percent of the total bid for the Project. Fifty percent of the mobilization bid price, less retention, will be paid on the initial billing provided all equipment and temporary facilities are in place and bond fees paid. The remaining 50 percent of the mobilization bid price will be paid on satisfactory removal of all facilities and equipment on completion of the project.

[END OF SECTION]

SECTION 01560

TEMPORARY CONTROLS

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. Temporary Controls required during the term of the Contract for the protection of the environment and the health and safety of workers and general public.

B. Furnishing all equipment, materials, tools, accessories, incidentals, and labor, and performing all work for the installation of equipment and construction of facilities, including their maintenance and operation during the term of the Contract.

C. Temporary Controls include:

1. Dust Control.
2. Pollution Control.
3. Traffic and Safety Controls.

D. Perform Work as specified in the Technical Specifications and as required by the Construction Manager. Maintain equipment and accessories in clean, safe, and sanitary condition at all times until completion of the Work.

1.02 DUST CONTROL

A. Provide dust control measures in-accordance with the Technical Specifications. Dust control measures must meet requirements of applicable laws, codes, ordinances, and permits.

B. Dust control consists of transporting water, furnishing required equipment, testing of equipment, additives, accessories and incidentals, and carrying out proper and efficient measures wherever and as often as necessary to reduce dust nuisance, and to prevent dust originating from construction operations throughout the duration of the Work.

C. Owner shall provide water. Contractor shall provide overhead tank and use water source to fill overhead tank on a continuous basis (i.e., water supply shall not be operated on and off quickly).

1.03 POLLUTION CONTROL

A. Pollution of Waterways:

1. Perform Work using methods that prevent entrance or accidental spillage of solid or liquid matter, contaminants, debris, and other objectionable pollutants and wastes into watercourses, flowing or dry, and underground water sources.
2. Such pollutants and wastes will include, but will not be limited to, refuse, earth and earth products, garbage, cement, concrete, sewage effluent, industrial waste, hazardous chemicals, oil and other petroleum products, aggregate processing tailings, and mineral salts.

B. Dispose of pollutants and wastes in accordance with applicable permit provisions or in a manner acceptable to and approved by the Construction Manager.

C. Storage and Disposal of Petroleum Product:

1. Petroleum products covered by this Section include gasoline, diesel fuel, lubricants, and refined and used oil. During project construction, store all petroleum products in such a way as to prevent contamination of all ground and surface waters and in accordance with local, state, and federal regulations.

2. Lubricating oil may be brought into the project area in steel drums or other means, as the Contractor elects. Store used lubricating oil in steel drums, or other approved means, and return them to the supplier for disposal. Do not burn or otherwise dispose of at the Site.

3. Secondary containment shall be provided for products stored on site, in accordance with the Owner provided Storm Water Pollution Prevention Plan.

1.04 TRAFFIC AND SAFETY CONTROLS

A. Perform in accordance with MSHA and other applicable requirements.

B. Post construction areas and roads with traffic control signs or devices used for protection of workmen, the public, and equipment. Signs and devices must conform to the American National Standards Institute (ANSI) Manual on Uniform Traffic Control Devices for Streets and Highways.

C. Remove signs or traffic control devices after they have finished serving their purpose. It is particularly important to remove any markings on road surfaces that under conditions of poor visibility could cause a driver to turn off the road or into traffic moving in the opposite direction.

D. Provide flag persons, properly equipped with International Orange protective clothing and flags, as necessary, to direct or divert pedestrian or vehicular traffic. A full-time flag person shall be required for the duration of importation of fill.

E. Barricades for protection of employees must conform to the portions of the ANSI Manual on Uniform Traffic Control Devices for Streets and Highways, relating to barricades.

F. Guard and protect all workers, pedestrians, and the public from excavations, construction equipment, all obstructions, and other dangerous items or areas by means of adequate railings, guard rails, temporary walks, barricades, warning signs, sirens, directional signs, overhead protection, planking, decking, danger lights, etc.

G. Construct and maintain fences, planking, barricades, lights, shoring, and warning signs as required by local authorities and federal and state safety ordinances, and as required to protect all property from injury or loss and as necessary for the protection of the public, and provide walks around any obstructions made in a public place for carrying out the Work covered in this Contract. Leave all such protection in place and maintained until removal is authorized by the Construction Manager.

1.05 MAINTENANCE

A. Maintain all temporary controls in good working conditions during the term of the Contract for the safe and efficient transport of equipment and supplies, and for construction of permanent works.

1.06 STATUS AT COMPLETION

A. Upon completion of the Work, or prior thereto as approved by the Construction Manager, remove all temporary controls and restore disturbed areas.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

4.01 TEMPORARY CONTROLS

A. Temporary Controls: the measurement and payment of temporary controls shall be in accordance with and as a part of Mobilization/Demobilization, as outlined in Section 01505.

[END OF SECTION]

SECTION 01700

CONTRACT CLOSEOUT

PART 1 – GENERAL

1.01 CLOSEOUT PROCEDURES

A. Contractor shall submit written certification that the Technical Specifications, CQA Plan, and Drawings have been reviewed, Work has been inspected, and that Work is complete and in-accordance with the Technical Specifications, CQA Plan, and Drawings and ready for Owner's inspection.

1.02 FINAL CLEANING

A. Contractor shall execute final cleaning prior to final inspection.

B. Contractor shall clean equipment and fixtures to a sanitary condition.

C. Contractor shall remove waste and surplus materials, rubbish, and construction facilities from the construction Site.

1.03 PROJECT RECORD DOCUMENTS

A. Maintain on Site, one set of the following record documents and record actual revisions to the Work.

1. Drawings.
2. Specifications.
3. Addenda.
4. Change Orders and other Modifications to the Contract.
5. Reviewed Shop Drawings, product data, and samples.

B. Store Record Documents separate from documents used for construction.

C. Record information concurrent with construction progress.

D. Specifications: Legibly mark and record at each product Section a description of actual products installed, including the following:

1. Manufacturer's name and product model and number.
2. Product substitutions or alternates utilized.
3. Changes made by Addenda and Modifications.

E. Record Documents and Shop Drawings: Legibly mark each item to record actual construction including:

1. Measured horizontal and vertical location of underground utilities and appurtenances referenced to permanent surface features.
2. Measured locations of internal utilities and appurtenances concealed in construction, referenced to visible, accessible, and permanent features of the Work.
3. Field changes of dimension and detail.
4. Details not shown on original Construction Drawings.

F. Submit record documents to the Construction Manager.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

4.01 CONTRACT CLOSEOUT

A. Contract Closeout: the measurement and payment of contract close out shall be in accordance with and as part of Mobilization/Demobilization, as outlined in Section 01505.

[END OF SECTION]

SECTION 02070

WELL ABANDONMENT

PART 1 — GENERAL

1.01 DESCRIPTION OF WORK

A. Supply all equipment, materials, and labor needed to abandon two (2) 3-inch diameter polyvinyl chloride (PVC) casing groundwater monitoring wells as specified herein and as indicated on the Drawings.

B. Well abandonment shall be accomplished under the direct supervision of a currently licensed water well driller who shall be responsible for verification of the procedures and materials used.

1.02 RELATED SECTIONS

Section 01025 – Measurement and Payment

Section 01300 – Submittals

Section 01400 – Quality Control

1.03 REFERENCES

A. Drawings.

B. Construction Quality Assurance (CQA) Plan

C. Latest version of the ASTM International (ASTM) standards:

ASTM C-150 Standard Specification for Portland Cement.

D. Latest version of the American Petroleum Institute (API) standards:

API - 13A Specification for Drilling-Fluid Materials

1.04 SUBMITTALS

A. The Contractor shall keep detailed drilling logs for all wells abandoned, including drilling procedures, total depth of abandonment, depth to groundwater (if applicable), final depth of boring, and well destruction details, including the depths of placement of all well abandonment materials. The Contractor shall provide a minimum of 7 days advance notice prior to beginning drilling and shall submit a list of the type and quantity of materials used for well abandonment.

B. The Contractor shall acquire all necessary permits and prepare and file a well abandonment report as required by the State of Utah, Division of Water Rights.

PART 2 — PRODUCTS

2.01 BENTONITE

A. Bentonite shall be Volclay (powdered sodium bentonite API-13A) or as otherwise approved by the Design Engineer.

2.02 WATER

A. Water used in the grout mixture shall be potable water or disinfected in accordance with R655-4-9.6.5 Utah Administrative Code (UAC).

2.03 CEMENT

A. Cement shall be Portland Type I (ASTM C-150).

PART 3 — EXECUTION

3.01 GENERAL

A. The Contractor is responsible for obtaining all permits for the abandonment of wells and shall be responsible for following all regulatory requirements as outlined in the Administrative Rules for Water Well Drillers R655-4 UAC.

B. The Contractor shall be responsible for reviewing the well construction boring log for the groundwater well to be abandoned. The original construction boring logs for the well to be abandoned are attached to the end of this Section, as Exhibit I.

3.02 DRILLING

A. The Contractor shall sound and record the total depth of the well casing, depth to groundwater (if encountered), and depth of the over boring.

B. Each well shall be over bored to a diameter 3 inches greater than the well casing diameter to a depth of 3 feet below the well bottom of casing. The exact depth of the wells shall be in accordance with the Contract Documents and as determined by the Design Engineer.

3.03 CEMENT-BENTONITE GROUT

A. A cement-bentonite grout shall be mixed for each well. The cement-bentonite grout shall have approximately 2% by weight bentonite (i.e. one 94-lbs sack of cement and two lbs. of bentonite) and be mixed with approximately 6.5 gallons of water. The cement-bentonite grout shall be mixed using a recirculating pump to form a homogeneous mixture free of lumps.

B. Immediately after removing all well materials and recording the over bored depth, the slurry shall be pressure grouted into the well borehole to 10 feet below final ground surface (bgs) (i.e. subgrade elevations for Cells 5A and 5B).

C. The uppermost 10 feet of the abandoned well shall consist of neat cement grout or sand cement grout.

D. The Contractor shall monitor the mass, volume, and level of cement-bentonite grout placed in each well borehole. These quantities shall be reported to the Construction Manager during the abandonment process.

E. The cement grout or sand cement grout shall be allowed to settle. Cement grout or sand cement grout shall be added, as necessary, until the elevation of the cured and settled cement grout or sand cement grout conforms to the surface topography at the time of abandonment.

PART 4 — MEASUREMENT AND PAYMENT

4.01 GENERAL

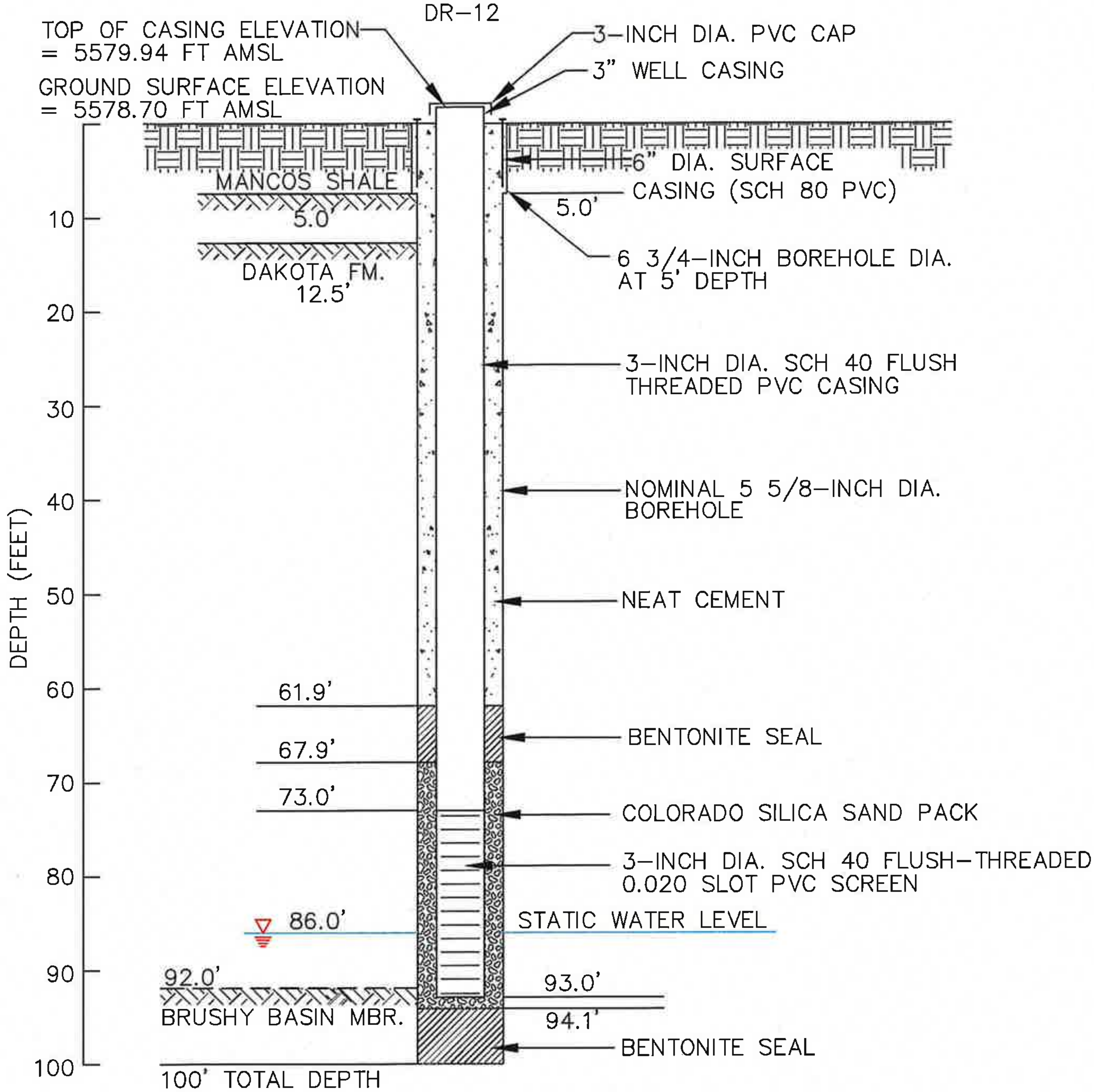
A. Providing for and complying with the requirements for well abandonment set forth in this Section will be measured as lump sum (LS); and payment will be based on the unit price provided on the Bid Schedule.

B. The following are considered incidental to the Work:

1. Submittals.
2. Bentonite.
3. Water.
4. Cement.
5. Well permits.
6. Mobilization.
7. Drilling.
8. Grading.
9. Decontamination of well abandonment equipment.
10. Disposal of decontamination materials.
11. Disposal of drill cuttings.

[END OF SECTION]

Well Completion Logs
DR-12 and DR-13



NOT TO SCALE

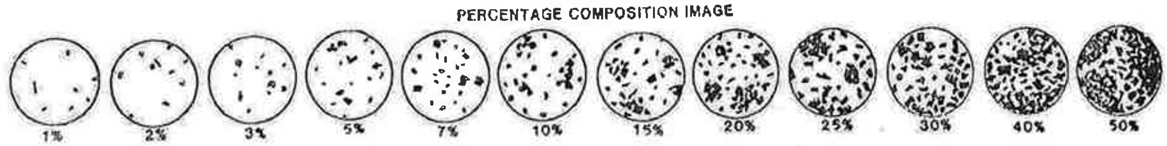
HYDRO GEO CHEM, INC.	DR-12 AS-BUILT WELL CONSTRUCTION SCHEMATIC		
Approved SJS	Date 1/9/12	Reference K:\7180257A Well Construction Diagram	Figure

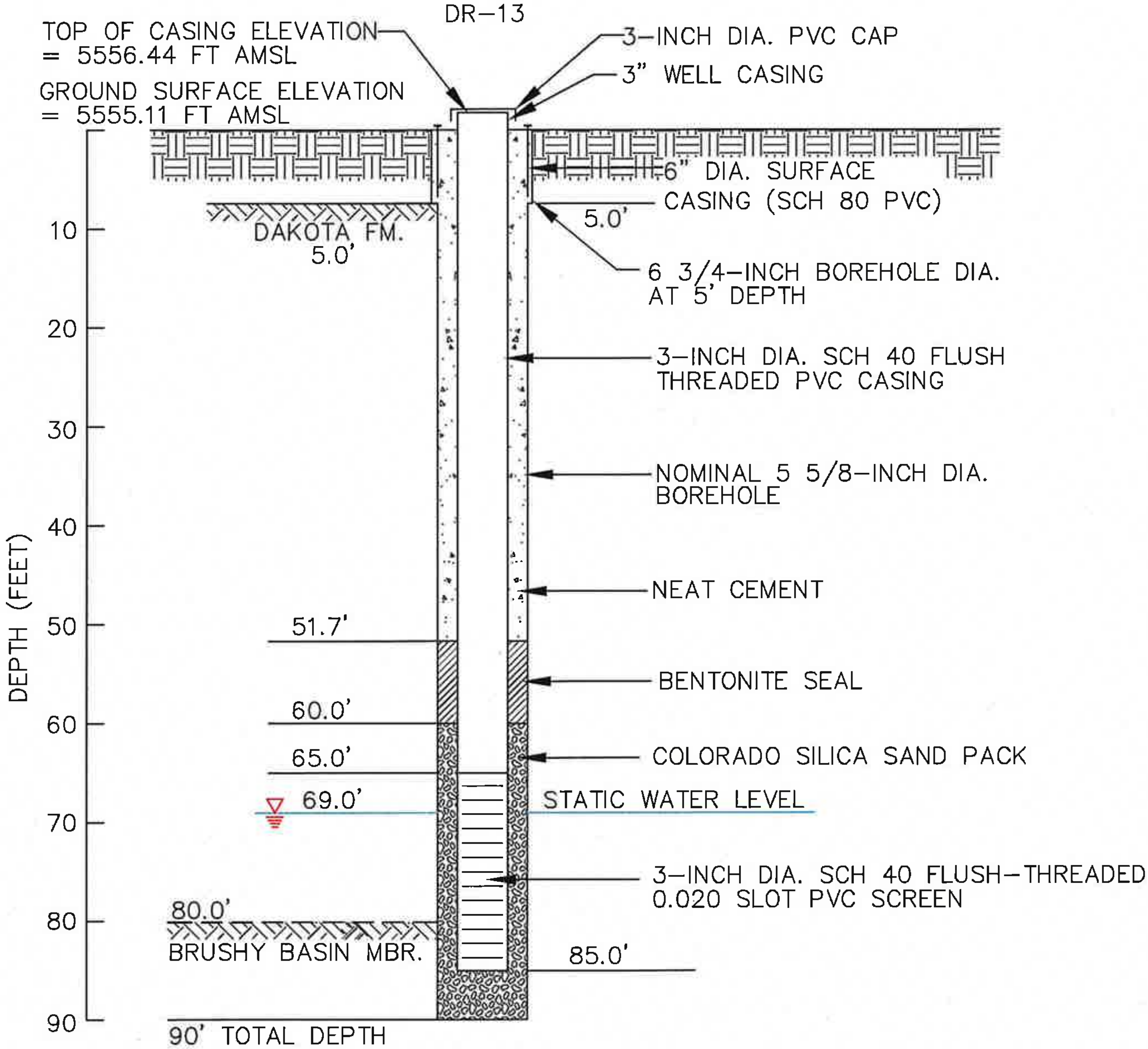
Date 28 APR 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. DR12
Property White Mesa Mill Project Cell 4B Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ≈5584

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 100.0
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0–2.5						mdst	rdbn											W			Surface Soil unconsolidated fat clay w/sand CH
2.5–5.0						mdst	rdbn											W			Surface Soil " " " " CH
5.0–7.5						sh	ltpktn											VS			Mancos Shale Fm. consolidated. Lean clay w/ sand CL
7.5–10.0						sh	ltpktn											VS			" "
10.0–12.5						sh	ltpktn											S			" "
12.5–15.0						qtz ss sh	lt bn	m	w	r		L						N			Upper Dakota Ct @ 12.5'
15.0–17.5						qtz ss	tn	m	w	r		L						N			
17.5–20.0						qtz ss	lt or-tn	m	w	r		L						N			
20.0–22.5						qtz ss	tn	m	w	a								N			
22.5–25.0						qtz ss	tn	m	w	a								N			
25.0–27.5						qtz ss	ltgytn	m	w	r								N			Some chert grains
27.5–30.0						qtz ss	tn	m-c	m	r								N			" " "
30.0–32.5						qtz ss	tn	m-c	m	r								N			
32.5–35.0						qtz ss	tn	m-c	m	r								N			
35.0–37.5						qtz ss	ltortn	m	w	R		L						N			
37.5–40.0						qtz ss	tn	m	w	R								N			
40.0–42.5						qtz ss	tn	m-peb	f	a								N			Some chert grains
42.5–45.0						qtz ss	lt bn	f-peb	p	a								N			" " "
45.0–47.5						qtz ss, sh, cgl	tn-gn	f-peb	p	a								N			" " "
47.5–50.0						qtz ss, sh, cgl	gn-tn	m-peb	p	A								N			" " "
50.0–52.5						qtz ss, sh	gn-tn	m-peb	p	a								N			abund. chert frags. grains
52.5–55.0						qtz ss	tn	m-peb	p	a		L						N			" " " "
55.0–57.5						qtz ss	tn	f-c	p	a		L						N			
57.5–60.0						qtz ss	tn	f-c	p	a								N			
60.0–62.5						qtz ss	ltgytn	m	w	r								N			
62.5–65.0						qtz ss	ltgytn	m	w	r								N			
65.0–67.5						qtz ss	ltgytn	m	w	r								N			
67.5–70.0						qtz ss	tn	m	w	r								N			
70.0–72.5						qtz ss	ltgytn	m	w	r								N			
72.5–75.0						qtz ss	lt bn	m	w	a								N			
75.0–77.5						qtz ss	ltgytn	m	w	a								N			
77.5–80.0						qtz ss	tn	f-m	m	r								N			
80.0–82.5						qtz ss	m	m	w	a								N			
82.5–85.0						qtz ss	tn	m-c	m	a			tr	c				N			
85.0–87.5						qtz ss, sh	gn-tn	f-c	m	a			tr	c				N			
87.5–90.0						qtz ss, sh	wh-ltgn	f-m	m	r			tr	c				N			
90.0–92.5						qtz ss, sh	wh-ltgn	f-m	m	r								N			Brushy Basin Ct @ 92.0 ft.
92.5–95.0						sh	gn, rdbn											N			
95.0–97.5						qtz ss, sh	wh-gn	f-m	m	R								N			
97.5–100.0						sh	gn-rdbn											N			T.D. Mottled Frags.
100.0–102.5																					
102.5–105.0																					
105.0–107.5																					
107.5–110.0																					
110.0–112.5																					
112.5–115.0																					
115.0–117.5																					
117.5–120.0																					
120.0–122.5																					
122.5–125.0																					

PERCENTAGE COMPOSITION IMAGE





NOT TO SCALE

HYDRO GEO CHEM, INC.

DR-13
AS-BUILT WELL CONSTRUCTION SCHEMATIC

Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180258A Well Construction Diagram	

Changed P& Ct from 82

Date 27 APR 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. DR13

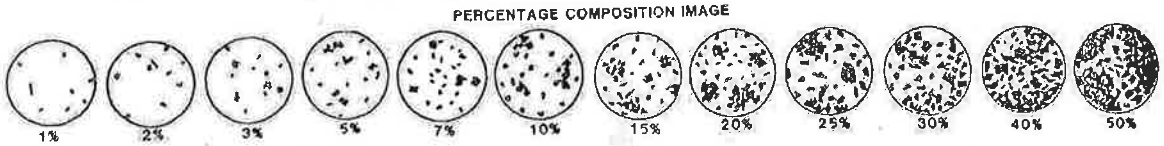
Property White Mesa Mill Project Cell 4B Unit No. ______ Sec. ______ Twp. ______ Rge. ______

County San Juan State Utah Location ______ Elev. 5575

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 90.0
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						mdst	rdbn											W			Surface Soil. unconsolidated - lean clay w/sand CL
5.0						mdst	rdbn											S			surface Soil - unconsolidated - lean clay w/sand CL
7.5						qtz ss	or tn	m-peb	p	A								N			Upper Dakota Ct @ 5.0' abund. chert frags, pebbles,
10.0						qtz ss, cgl	gy or tn	m-peb	p	A								N			abundant chert frags + pebbles.
12.5						qtz ss	or tn	m-peb	p	r		L						N			" " " "
15.0						qtz ss, sh	lt gy tn	m-peb	p	a								N			Some chert frag, pebbles sandy fat clay CH
17.5						qtz ss, sh	lt gy gn tn	m-peb	p	a								N			" " " "
20.0						qtz ss, cgl	lt gy tn-rd	m-peb	p	a								N			" " " "
22.5						qtz ss	lt tn	m-c	m	a								N			
25.0						qtz ss, sh	lt tn-lt gn	m-vc	f	a								N			
27.5						qtz ss, sh	lt tn-lt gy gn	m-peb	p	a								N			
30.0						qtz ss	tn	m	w	r								N			
32.5						qtz ss	tn	m	w	a								N			
35.0						qtz ss	lt bn	m-peb	p	a								N			
37.5						qtz ss, cgl	dk bn	m-peb	p	a								W			
40.0						qtz ss	tn	m	w	R								N			
42.5						qtz s	tn	m-peb	p	r								N			
45.0						qtz ss	tn	f-peb	p	a								N			
47.5						qtz ss	tn	m	w	r								N			
50.0						qtz ss	tn	m	w	r								N			
52.5						qtz ss	vlt tn	m	w	r								N			
55.0						qtz ss	vlt tn	m	w	r								N			
57.5						qtz ss	lt tn	m	w	r								N			
60.0						qtz ss, cgl	gy tn	m-peb	p	a		L						N			abund multi colored chert frags + grains
62.5						qtz ss, cgl	lt gy tn	m-peb	p	a		L						N			" " " " " "
65.0						qtz ss	lt tn	m	w	r								VS			
67.5						sh, qtz ss	lt bl gy	m-peb	p	a								VW			
70.0						qtz ss, sh	wh-bl gy	vf-m	f	r								N			
72.5						qtz ss	wh-lt gy	f	w	r								N			
75.0						qtz ss	wh-lt gy	f	w	r								N			
77.5						qtz ss	wh-lt bl gn	f	w	r								N			
80.0						qtz ss	wh-lt bl gn	f	w	r								N			sparse chert pebble frags.
82.5						sh	gy-rdbn											N			Brushy Basin Fm Ct @ 80.0'
85.0						sh	bl gy-rdbn											N			
87.5						sh	bl gy-rdbn											N			
90.0						sh	pp rdbn-gn											N			TD
92.5																					
95.0																					
97.5																					
100.0																					
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE



SECTION 02200

EARTHWORK

PART 1 — GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary to perform all Earthwork. The Work shall be carried out as specified herein and in accordance with the Drawings.

B. The Work shall include, but not be limited to excavating, blasting, ripping, trenching, hauling, placing, moisture conditioning, backfilling, compacting and grading. Earthwork shall conform to the dimensions, lines, grades, and sections shown on the Drawings or as directed by the Construction Manager.

1.02 RELATED SECTIONS

Section 02220 – Subgrade Preparation

1.03 REFERENCES

A. Drawings

B. Latest version of ASTM International (ASTM) standards:

ASTM D 422	Standard Method for Particle-Size Analysis of Soils
ASTM D 1557	Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lb-ft/ft^3 (2,700 kN-m/m^3))
ASTM D 6938	Standard Test Method for In-Place Density and Water Content of Soil-Aggregate by Nuclear Methods (Shallow Depth)

C. Results of seismic refraction survey for Cells 5A and 5B (Attached Herein).

1.04 QUALIFICATIONS

A. The Contractor's Site superintendent for the earthworks operations shall have supervised the construction of at least three earthwork construction projects, in accordance with Section 01010, Part 1.11.

1.05 SUBMITTALS

A. The Contractor shall submit to the Construction Manager a baseline survey to the limits of the work. The baseline survey shall be prepared by a Utah licensed professional land surveyor and shall form the basis for establishing pay quantities.

B. The Contractor shall submit to the Construction Manager a description of equipment and methods proposed for excavation, and fill placement and compaction construction at least 14 days prior to the start of activities covered by this Section.

C. If rock blasting is the chosen rock removal technique, the Contractor shall submit to the Construction Manager a blast plan describing blast methods to remove rock to proposed grade. The blast plan shall include a pre-blast survey, blast schedule, seismic monitoring records, blast design and diagrams, and blast safety. The Contractor shall submit the plan to the Construction Manager at least 21 days prior to blast.

D. If the Work of this Section is interrupted for reasons other than inclement weather, the Contractor shall notify the Construction Manager a minimum of 48 hours prior to the resumption of Work.

E. If foreign borrow materials are proposed to be used for any earthwork material on this project, the Contractor shall provide the Construction Manager information regarding the source of the material. In addition, the Contractor shall provide the Construction Manager an opportunity to obtain samples for conformance testing 14 days prior to delivery of foreign borrow materials to the Site. If conformance testing fails to meet these Specifications, the Contractor shall be responsible for reimbursing the Owner for additional conformance testing costs.

F. The Contractor shall submit as-built Record Drawing electronic files and data, to the Construction Manager, within 7 days of project substantial completion, in accordance with this Section.

1.06 QUALITY ASSURANCE

A. The Contractor shall ensure that the materials and methods used for Earthwork meet the requirements of the Drawings and this Section. Any material or method that does not conform to these documents, or to alternatives approved in writing by the Construction Manager will be rejected and shall be repaired, or removed and replaced, by the Contractor at no additional expense to the Owner.

B. The Contractor shall be aware of and accommodate all monitoring and field/laboratory conformance testing required by the Contract Documents. This monitoring and testing, including random conformance testing of construction materials and completed Work, will be performed by the CQA Consultant. If nonconformances or other deficiencies are found in the materials or completed Work, the Contractor will be required to repair the deficiency or replace the deficient materials at no additional cost to the Owner.

PART 2 — PRODUCTS

2.01 MATERIAL

A. Top soil material shall consist of the top 6 to 12 inches of existing grade.

B. All materials excavated not considered as rock, boulders, or detached pieces of solid rock less than 1 cubic yard in volume are classified as common excavation.

C. Engineered fill material shall consist of on-site soil obtained from excavation or owner provided stockpile and shall be free from rock larger than 6 inches, organic or other deleterious material.

D. Rock shall consist of all hard, compacted, or cemented materials that require blasting or the use of ripping and excavating equipment larger than defined for common excavation. The excavation and removal of isolated boulders or rock fragments larger than 1 cubic yard encountered in materials otherwise conforming to the definition of common excavation shall be classified as rock excavation. The presence of isolated boulders or rock fragments larger than 1 cubic yard is not in itself sufficient to cause to change the classification of the surrounding material.

E. Rippable Soil and Rock, common excavation: Material that can be ripped at more than 250 cubic yards per hour for each Caterpillar D9N dozer (or equivalent) with a single shank ripper attachment.

F. Loose material: Soil and rock material below finished grade elevations that was blasted or loosened by ripping or is naturally loose.

2.02 EQUIPMENT

A. The Contractor shall furnish, operate, and maintain compaction equipment as is necessary to produce the required in-place soil density and moisture content.

B. The Contractor shall furnish, operate and maintain tank trucks, pressure distributors, or other equipment designed to apply water uniformly and in controlled quantities.

C. The Contractor shall furnish, operate, and maintain miscellaneous equipment such as earth excavating equipment, earth hauling equipment, and other equipment, as necessary for Earthwork construction.

D. The Contractor shall be responsible for cleaning up all fuel, oil, or other spills, at the expense of the Contractor, and to the satisfaction of the Construction Manager.

PART 3 — EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the Work in this Section, the Contractor shall become thoroughly familiar with the Site, the Site conditions, and all portions of the Work falling within this and other related Sections.

B. Inspection:

1. The Contractor shall carefully inspect the installed Work of all other Sections and verify that all Work is complete to the point where the installation of the Work specified in this Section may properly commence without adverse impact.

2. If the Contractor has any concerns regarding the installed Work of other Sections, the Construction Manager shall be notified in writing prior to commencing Work. Failure to notify the Construction Manager, or commencement of the Work of this Section, will be construed as Contractor's acceptance of the related Work of all other Sections.

C. Existing soil and top of rock information is provided in the attached trench logs (Exhibit I). In addition, rock rippability data obtained during site seismic refraction surveys is attached.

3.02 SOIL EXCAVATION

A. The Contractor shall excavate materials to the limits and grades shown on the Drawings.

B. The Contractor shall excavate top soil (top 6 to 12 inches of existing ground) to the limits of the work and stockpile as directed by Construction Manager. During top soil removal, archeologist personnel employed by the Owner will monitor excavation for archeological artifacts and may stop excavation in a defined area to remove these artifacts.

C. The Contractor shall rip, blast, and/or mechanically remove rock 6-inches below final grades shown on the Drawings.

D. The Contractor shall excavate loose soil/rock below final grades shown on the Drawings until competent soil/rock surface is achieved to allow construction of engineered fill.

E. All excavated material not used as fill shall be stockpiled as shown on the Drawings and in accordance with Subpart 3.05 of this Section.

3.03 ROCK EXCAVATION

A. The Contractor shall remove rock by ripping, drilling, or blasting, or as approved by Construction Manager.

B. Requirements for Blasting:

1. The Contractor shall arrange for a pre-blast survey of nearby buildings, berms, or other structures that may potentially be at risk from blasting damage. The survey method used shall be acceptable to the Contractor's insurance company. The Contractor shall be responsible for any damage resulting from blasting. The preblast survey shall be made available for review three weeks before any blasting begins. Pre-blast surveys shall be completed by a practicing civil engineer registered in the State of Utah, who has experience in rock excavation and geotechnical design.

2. The Contractor shall submit for review the proposed methods and sequence of blasting for rock excavations. The Contractor shall identify the number, depth, and spacing of holes; stemming and number and type of delays; methods of controlling overbreak/overblasting at excavation limits, procedures for monitoring the shots and recording information for each shot; proposed depth of cover soil and overblasting; and other data that may be required to control the blasting.

3. Blasting shall be done in accordance with the federal, state, or local regulatory requirements for explosives and firing of blasts. Such regulations shall not relieve the Contractor of any responsibility for damages caused by them or their employees due to the work of blasting. All blasting work must be performed or supervised by a licensed blaster who shall at all times have a license on their person and shall permit examination thereof by the Construction Manager or other officials having jurisdiction.

4. The Contractor shall develop a trial blasting technique that identifies and limits the vibrations and damage at varying distances from each shot. This trial blasting information shall be collected and recorded by beginning the work at points farthest from areas to remain without damage. The Contractor can vary the hole spacing, depths and orientations, explosive types and quantities, blasting sequence, and delay patterns to obtain useful information to safeguard against damage at critical areas.

5. Establish appropriate maximum limit for peak particle velocity for each structure or facility that is adjacent to, or near blast sites. Base maximum limits on expected sensitivity of each structure or facility to blast induced vibrations and federal, state, or local regulatory requirements. In areas of blasting within 100 feet from the top of the existing berms, the blasting peak particle velocities (PPV) shall not exceed 2 inches per second.

6. The Contractor shall discontinue any method of blasting which leads to overshooting/overblasting or is dangerous to the berms surrounding the existing pond structures.

7. The Contractor shall have sufficient cover soil to provide safety and minimize fly rock while minimizing the quantity of fill material impacted with oversized rock and boulders.

8. The Contractor shall minimize overshooting/overblasting. All loose material shall be removed prior to placing engineered fill.

9. The Contractor shall install a blast warning sign to display warning signals. Sign shall indicate the following:

   a. Five (5) minutes before blast: Three (3) long sounds of airhorn or siren
   b. Immediately before blast: Three (3) short sounds of airhorn or siren
   c. All clear signal after blast: one (1) long sound of airhorn or siren

3.04 FILL

A. Prior to fill placement, areas to receive fill shall be cleared and grubbed and top soil shall be removed.

B. The fill material shall be placed to the lines and grades shown on the Drawings.

C. Soil used for fill shall meet the requirements of Subpart 2.01 of this Section.

D. Soil used for fill shall be placed in a loose lift that results in a compacted lift thickness of no greater 8 inches and compacted to 90% of the maximum density at a moisture content of between -3% and +3% of optimum moisture content, as determined by ASTM D 1557.

E. The Contractor shall utilize compaction equipment suitable and sufficient for achieving the soil compaction requirements.

F. During soil wetting or drying, the material shall be regularly disced or otherwise mixed so that uniform moisture conditions in the appropriate range are obtained.

3.05 STOCKPILING

A. Soil suitable for fill and excavated rock shall be stockpiled, separately, in areas as shown on the Drawings or as designated by the Construction Manager, and shall be free of incompatible soil, clearing debris, or other objectionable materials.

B. Separate soil stockpiles shall be constructed to contain topsoil, rock, sandy soil, and clayey soil.

C. Stockpiles shall be no steeper than 2H:1V (Horizontal:Vertical) or other slope approved by the Design Engineer, graded to drain, sealed by tracking parallel to the slope with a dozer or other means approved by the Construction Manager, and dressed daily during periods when fill is taken from the stockpile. The Contractor shall employ temporary erosion and sediment control measures (i.e. silt fence) as directed by the Construction Manager around stockpile areas.

D. There are no compaction requirements for stockpiled materials.

3.06 FIELD TESTING

A. The minimum frequency and details of quality control testing for Earthwork are provided below. This testing will be performed by the CQA Consultant. The Contractor shall take this testing frequency into account in planning the construction schedule.

1. The CQA Consultant will perform conformance tests on placed and compacted fill to evaluate compliance with these Specifications. The dry density and moisture content of the soil will be measured in-situ with a nuclear moisture-density gauge in accordance with ASTM D 6938. The frequency of testing will be one test per 500 cubic yards of soil placed.

2. A special testing frequency will be used by the CQA Consultant when visual observations of construction performance indicate a potential problem. Additional testing will be considered when:

   a. The rollers slip during rolling operation;
   b. The lift thickness is greater than specified;
   c. The fill is at improper and/or variable moisture content;
   d. Fewer than the specified number of roller passes are made;
   e. Dirt-clogged rollers are used to compact the material;
   f. The rollers do not have optimum ballast; or

g. The degree of compaction is doubtful.

3. During construction, the frequency of testing will be increased by the Construction Manager in the following situations:

a. Adverse weather conditions;

b. Breakdown of equipment;

c. At the start and finish of grading;

d. If the material fails to meet Specifications; or

e. The work area is reduced.

B. Defective Areas:

1. If a defective area is discovered in the Earthwork, the CQA Consultant will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Consultant will determine the extent of the defective area by additional tests, observations, a review of records, or other means that the Construction Manager deems appropriate. If the defect is related to adverse Site conditions, such as overly wet soils or surface desiccation, the CQA Site Manager shall define the limits and nature of the defect.

2. Once the extent and nature of a defect is determined, the Contractor shall correct the deficiency to the satisfaction of the CQA Consultant. The Contractor shall not perform additional Work in the area until the Construction Manager approves the correction of the defect.

3. Additional testing may be performed by the CQA Consultant to verify that the defect has been corrected. This additional testing will be performed before any additional Work is allowed in the area of deficiency. The cost of the additional Work and the testing shall be borne by the Contractor.

3.07 SURVEY CONTROL

A. The Contractor shall perform all surveys necessary for construction layout and control.

3.08 CONSTRUCTION TOLERANCE

A. The Contractor shall perform the Earthwork construction to within ±0.1 vertical feet of elevations on the Drawings.

3.09 AS-BUILT SURVEY

A. For purposes of payment on Earthwork quantities, the Contractor shall conduct a comprehensive as-built survey that complies with this Section.

B. The Contractor shall produce complete electronic as-built Record Drawings in conformance with the requirements set forth in this Section. This electronic file shall be provided to the Construction Manager for verification. Surveys shall be submitted for existing topography, top of rock, base of excavation, and top of fill.

C. The Contractor shall produce an electronic boundary file that accurately conforms to the project site boundary depicted on the plans or as modified during construction by approved change order. The electronic file shall be provided to the Construction Manager for verification prior to use in any earthwork computations or map generation.

D. As-built survey data shall be collected throughout the project as indicated in these Specifications. This data shall be submitted in hard-copy and American Standard Code for Information Interchange (ASCII) format. ASCII format shall include: point number, northing and easting, elevations, and descriptions of point. The ASCII format shall be as follows:

1. PPPP,NNNNNN.NNN,EEEEEE.EEE,ELEV.XXX,Description

a. Where:

- P – point number
- N- Northing
- E – Easting
- ELEV.XXX – Elevation
- Description – description of the point

3.10 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect completed Work of this Section.

B. At the end of each day, the Contractor shall verify that the entire work area is left in a state that promotes drainage of surface water away from the area and from finished Work. If threatening weather conditions are forecast, soil surfaces shall be seal-rolled at a minimum to protect finished Work.

C. In the event of damage to Work, the Contractor shall make repairs and replacements to the satisfaction of the Construction Manager, at the expense of the Contractor.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. All earthwork quantities shall be independently verified by the Construction Manager prior to approval. The independent verification by the Construction Manager shall utilize the same basic procedures as those used by the Contractor.

B. Any interim or soon-to-be buried (or otherwise obstructed) earthwork shall be surveyed and quantified as the project progresses to enable timely verification by the Construction Manager.

C. Providing for and complying with the requirements set forth in this Section for Soil Excavation will be measured as lump sum (LS) and payment will be based on the unit price provided on the Bid Schedule.

D. Providing for and complying with the requirements set forth in this Section for Rock Excavation will be measured as lump sum (LS) and payment will be based on the unit price provided on the Bid Schedule.

E. Providing for and complying with the requirements set forth in this Section for Fill will be measured as lump sum (LS) and payment will be based on the unit price provided on the Bid Schedule.

F. The following are considered incidental to the work:

- Submittals.
- Quality Control.
- Material samples, sampling, and testing.
- Excavation.
- Blasting, ripping, and hammering.
- Loading, and hauling.
- Scarification.

- Screening.
- Layout survey.
- Rejected material removal, retesting, handling, and repair.
- Temporary haul roads.
- Erosion control.
- Dust control.
- Spill cleanup.
- Placement, compaction, and moisture conditioning.
- Stockpiling.
- Record survey.

[END OF SECTION]

TABLE 02200-1

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TABLE 02200-1
SUMMARY OF SEISMIC REFRACTION SURVEYS - Cells 5A and 5B
Energy Fuels, White Mesa Mill
Blanding, Utah

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
SL-12-01-01F	N37.52603	W109.51611	Fwd S32E	5A	0 to 4 4 to 36 > 36	1287 to 1392 4944 to 5053 6195 to 7403	Rippable Rippable Rippable	
SL-12-01-01R	N37.52554	W109.51566	Rev N32W	5A	0 to 6 > 6	1312 to 2563 5358 to 6372	Rippable Rippable	
SL-12-02-01F	N37.52603	W109.51611	Fwd N32W	5A	0 to 4 4 to 14 > 14	1341 to 1408 3457 to 5578 6512 to 6802	Rippable Rippable Rippable	
SL-12-02-01R	N37.52647	W109.51649	Rev S32E	5A	0 to 8 8 to 12 >12	1571 to 2191 4245 to 5672 6538 to 7012	Rippable Rippable Rippable	
TP12-02	N37.52600	W109.51614	Fwd N30W	5A	-	-		0-5.25 FT Residual Soil 5.25-6.75 FT Weathered Sandstone 6.75 to 7.0 FT Dakota Sandstone
SL-12-03-01F	N37.52499	W109.51506	Fwd S30W	5A	0 to 5 5 to 21 >21	1482 to 1658 3866 to 4754 6087 to 6492	Rippable Rippable Rippable	
SL-12-03-01R	N37.52447	W109.51466	Rev N30E	5A	0 to 6 >6	1804 to 2078 4854 to 5966	Rippable Rippable	
TP12-04	N37.52507	W109.51506	Fwd N32W	5A	-	-		0-1.5 FT Residual Soil 1.5-7.5 FT Weathered Sandstone 7.5-8.0 FT Shale Layer 8.0 FT Dakota Sandstone
SL-12-04-01F	N37.52546	W109.51749	Fwd S75E	5A	0 to 4 4 to 25 >25	1059 to 1317 3264 to 4564 5918 to 6499	Rippable Rippable Rippable	
SL-12-04-01R	N37.52532	W109.51675	Rev N75W	5A	0 to 5 5 to 14 >14	1052 to 1681 2998 to 5299 5663 to 7907	Rippable Rippable Marginal	
TP12-01	N37.52546	W109.51749	Fwd S65E	5A	-	-		0-5 FT Residual Soil 5.0-6.75 FT Weathered Sandstone 6.75 to 7.0 FT Dakota Sandstone
SL-12-05-01F	N37.52384	W109.51791	Fwd N62E	5A	0 to 9 >9	1137 to 1691 6235 to 7003	Rippable Rippable	
SL-12-05-01R	N37.52416	W109.51729	Rev S62W	5A	0 to 7 >7	1684 to 1939 6281 to 8285	Rippable Marginal	
TP12-07	N37.52388	W109.51793	Fwd N20E	5A	-	-		0-7.0 FT Residual Soil 7.0-8.5 FT Weathered Sandstone 8.5-9.5 FT Dakota Sandstone
SL-12-06-01F	N37.52438	W109.51460	Fwd S30E	5A	0 to 3 3 to 46	2083 to 2347 4826 to 4905	Rippable Rippable	
SL-12-06-01R	N37.52388	W109.51418	Rev N30W	5A	0 to 4 >4	1489 to 2965 4955 to 6415	Rippable Rippable	
TP12-06	N37.52408	W109.51434	Fwd N30W	5A	-	-		0-2.0 FT Residual Soil 2.0-3.5 FT Weathered Sandstone 3.5 FT Dakota Sandstone
SL-12-07-01F	N37.52438	W109.51460	Fwd S30E	5A	0 to 4 4 to 19 > 19	1488 to 2035 4757 to 5046 6696	Rippable Rippable Rippable	
SL-12-07-01R	N37.52338	W109.51372	Rev N30W	5A	0 to 4 4 to 34 > 34	1308 to 2080 4899 to 5169 8444 to 8736	Rippable Rippable Marginal	

Geosyntec consultants

TABLE 02200-1
SUMMARY OF SEISMIC REFRACTION SURVEYS - Cells 5A and 5B
Energy Fuels, White Mesa Mill
Blanding, Utah

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
TP12-09	N37.52294	W109.51320	Fwd N20E	5A/5B	-	-		0-5.5 FT Residual Soil 5.5-6.5 FT Weathered Sandstone 6.5-7.5 FT Dakota Sandstone
SL-12-08-01F	N37.52443	W109.51648	Fwd N62E	5A	0 to 5	1061 to 1283	Rippable	
					5 to 17	3354 to 4800	Rippable	
					> 17	6025	Rippable	
SL-12-08-01R	N37.52477	W109.51582	Rev S62W	5A	0 to 7	1521 to 1732	Rippable	
					> 7	4927 to 5849	Rippable	
TP12-05	N37.52443	W109.51621	Fwd N40E	5A	-	-		0-4.5 FT Residual Soil 4.5-6.5 FT Weathered Sandstone 6.5-7.5 FT Dakota Sandstone
TP12-08	N37.52326	W109.51534	Fwd N10W	5A	-	-		0-6.0 FT Residual Soil 6.0-7.5 FT Weathered Sandstone 7.5 FT Dakota Sandstone
SL-12-09-01F	N37.52544	W109.51392	Fwd N65E	5A	0 to 5	1211 to 2207	Rippable	
					>5	5570 to 6148	Rippable	
SL-12-09-01R	N37.52570	W109.51324	Rev S65W	5A	0 to 6	1269 to 1639	Rippable	
					6 to 17	4661 to 6630	Rippable	
					>17	7230 to 7274	Rippable	
TP12-03	N37.52559	W109.51355	Fwd S65W	5A	-	-		0-5.5 FT Residual Soil 5.5-7.0 FT Weathered Sandstone 7.0 FT Dakota Sandstone
TP12-10	N37.52464	W109.51260	Fwd N88W	5A/5B	-	-		0-4.5 FT Residual Soil 4.5-9.0 FT Weathered Sandstone 9.0-9.5 FT Dakota Sandstone
SL-12-10-01F	N37.524778	W109.50861	Fwd S68W	5B	0 to 6	1442 to 1904	Rippable	
					>6	5620 to 7611	Marginal	
SL-12-10-01R	N37.52452	W109.50928	Rev N68E	5B	0 to 4	1835 to 2395	Rippable	
					>4	6387 to 7509	Marginal	
TP12-12	N37.52479	W109.50859	Fwd S65W	5B	-	-		0-6.5 FT Residual Soil 6.5-7.5 FT Weathered Sandstone 7.5-8.0 FT Dakota Sandstone
SL-12-11-01F	N37.525045	W109.507928	Fwd N68E	5B	0 to 6	1157 to 1227	Rippable	
					>6	7036 to 7052	Rippable	
SL-12-11-01R	N37.524778	W109.50861	Rev S68W	5B	0 to 10	1411 to 1480	Rippable	
					>10	7343 to 8088	Marginal	
SL-12-12-01F	N37.52419	W109.51025	Fwd N70E	5B	0 to 4	1061 to 1488	Rippable	
					4 to 17	3331 to 4947	Rippable	
					> 17	8999 to 9761	Non-Rippable	
SL-12-12-01R	N37.52441	W109.50956	Rev S70W	5B	0 to 3	1672 to 1955	Rippable	
					3 to 18	4721 to 5496	Rippable	
					>18	6643 to 7372	Rippable	
TP12-13	N37.52419	W109.51025	Fwd S70W	5B	-	-	-	0-0.5 FT Residual Soil 0.5-1.0 FT Weathered Sandstone 1.0-2.0 FT Dakota Sandstone
SL-12-13-01F	N37.5249	W109.51025	Fwd S70W	5B	0 to 6	1349 to 3557	Rippable	
					>6	7286 to 9352	Non-Rippable	
SL-12-13-01R	N37.52389	W109.51102	Rev N70E	5B	0 to 5	1138 to 1248	Rippable	
					>5	6186 to 8977	Marginal	

Geosyntec consultants

TABLE 02200-1
SUMMARY OF SEISMIC REFRACTION SURVEYS -
Cells 5A and 5B
Energy Fuels, White Mesa Mill
Blanding, Utah

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
SL-12-14-01F	N37.52330	W109.51234	Fwd N62E	5B	0 to 6	1098 to 1775	Rippable	
					6 to 28	6361 to 6041	Rippable	
					>28	8046 to 8964	Marginal	
SL-12-14-01R	N37.52361	W109.51167	Rev S62W	5B	0 to 6	1369 to 1419	Rippable	
					>6	7171 to 7762	Marginal	
TP12-15	N37.52361	W109.51167	Fwd S60W	5B	-	-		0-5.5 FT Residual Soil 5.5-6.0 FT Weathered Sandstone 6.5 FT Dakota Sandstone
TP12-17	N37.52253	W109.51065	Fwd N8E	5B	-	-	-	0-0.5 FT Residual Soil 0.5-2.0 FT Weathered Sandstone 2.0-3.5 FT Dakota Sandstone
SL-12-15-01F	N37.52542	W109.51112	Fwd S20E	5B	0 to 8	1478 to 3030	Rippable	
					>8	6346 to 7738	Marginal	
SL-12-15-01R	N37.52493	W109.51077	Rev S30E	5B	0 to 9	1305 to 1554	Rippable	
					9 to 16	3197 to 4279	Rippable	
					>16	7886 to 8107	Marginal	
TP12-11	N37.52512	W109.51098	Fwd N25W	5B	-	-		0-3.5 FT Residual Soil 3.5-11.0 FT Weathered Sandstone 11.0-12.0 FT Dakota Sandstone
TP12-19	N37.52550	W109.50965	Fwd N15W	5B	-	-		0-1.5 FT Residual Soil 1.5 FT Dakota Sandstone
SL-12-16-01F	N37.52330	W109.50919	Fwd N32W	5B	0 to 6	1388	Rippable	
					6 to 22	2951 to 5517	Rippable	
					>22	9648	Non-Rippable	
SL-12-16-01R	N37.52380	W109.50957	Rev S32E	5B	0 to 6	1215 to 1816	Rippable	
					>6	6435 to 6930	Rippable	
TP12-16	N37.52329	W109.50913	Fwd S40E	5B	-	-	-	0-0.5 FT Residual Soil 0.5-6.0 FT Weathered Sandstone 6.0-6.5 FT Dakota Sandstone
SL-12-17-01F	N37.52330	W109.50919	Fwd S32E	5B	0 to 4	1391 to 2336	Rippable	
					4 to 37	4801 to 4874	Rippable	
					>37	7554	Marginal	
SL-12-17-01R	N37.52280	W109.50872	Rev N32W	5B	0 to 5	1694 to 1730	Rippable	
					5 to 22	4762 to 5491	Rippable	
					>22	6479 to 6483	Rippable	
TP12-18	N37.52223	W109.50835	Fwd N30W	5B	-	-		0-4.5 FT Residual Soil 4.5-6.0 FT Weathered Sandstone 6.0-6.5 FT Dakota Sandstone
SL-12-18-01F	N37.52431	W109.50755	Fwd E-W	5B	0 to 5	1090 to 1379	Rippable	
					5 to 26	5202 to 6893	Rippable	
					>26	7491 to 10938	Non-Rippable	
SL-12-18-01R	N37.52430	W109.50829	Rev E-W	5B	0 to 4	1361 to 1420	Rippable	
					4 to 20	5110 to 5363	Rippable	
					>20	7861 to 11264	Non-Rippable	
TP12-14	N37.52431	W109.50749	Fwd S88W	5B	-	-	-	0-4.5 FT Residual Soil 4.5-7.5 FT Weathered Sandstone 7.5 FT Dakota Sandstone

Notes:
1 - Surveyed end point of refraction survey lines coordinates in Latitude/Longitude decimal degree World Geodetic System (WGS) 84. Data collected in field.
2 - Calculated depth of seismic refractor based on P-wave first arrival times using Snells Law.
3 - Excavatability assessment based on correlations between seismic wave velocities and rippability using a Single Shank No. 9 ripper on a D9N dozer (Caterpillar, 2006)
RS - Residual Soil
wxs - weathered sandstone
Kds - Cretaceous Dakota Sandstone

SECTION 02220

SUBGRADE PREPARATION

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary to perform all Subgrade Preparation. The Work shall be carried out as specified herein and in accordance with the Drawings and the Construction Quality Assurance (CQA) Plan.

B. The Work shall include, but not be limited to placement, moisture conditioning, compaction, and grading of subgrade soil and construction of geosynthetics anchor trench. Earthwork shall conform to the dimensions, lines, grades, and sections shown on the Drawings or as directed by the Design Engineer.

1.02 RELATED SECTIONS

Section 02200 – Earthwork

Section 02270 – Geomembrane

1.03 REFERENCES

A. Drawings

B. Site CQA Plan

C. Latest version of ASTM International (ASTM) standards:

ASTM D 422	Standard Method for Particle-Size Analysis of Soils
ASTM D 1557	Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lb_f/ft^3 (2,700 kN-m/m^3))
ASTM D 6938	Standard Test Method for In-Place Density and Water Content of Soil and Rock In-Place by Nuclear Methods (Shallow Depth)

1.04 QUALITY ASSURANCE

A. The Contractor shall ensure that the materials and methods used for subgrade preparation meet the requirements of the Drawings and this Section. Any material or method that does not conform to these documents, or to alternatives approved in writing by the Design Engineer will be rejected and shall be repaired, or removed and replaced, by the Contractor at no additional expense to the Owner.

PART 2 – PRODUCTS

2.01 SUBGRADE SOIL

A. Subgrade surface shall be free of protrusions larger than 0.7 inches. Any such observed particles shall be removed prior to placement of geosynthetics.

B. Subgrade surface shall be free of large desiccation cracks (ie, larger than ¼ inch) at the time of geosynthetics placement.

C. Subgrade soil shall consist of on-site soils that are free of particles greater than 3 inches in longest dimension, deleterious, organic, and/or other soil impacts that can damage the overlying liner system.

D. The subgrade surface shall be firm and unyielding, with no abrupt elevation changes, ice, or standing water.

E. The subgrade surface shall be smooth and free of vegetation, sharp-edged rock, stones, sticks, construction debris, and other foreign matter that could contact the geosynthetics.

F. At a minimum, the subgrade surface shall be rolled with a smooth-drum compactor of sufficient weight to remove any excessive wheel ruts greater than 1-inch or other abrupt grade changes.

2.02 ANCHOR TRENCH BACKFILL

A. Anchor trench backfill is the soil material that is placed in the anchor trench, as shown on the Drawings.

B. Where rocks are included in the anchor trench backfill, they shall be mixed with suitable excavated materials to eliminate voids.

C. Material removed during trench excavation may be utilized for anchor trench backfill, provided that all organic material, rubbish, debris, and other objectionable materials are first removed.

2.03 EQUIPMENT

A. The Contractor shall furnish, operate, and maintain grading and compaction equipment as is necessary to produce smooth surfaces for the placement of geosynthetics and acceptable in-place soil density in the anchor trenches.

B. The Contractor shall furnish, operate, and maintain tank trucks, pressure distributors, or other equipment designed to apply water uniformly and in controlled quantities for dust control and for moisture conditioning soils to be placed as trench backfill.

C. The Contractor shall be responsible for cleaning up all fuel, oil, or other spills, at the expense of the Contractor, and to the satisfaction of the Construction Manager.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work in this Section, the Contractor shall become thoroughly familiar with the Site, the Site conditions, and all portions of the work falling within this and other related Sections.

B. The Contractor shall provide for the protection of work installed in accordance with other Sections. In the event of damage to other work, the Contractor shall make repairs and replacements to the satisfaction of the Construction Manager, at the expense of the Contractor.

3.02 SUBGRADE SOIL SURFACE

A. The Contractor shall remove vegetation and roots to a minimum depth of 4-inches below ground surface in all areas where geosynthetic materials are to be installed.

B. Contractor shall grade subgrade soil to be uniform in slope, free from ruts, mounds, or depressions.

C. Prior to tertiary geomembrane (Option A) or GCL (Option B) installation, the subgrade surface shall be proof-rolled with appropriate compaction equipment to confirm subgrade stability.

3.03 TRENCH EXCAVATION

A. The Contractor shall excavate the anchor trench to the limits and grades shown on the Drawings.

B. Excavated anchor trench materials shall be returned as backfill for the anchor trench and compacted.

C. Material not suitable for anchor trench backfill shall be relocated as directed by the Construction Manager.

3.04 TRENCH BACKFILL

A. The anchor trench backfill shall be placed to the lines and grades shown on the Drawings.

B. Soil used for anchor trench backfill shall meet the requirements of Subpart 2.02 of this Section.

C. Soil used for anchor trench backfill shall be placed in loose lifts of no more than 12 inches and compacted to 90% of maximum dry density per ASTM D 1557. Backfill shall be within -3% to +3% of optimum moisture content. The maximum permissible pre-compaction soil clod size is 6 inches.

D. The Contractor shall compact each lift of anchor trench backfill to the satisfaction of the Construction Manager.

E. The Contractor shall utilize compaction equipment suitable and sufficient for achieving the soil compaction requirements.

F. During soil wetting or drying, the material shall be regularly disked or otherwise mixed so that uniform moisture conditions are obtained in the appropriate range.

3.05 SURVEY CONTROL

A. The Contractor shall perform all surveys necessary for construction layout and control.

B. The Contractor shall perform as-built surveys for all completed surfaces for purposes of Record Drawing preparation. At a minimum, survey points shall be obtained at grade breaks, top of slope, toe of slope, and limits of material type.

3.06 PROTECTION OF WORK

A. The Contractor shall protect completed work of this Section.

B. At the end of each day, the Contractor shall verify that the entire work area is left in a state that promotes drainage of surface water away from the area and from finished work.

C. In the event of damage to Work, the Contractor shall make repairs and replacements to the satisfaction of the Construction Manager, at the expense of the Contractor.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements for subgrade preparation will be measured as lump sum (LS) and payment will be based on the unit price as provided on the Bid Schedule.

B. Providing for and complying with the requirements for anchor trench excavation and backfill shall be measured on a lineal foot (LF) basis and payment will be based on the unit price as provided on the Bid Schedule.

C. The following are considered incidental to the work:

- Submittals.
- Quality Control.
- Material samples.
- Screening.
- Excavation, loading, and hauling.
- Temporary haul roads.
- Layout survey.
- Rejected material removal, testing, hauling, and repair.
- Erosion Control
- Dust control.
- Spill Clean-up
- Placement, compaction, and moisture conditioning.
- Stockpiling.
- Record survey.

[END OF SECTION]

SECTION 02225

DRAINAGE AGGREGATE

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary for the installation of Drainage Aggregate. The work shall be carried out as specified herein and in accordance with the Drawings and the site Construction Quality Assurance (CQA) Plan.

B. The work shall include, but not be limited to, delivery, offloading, storage, and placement of Drainage Aggregate (aggregate).

1.02 RELATED SECTIONS

Section 02616 – PVC Pipe

Section 02770 – Geomembrane

Section 02771 – Geotextile

Section 02773 – Geonet

1.03 REFERENCES

A. Drawings

B. Site Construction Quality Assurance (CQA) Plan

C. Latest Version of ASTM International (ASTM) Standards:

ASTM C 33	Standard Specification for Concrete Aggregates
ASTM C 136	Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM D 2434	Test Method for Permeability of Granular Soils (Constant Head)
ASTM D 3042	Standard Test Method for Insoluble Residue in Carbonate Aggregates

1.04 SUBMITTALS

A. The Contractor shall submit to the Construction Manager for approval, at least 7 days prior to the start of construction, Certificates of Compliance for proposed aggregate materials. Certificates of Compliance shall include, at a minimum, typical gradation, insoluable residue content, representative sample, and source of aggregate materials.

B. The Contractor shall submit to the Construction Manager a list of equipment and technical information for equipment proposed for use in placing the aggregate material in accordance with this Section.

1.05 CONSTRUCTION QUALITY ASSURANCE (CQA) MONITORING

A. The Contractor shall be aware of and accommodate all monitoring and field/laboratory conformance testing required by the CQA Plan. This monitoring and testing, including random conformance testing of construction materials and completed work, will be performed by the CQA Consultant. If nonconformances or other deficiencies are found in the materials or completed work, the Contractor will be required to repair the deficiency or replace the deficient materials.

PART 2 – PRODUCTS

2.01 MATERIALS

A. Aggregate shall meet the requirements specified in ASTM C 33 and shall not contain limestone. Aggregate shall have a minimum permeability of 1×10^{-1} cm/sec when tested in accordance with ASTM D 2434. The requirements of the Aggregate are presented below:

Maximum Particle Size	Percent Finer
1 - inch	100
¼ - inch	0 to 5
No. 200 Sieve	0 to 2

B. Carbonate loss shall be no greater than 10 percent by dry weight basis when tested in accordance with ASTM D 3042.

2.02 EQUIPMENT

A. The Contractor shall furnish, operate, and maintain hauling, placing, and grading equipment as necessary for aggregate placement.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work in this Section, the Contractor shall become thoroughly familiar with the site, the site conditions, and all portions of the work falling within this and other related Sections.

B. Inspection:

1. The Contractor shall carefully inspect the installed work of all other Sections and verify that all work is complete to the point where the installation of the work specified in this Section may properly commence without adverse impact.

2. If the Contractor has any concerns regarding the installed work of other Sections, the Construction Manager shall be notified in writing prior to commencing work. Failure to notify the Construction Manager or commencement of the work of this Section will be construed as Contractor's acceptance of the related work of all other Sections.

3.02 PLACEMENT

A. Place after underlying geosynthetic installation is complete, including construction quality control (CQC) and CQA work.

B. Place to the lines, grades, and dimensions shown on the Drawings.

C. The subgrade of the aggregate consists of a geotextile overlying a geomembrane. The Contractor shall avoid creating large wrinkles (greater than 6-inches high), tearing, puncturing, folding, or damaging in any way the geosynthetic materials during placement of the aggregate material.

D. Damage to the geosynthetic liner system caused by the Contractor or his representatives shall be repaired by the Geosynthetic Installer, at the expense of the Contractor.

E. No density or moisture requirements are specified for placement of the aggregate material.

3.03 FIELD TESTING

A. The minimum frequency and details of conformance testing are provided below. This testing will be performed by the CQA Consultant. The Contractor shall take this testing frequency into account in planning the construction schedule.

1. Aggregates conformance testing:

a. particle-size analyses conducted in accordance with ASTM C 136 at a frequency of one per source; and

b. permeability tests conducted in accordance with ASTM D 2434 at a frequency of one per source.

3.04 SURVEY CONTROL

A. The Contractor shall perform all surveys necessary for construction layout, control, and Record Drawings.

3.05 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all work of this Section.

B. In the event of damage, the Contractor shall make repairs and replacements to the satisfaction of the Construction Manager at no additional cost to the Owner.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for Drainage Aggregate will be incidental to the PVC pipe, and payment will be based on the unit price for PVC pipe provided on the Bid Schedule.

B. The following are considered incidental to the work:

- Submittals.
- Quality Control.
- Material samples, sampling, and testing.
- Excavation, loading, stockpiling, and hauling.
- Placing and grading.
- Layout survey.
- Rejected material.
- Rejected material removal, re-testing, handling, and repair.
- Mobilization.

[END OF SECTION]

SECTION 02616

POLYVINYL CHLORIDE (PVC) PIPE

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, and equipment necessary to install perforated and solid wall polyvinyl chloride (PVC) Schedule 40 pipe and fittings, as shown on the Drawings and in accordance with the Construction Quality Assurance (CQA) Plan.

1.02 RELATED SECTIONS

Section 02225 – Drainage Aggregate

Section 02270 – Geomembrane

Section 02771 – Geotextile

Section 02773 – Geonet

1.03 REFERENCES

A. Drawings.

B. Site CQA Plan.

C. Latest version of the ASTM International (ASTM) standards:

ASTM D 1784	Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and chlorinated Poly (Vinyl Chloride) (CPVC) Compounds.
ASTM D 1785	Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120.
ASTM D 2466	Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40.
ASTM D 2564	Standard Specification for Solvent Cements for Poly (Vinyl Chloride) (PVC) Plastic Pipe and Fittings.
ASTM D 2774	Practice for Underground Installation of Thermoplastic Pressure Piping.
ASTM D 2855	Standard Practice for Making Solvent-Cemented Joints with Poly (Vinyl Chloride) (PVC) Pipe and Fittings.
ASTM F 656	Standard Specification for Primers for Use in Solvent Cement Joints of Poly (Vinyl Chloride) (PVC) Plastic Pipe and Fittings.

1.04 SUBMITTALS

A. The Contractor shall submit to the Construction Manager for approval, at least 7 days prior to installation of this material, Certificates of Compliance for the pipe and fittings to be furnished. Certificates of Compliance shall consist of a properties sheet, including specified properties measured using test methods indicated herein.

B. The Contractor shall submit to the Construction Manager, Record Drawings of the installed piping at a frequency of not less than once per every 100 feet of installed pipe and strip composite. Record Drawings shall be submitted within 7 days of completion of the record survey.

1.05 CQA MONITORING

A. The Contractor shall ensure that the materials and methods used for PVC pipe and fittings installation meet the requirements of the Drawings and this Section. Any material or method that does not conform to these documents, or to alternatives approved in writing by the Construction Manager, will be rejected and shall be repaired or replaced by the Contractor at no additional cost to the Owner.

PART 2 – MATERIALS

2.01 PVC PIPE & FITTINGS

A. PVC pipe and fittings shall be manufactured from a PVC compound which meets the requirements of Cell Classification 12454 polyvinyl chloride as outlined in ASTM D 1784.

B. PVC pipe shall meet the requirements of ASTM D 1784 and ASTM D 1785 for Schedule 40 PVC pipe.

C. PVC fittings shall meet the requirements of ASTM D 2466.

D. Clean rework or recycle material generated by the Manufacturer's own production may be used so long as the pipe or fittings produced meet all the requirements of this Section.

E. Pipe and fittings shall be homogenous throughout and free of visible cracks, holes, foreign inclusions, or other injurious defects, being uniform in color, capacity, density, and other physical properties.

F. PVC pipe and fitting primer shall meet the requirements of ASTM F 656 and solvent cements shall meet the requirements of ASTM D 2564.

2.02 PVC PERFORATED PIPE

A. Perforated pipe shall meet the requirements listed above for solid wall pipe, unless otherwise approved by the Design Engineer. PVC pipe perforations shall be as shown on the Drawings.

2.03 STRIP COMPOSITE

A. Strip composite shall be comprised of high density polyethylene core Multi-Flow Drainage Systems 12-inch product, or Design Engineer approved equal. Consideration for equality will involve chemical resistance, compressive strength, and flow capacity. Strip composite shall be installed as shown on the Drawings.

B. Sand bags used to continuously cover the strip composite shall be comprised of woven geotextile capable of allowing liquids to pass and shall have a minimum length of 18-inches.

C. Sand bags shall contain Utah Department of Transportation (UDOT) concrete sand having a carbonate loss of no greater than 10 percent by dry weight basis when tested in accordance with ASTM D 3042 and meeting the following gradation.

Sieve Size	Percent Passing
3/8 inch	100%
No. 4	95% to 100%
No. 16	45% to 80%
No. 50	10% to 30%
No. 100	2% to 10%

D. Contractor shall monitor that sand bags shall not be overfilled to the extent that the underlying strip composite is visible.

E. In lieu of sand bag replacement if underlying strip composite is visible, additional sand bags may be placed parallel and adjacent to strip composite and overlying sandbags such that visible portions of the strip composite are covered.

F. In lieu of sandbags, Contractor may elect to install woven geotextile strips, partially covered with UDOT concrete sand, overlying the strip of composite. Woven geotextile shall be folded over the top of the sand and sewn to complete a geotextile wrap of the sand as shown on the Drawings.

PART 3 – PART 3 EXECUTION

3.01 PVC PIPE HANDLING

A. When shipping, delivering, and installing pipe, fittings, and accessories, do so to ensure a sound, undamaged installation. Provide adequate storage for all materials and equipment delivered to the site. PVC pipe and pipe fittings shall be handled carefully in loading and unloading so as not to damage the pipe, fittings, or underlying materials.

3.02 PVC PIPE INSTALLATION

A. PVC pipe installation shall conform to these Specifications, the Manufacturer’s recommendations, and as outlined in ASTM D 2774.

B. PVC perforated and solid wall pipe shall be installed as shown on the Drawings.

C. PVC pipe shall be inspected for cuts, scratches, or other damages prior to installation. Any pipe showing damage, which in the opinion of the CQA Consultant will affect performance of the pipe, must be removed from the site. Contractor shall replace any material found to be defective at no additional cost to the Owner.

3.03 JOINING OF PVC PIPES

A. PVC pipe and fittings shall be joined by primer and solvent-cements per ASTM D 2855.

B. All loose dirt and moisture shall be wiped from the interior and exterior of the pipe end and the interior of fittings.

C. All pipe cuts shall be square and perpendicular to the centerline of the pipe. All burrs, chips, etc., from pipe cutting shall be removed from pipe interior and exterior.

D. Pipe and fittings shall be selected so that there will be as small a deviation as possible at the joints, and so inverts present a smooth surface. Pipe and fittings that do not fit together to form a tight fit will be rejected.

3.04 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all work of this Section.

B. In the event of damage, the Contractor shall make all repairs and replacements necessary, to the satisfaction of the Construction Manager.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for 4-inch PVC Pipe will be measured as in-place linear foot (LF) to the limits shown on the Drawings, and payment will be based on the unit price provided on the Bid Schedule.

B. Providing for and complying with the requirements set forth in this Section for 18-inch PVC Pipe will be measured as in-place LF to the limits shown on the Drawings, and payment will be based on the unit price provided on the Bid Schedule.

C. Providing for and complying with the requirements set forth in this Section for Strip Drain, including connectors and sand bags or geotextile alternative, will be measured as in-place LF to the limits shown on the Drawings, and payment will be based on the unit price provided on the Bid Schedule.

D. The following are considered incidental to the Work:

- Submittals.
- Quality Control.
- Shipping, handling and storage.
- Fittings.
- Drainage aggregate.
- Joining.
- Mobilization.
- Placement.
- Rejected material.
- Rejected material removal, handling, re-testing, and repair.
- Gravel and sand bags and/or woven geotextile.
- UDOT sand.

[END OF SECTION]

SECTION 02770

GEOMEMBRANE

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary for the installation of smooth and textured high-density polyethylene (HDPE) geomembrane and HDPE Drain Liner™ geomembrane, as shown on the Drawings. The work shall be performed as specified herein and in accordance with the Drawings and the site Construction Quality Assurance (CQA) Plan.

B. The work shall include, but not be limited to, delivery, offloading, storage, placement, anchorage, and seaming of the geomembrane.

1.02 RELATED SECTIONS

Section 02225 – Drainage Aggregate

Section 02771 – Geotextile

Section 02772 – Geosynthetic Clay Liner

Section 02773 – Geonet

1.03 REFERENCES

A. Drawings

B. Site CQA Plan

C. Latest version of Geosynthetic Research Institute (GRI) GM-9 – Cold Weather Seaming of Geomembranes

D. Latest version of the ASTM International (ASTM) standards:

ASTM D 638	Standard Test Method for Tensile Properties of Plastics
ASTM D 792	Standard Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement
ASTM D 1505	Standard Test Methods for Density of Plastics by Density-Gradient Technique
ASTM D 1603	Standard Test Method for Carbon Black in Olefin Plastics
ASTM D 4439	Terminology for Geosynthetics
ASTM D 4833	Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
ASTM D 5199	Standard Test Method for Measuring the Nominal Thickness of Geosynthetics
ASTM D 5397	Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test
ASTM D 5596	Recommended Practice for Microscopical Examination of Pigment Dispersion in Plastic Compounds

ASTM D 5641	Practice for Geomembrane Seam Evaluation by Vacuum Chamber
ASTM D 5820	Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes
ASTM D 6365	Standard Test Method for the Non-destructive Testing of Geomembrane Seams using the Spark Test.
ASTM D 6392	Standard Test Method for Determining the Integrity of Non-reinforced Geomembrane Seams Produced using Thermo-Fusion Methods.

1.04 QUALIFICATIONS

A. Geomembrane Manufacturer:

1. The Geomembrane Manufacturer shall be responsible for the production of geomembrane rolls from resin and shall have sufficient production capacity and qualified personnel to provide material meeting the requirements of this Section and the construction schedule for this project.

2. The Geomembrane Manufacturer shall have successfully manufactured a minimum of 20,000,000 square feet of polyethylene geomembrane.

B. Geosynthetics Installer:

1. The Geosynthetics Installer shall be responsible and shall provide sufficient resources for field handling, deploying, seaming, temporarily restraining (against wind), and other aspects of the deployment and installation of the geomembrane and other geosynthetic components of the project.

2. The Geosynthetics Installer shall have successfully installed a minimum of 20,000,000 square feet of polyethylene geomembrane on previous projects with similar side slopes, bench widths, and configurations.

3. The installation crew shall have the following experience.

a. The Superintendent shall have supervised the installation of a minimum of 10,000,000 square feet of polyethylene geomembrane on at least ten (10) different projects.

b. At least one seamer shall have experience seaming a minimum of 2,000,000 square feet of polyethylene geomembrane using the same type of seaming apparatus to be used at this Site. Seamers with such experience will be designated "master seamers" and shall provide direct supervision over less experienced seamers.

c. All other seaming personnel shall have seamed at least 100,000 square feet of polyethylene geomembrane using the same type of seaming apparatus to be used at this site. Personnel who have seamed less than 100,000 square feet shall be allowed to seam only under the direct supervision of the master seamer or Superintendent.

1.05 WARRANTY

A. The Geosynthetic Manufacturer shall furnish the Owner a 20-year written warranty against defects in materials. Warranty conditions concerning limits of liability will be evaluated by, and must be acceptable to, the Owner.

B. The Geosynthetic Installer shall furnish the Owner with a 1-year written warranty against defects in workmanship. Warranty conditions concerning limits of liability will be evaluated by, and must be acceptable to, the Owner.

1.06 SUBMITTALS

A. The Geosynthetic Installer shall submit the following documentation on the resin used to manufacture the geomembrane to the Construction Manager for approval 14 days prior to transporting any geomembrane to the Site.

1. Copies of quality control certificates issued by the resin supplier including the production dates, brand name, and origin of the resin used to manufacture the geomembrane for the project.

2. Results of tests conducted by the Geomembrane Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the project.

3. Certification that no reclaimed polymer is added to the resin during the manufacturing of the geomembrane to be used for this project, or, if recycled polymer is used, the Manufacturer shall submit a certificate signed by the production manager documenting the quantity of recycled material, including a description of the procedure used to measure the quantity of recycled polymer.

B. The Geosynthetic Installer shall submit the following documentation on geomembrane roll production to the Construction Manager for approval 14 days prior to transporting any geomembrane to the site.

1. Quality control certificates, which shall include:

a. roll numbers and identification; and

b. results of quality control tests, including descriptions of the test methods used, outlined in Subpart 2.02 of this Section.

2. The manufacturer warranty specified in Subpart 1.05 of this Section.

C. The Geosynthetic Installer shall submit the following information to the Construction Manager for approval 14 days prior to mobilization.

1. A Panel Layout Drawing showing the installation layout and identifying geomembrane panel configurations, dimensions, details, locations of seams, as well as any variance or additional details that deviate from the Drawings. The Panel Layout Drawing shall be adequate for use as a construction plan and shall include dimensions, details, etc. The Panel Layout Drawing, as modified and/or approved by the Construction Manager, shall become Subpart of these Technical Specifications.

2. Installation schedule.

3. Copy of Geosynthetic Installer's letter of approval or license by the Geomembrane Manufacturer.

4. Installation capabilities, including:

a. information on equipment proposed for this project;

b. average daily production anticipated for this project; and

c. quality control procedures.

5. A list of completed facilities for which the Geosynthetic Installer has installed a minimum of 20,000,000 square feet of polyethylene geomembrane, in accordance with Subpart 1.04 of this Section. The following information shall be submitted to the Construction Manager for each facility:

   a. the name and purpose of the facility, its location, and dates of installation;

   b. the names of the owner, Engineer, and geomembrane manufacturer;

   c. name of the supervisor of the installation crew; and

   d. thickness and surface area of installed geomembrane.

6. In accordance with Subpart 1.04 of this Section, a resume of the Superintendent to be assigned to this project, including dates and duration of employment, shall be submitted at least 7 days prior to beginning geomembrane installation.

7. In accordance with Subpart 1.04 of this Section, resumes of all personnel who will perform seaming operations on this project, including dates and duration of employment, shall be submitted at least 7 days prior to beginning geomembrane installation.

D. A Certificate of Calibration less than 12 months old shall be submitted for each field tensiometer prior to installation of any geomembrane.

E. During installation, the Geosynthetic Installer shall be responsible for the timely submission to the Construction Manager of:

1. Quality control documentation; and

2. If geomembrane is placed directly on the subgrade (Option A), Subgrade Acceptance Certificates, signed by the Geosynthetic Installer, for each area of subgrade to be covered by geosynthetic materials.

F. Upon completion of the installation, the Geosynthetic Installer shall be responsible for the submission to the Construction Manager of a warranty from the Geosynthetic Installer as specified in Subpart 1.05.B of this Section.

G. Upon completion of the installation of each layer, the Geosynthetic Installer shall be responsible for the submission to the Construction Manager of a Record Drawing showing the location and number of each panel and locations and numbers of destructive tests and repairs.

H. The Geosynthetic Installer shall submit samples and material property cut-sheets on the proposed geomembrane to the Construction Manager at least 7 days prior to delivery of this material to the site.

I. The Geosynthetic Installer shall submit the following documentation on welding rod to the Construction Manager for approval 14 days prior to transporting welding rod to the Site:

1. Quality control documentation, including lot number, welding rod spool number, and results of quality control tests on the welding rod.

2. Certification that the welding rod is compatible with the geomembrane and this Section.

1.07 CONSTRUCTION QUALITY ASSURANCE (CQA) MONITORING

A. The Geosynthetic Installer shall be aware of and accommodate all monitoring and conformance testing required by the CQA Plan. This monitoring and testing, including random conformance testing of construction materials and completed work, will be performed by the CQA Consultant. If nonconformances or other deficiencies are found in the Geosynthetic Installer's materials or completed work, the Geosynthetic Installer will be required to repair the deficiency or replace the deficient materials.

PART 2 – PRODUCTS

2.01 GEOMEMBRANE PROPERTIES

A. The Primary Geomembrane Manufacturer shall furnish white-or off-white-surfaced (upper side only), smooth and textured geomembrane having properties that comply with the required property values shown in Table 02770-1.

B. The Secondary Floor Geomembrane Manufacturer shall furnish black, smooth and textured geomembrane having properties that comply with the required property values shown in Table 02770-1

C. The Secondary Side Slope Geomembrane Manufacturer shall furnish black Drain Liner™ geomembrane having properties that comply with the required property values shown in Table 02770-2.

D. The Tertiary Geomembrane Manufacturer shall furnish black Drain Liner™ geomembrane having properties that comply with the required property values shown in Table 02770-2, if applicable.

E. In addition to the property values listed in Tables 02770-1 and 02770-2, the geomembrane shall:

1. Contain a maximum of 1 percent by weight of additives, fillers, or extenders (not including carbon black and titanium dioxide).

2. Not have striations, pinholes (holes), bubbles, blisters, nodules, undispersed raw materials, or any sign of contamination by foreign matter on the surface or in the interior.

2.02 MANUFACTURING QUALITY CONTROL (MQC)

A. Rolls:

1. The Geomembrane Manufacturer shall continuously monitor geomembrane during the manufacturing process for defects.

2. No geomembrane shall be accepted that exhibits any defects.

3. The Geomembrane Manufacturer shall measure and report the geomembrane thickness at regular intervals along the roll length.

4. No geomembrane shall be accepted that fails to meet the specified thickness.

5. The Geomembrane Manufacturer shall sample and test the geomembrane at a minimum of once every 50,000 square feet, to demonstrate that its properties conform to the values specified in Tables 02770-1 and 02770-2. At a minimum, the following tests shall be performed:

Test	Procedure
Thickness	ASTM D 5199 or ASTM D 5994
Specific Gravity	ASTM D 792
Tensile Properties	ASTM D 6933
Puncture Resistance	ASTM D 4833
Carbon Black	ASTM D 4218
Carbon Black Dispersion	ASTM D 5596

6. Tests not listed above but listed in Table 02770-1 or Table 02770-2 need not be run at the one per 50,000 square feet frequency. However, the Geomembrane Manufacturer shall certify that these tests are in compliance with this Section and have been performed on a sample that is identical to the geomembrane to be used on this project. The Geosynthetic Installer shall provide the test result documentation to the Construction Manager.

7. Any geomembrane sample that does not comply with the requirements of this Section will result in rejection of the roll from which the sample was obtained and will not be used for this project.

8. If a geomembrane sample fails to meet the quality control requirements of this Section, the Geomembrane Manufacturer shall sample and test, at the expense of the Manufacturer, rolls manufactured in the same resin batch, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established to bound the failed roll(s).

9. Additional testing may be performed at the Geomembrane Manufacturer's discretion and expense, to isolate and more closely identify the non-complying rolls and/or to qualify individual rolls.

B. The Geomembrane Manufacturer shall permit the CQA Consultant to visit the manufacturing plant for project specific visits. If possible, such visits will be prior to or during the manufacturing of the geomembrane rolls for the specific project. The CQA Consultant may elect to collect conformance samples at the manufacturing facility to expedite the acceptance of the materials.

2.03 INTERFACE SHEAR TESTING

A. Interface shear test(s) shall be performed by the CQA Consultant on the proposed geosynthetic components in accordance with ASTM D 5321. Tests shall be performed on geosynthetic interfaces as outlined below.

1. Geotextile and Textured HDPE Geomembrane – the nonwoven cushion geotextile shall be overlain by a 60-mil textured HDPE geomembrane.

a. Concrete sand shall be placed overlying and underlying the materials being tested. The test shall be performed at normal stresses of 100, 200, and 400 psf at a shear rate of no more than 0.20 in./min (5 mm/min.).

b. The results of this test shall have peak shear strength values in excess of 53 psf, 106 psf, and 213 psf for normal stresses of 100 psf, 200 psf, and 400 psf, respectively.

2. Drain Liner™ and Smooth HDPE Geomembrane – the Drain Liner™ shall be overlain by a 60-mil smooth geomembrane.

   a. Concrete sand shall be placed overlying and underlying the materials being tested. The test shall be performed at normal stresses of 10, 20, and 40 psi at a shear rate of no more than 0.20 in./min. (5 mm/min.).

   b. The results of this test shall have a peak apparent friction angle in excess of 11 degrees.

3. Geonet and smooth HDPE Geomembrane – the geonet shall be overlain by a 60-mil smooth HDPE geomembrane.

   a. Concrete sand shall be placed overlying the geomembrane being tested. The test shall be performed at normal stresses of 10, 20, and 40 psi at a shear rate of no more than 0.20 in./min. (5 mm/min.).

   b. The results of this test shall have a peak apparent friction angle in excess of 11 degrees.

4. Hydrated GCL interface – the GCL shall be overlain by a textured 60-mil HDPE Concrete sand shall be placed overlying and underlying the materials being tested.

   a. Before shearing, the GCL shall be hydrated under normal stresses for each individual test (e.g. 100, 200, and 400 psf) for 48 hours. The test shall be performed at normal stresses of 100, 200, and 400 psf at a shear rate of no more than 0.04 in./min. (1 mm/min.).

   b. The results of this test shall have peak shear strength values in excess of 53 psf, 106 psf, and 213 psf for normal stresses of 100 psf, 200 psf, and 400 psf, respectively.

5. Hydrated GCL interface – the GCL shall be overlain by a smooth 60-mil HDPE geomembrane. Concrete sand shall be placed overlying and underlying the materials being tested.

   a. Before shearing, the GCL shall be hydrated under a loading of 250 psf for 48 hours. The test shall be performed at normal stresses of 10, 20, and 40 psi at a shear rate of no more than 0.04 in./min. (1 mm/min.).

   b. The results of this test shall have a peak apparent friction angle in excess of 11 degrees.

2.04 LABELING

A. Geomembrane rolls shall be labeled with the following information.

   1. thickness of the material;

   2. length and width of the roll;

   3. name of Geomembrane Manufacturer;

   4. product identification;

5. lot number; and

6. roll number.

2.05 TRANSPORTATION, HANDLING, AND STORAGE

A. The Geosynthetic Manufacturer shall be liable for any damage to the geomembrane incurred prior to and during transportation to the site.

B. Handling and care of the geomembrane at the site prior to and following installation shall be the responsibility of the Geosynthetic Installer. The Geosynthetic Installer shall be liable for all damage to the materials incurred prior to final acceptance of the liner system by the Owner.

C. Geosynthetic Installer shall be responsible for storage of the geomembrane at the site. The geomembrane shall be protected from excessive heat or cold, dirt, puncture, cutting, or other damaging or deleterious conditions. Any additional storage procedures required by the Geomembrane Manufacturer shall be the Geosynthetic Installer's responsibility. Geomembrane rolls shall not be stored or placed in a stack of more than two rolls high.

D. The geomembrane shall be delivered at least 14 days prior to the planned deployment date to allow the CQA Consultant adequate time to perform conformance testing on the geomembrane samples as described in Subpart 3.05 of this Section. If the CQA Consultant performed a visit to the manufacturing plant and performed the required conformance sampling, geomembrane can be delivered to the site within the 14 days prior to the planned deployment date as long as there is sufficient time for the CQA Consultant to complete the conformance testing and confirm that the rolls shipped to the site are in compliance with this Section.

PART 3 – GEOMEMBRANE INSTALLATION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work described in this Section, the Geosynthetic Installer shall become thoroughly familiar with all portions of the work falling within this Section.

B. Inspection:

1. The Geosynthetic Installer shall carefully inspect the installed work of all other Sections and verify that all work is complete to the point where the work of this Section may properly commence without adverse effect.

2. If the Geosynthetic Installer has any concerns regarding the installed work of other Sections, he shall notify the Construction Manager in writing prior to the start of the work of this Section. Failure to inform the Construction Manager in writing or commencing installation of the geomembrane will be construed as the Geosynthetic Installer's acceptance of the related work of all other Sections.

C. A pre-installation meeting shall be held to coordinate the installation of the geomembrane with the installation of other components of the liner system.

3.02 GEOMEMBRANE DEPLOYMENT

A. Layout Drawings:

1. The Geosynthetic Installer shall deploy the geomembrane panels in general accordance with the Panel Layout Drawing specified. The Panel Layout Drawing must be approved by the CQA Consultant prior to installation of any geomembrane.

B. Field Panel Identification:

1. A geomembrane field panel is a roll or a portion of roll cut in the field.

2. Each field panel shall be given a unique identification code (number or letter-number). This identification code shall be agreed upon by the Construction Manager and Geosynthetic Installer.

C. Field Panel Placement:

1. Field panels shall be installed, as approved or modified, at the location and positions indicated on the Panel Layout Drawing.

2. Primary geomembrane field panels shall be installed with the white side of the geomembrane upward with the exception of the splash pads which will have the black side of the geomembrane upward.

3. Drain Liner™ shall be placed with the studded side upward.

4. Panels shall be laid out in a manner which minimizes seams.

5. Field panels shall be placed one at a time.

6. Geomembrane shall not be placed when the ambient temperature is below 32°F or above 122°F, as measured in Subpart 3.03.C.3 in this Section, unless otherwise authorized in writing by the Design Engineer. Geomembrane panels shall be allowed to equilibrate to temperature of adjacent panels prior to seaming.

7. Geomembrane shall not be placed during any precipitation, in the presence of excessive moisture (e.g., fog, dew), in an area of ponded water, or in the presence of wind speeds greater than 20 mph.

8. The Geosynthetic Installer shall ensure that:

   a. No vehicular traffic is allowed on the geomembrane with the exception of all terrain vehicles with contact pressures at or lower than that exhibited by foot traffic.

   b. Equipment used does not damage the geomembrane by handling, trafficking, or leakage of hydrocarbons (i.e., fuels).

   c. Personnel working on the geomembrane do not smoke, wear damaging shoes, bring glass onto the geomembrane, or engage in other activities that could damage the geomembrane.

   d. The method used to unroll the panels does not scratch or crimp the geomembrane and does not damage the supporting soil or geosynthetics.

   e. The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels). The method used to place the panels results in intimate contact between the geomembrane and adjacent components.

   f. Temporary ballast and/or anchors (e.g., sand bags) are placed on the geomembrane to prevent wind uplift. Ballast methods must not damage the geomembrane.

   g. The geomembrane is especially protected from damage in heavily trafficked areas.

h. Any rub sheets to facilitate seaming are removed prior to installation of subsequent panels.

9. Any field panel or portion thereof that becomes seriously damaged (torn, twisted, or crimped) shall be replaced with new material. Less serious damage to the geomembrane may be repaired, as approved by the Construction Manager. Damaged panels or portions of damaged panels that have been rejected shall be removed from the work area and not reused.

10. Care shall be taken during placement of tertiary, Drain Liner™ geomembrane to prevent dirt or excessive dust in the liner studs that could cause clogging and/or damage to the adjacent materials.

D. If the Geosynthetic Installer intends to install geomembrane between one hour before sunset and one hour after sunrise, he shall notify the Construction Manager in writing prior to the start of the work. The Geosynthetic Installer shall indicate additional precautions that shall be taken during these installation hours. The Geosynthetic Installer shall provide proper illumination for work during this time period.

3.03 FIELD SEAMING

A. Seam Layout:

1. In corners and at odd-shaped geometric locations, the number of field seams shall be minimized. On slopes steeper than 10:1 (horizontal:vertical), geomembrane panels shall be continuous down the slope, i.e., no horizontal seams shall be allowed on the slope. Horizontal seams shall be considered as any seam having an alignment exceeding 45 degrees from being perpendicular to the slope contour lines, unless otherwise approved by the Design Engineer. No seams shall be located in an area of potential stress concentration.

2. Seams shall not be allowed within 5 feet of the top or toe of any slope.

B. Personnel:

1. All personnel performing seaming operations shall be qualified as indicated in Subpart 1.04 of this Section. No seaming shall be performed unless a "master seamer" is present on-site.

C. Weather Conditions for Seaming:

1. Unless authorized in writing by the Design Engineer, seaming shall not be attempted at ambient temperatures below 32°F or above 122°F. If the Geosynthetic Installer wishes to use methods that may allow seaming at ambient temperatures below 32°F or above 122°F, the procedure must be in accordance with GRI GM-9 for cold weather seaming and be approved by the Construction Manager.

2. A meeting will be held between the Geosynthetic Installer and Design Engineer to establish acceptable installation procedures. In all cases, the geomembrane shall be dry and protected from wind damage during installation.

3. Ambient temperatures, measured by the CQA Site Manager, shall be measured between 0 and 6 inches above the geomembrane surface.

D. Overlapping:

1. The geomembrane shall be cut and/or trimmed such that all corners are rounded.

2. Geomembrane panels shall be shingled with the upslope panel placed over the down slope panel.

3. Geomembrane panels shall be sufficiently overlapped for welding and to allow peel tests to be performed on the seam. Any seams that cannot be destructively tested because of insufficient overlap shall be treated as failing seams.

E. Seam Preparation:

1. Prior to seaming, the seam area shall be clean and free of moisture, dust, dirt, debris of any kind, and foreign material.

2. If seam overlap grinding is required, including to remove Drain Liner™ studs, the process shall be completed according to the Geomembrane Manufacturer's instructions within 20 minutes of the seaming operation and in a manner that does not damage the geomembrane. The grind depth shall not exceed ten percent of the core geomembrane thickness.

3. Seams shall be aligned with the fewest possible number of wrinkles and "fishmouths." Proper temperature and sunlight acclimation shall be allowed prior to seaming a newly placed panel to a previously placed panel (panels must be allowed to expand and contract to be in equilibrium with adjacent panels prior to seaming).

F. General Seaming Requirements:

1. Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle to achieve a flat overlap, ending the cut with circular cut-out. The cut fishmouths or wrinkles shall be seamed and any portion where the overlap is insufficient shall be patched with an oval or round patch of geomembrane that extends a minimum of 6 inches beyond the cut in all directions.

2. Any electric generator shall be placed outside the area to be lined or mounted in a manner that protects the geomembrane from damage due to the weight and frame of the generator or due to fuel leakage. The electric generator shall be properly grounded.

G. Seaming Process:

1. Approved processes for field seaming are extrusion welding and double-track hot-wedge fusion welding. Only equipment identified as part of the approved submittal specified in Subpart 1.06 of this Section shall be used.

2. Extrusion Equipment and Procedures:

a. The Geosynthetics Installer shall maintain at least one spare operable seaming apparatus on site.

b. Extrusion welding apparatuses shall be equipped with gauges giving the temperatures in the apparatuses.

c. Prior to beginning an extrusion seam, the extruder shall be purged until all heat-degraded extrudate has been removed from the barrel.

d. A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after use.

3. Fusion Equipment and Procedures:

a. The Geosynthetic Installer shall maintain at least one spare operable seaming apparatus on site.

b. Fusion-welding apparatus shall be automated vehicular-mounted devices equipped with gauges giving the applicable temperatures and speed.

c. A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after use.

H. Drain Liner™ butt-seams

1. At the Drain Liner™ butt-seams (end of panel), a 2-foot length of 200-mil geonet will be installed over the seams to extend a minimum of 6-inches onto the adjacent panel studs and shall extend across the width of the panel. Butt-seam requirement applies to Drain Liner™ to Drain Liner™, not to Drain Liner™ to smooth or textured HDPE geomembrane.

2. Distance between studs on the panel and studs on extrusion-welded patches shall not exceed 3-inches.

I. Trial Seams:

1. Trial seams shall be made on fragment pieces of geomembrane to verify that seaming conditions are adequate. Trial seams shall be conducted on the same material to be installed and under similar field conditions as production seams. Such trial seams shall be made at the beginning of each seaming period, typically at the beginning of the day and after lunch, for each seaming apparatus used each day, but no less frequently than once every 5 hours. The trial seam sample shall be a minimum of 5 feet long by 1 foot wide (after seaming) with the seam centered lengthwise for fusion equipment and at least 3 feet long by 1 foot wide for extrusion equipment. Seam overlap shall be as indicated in Subpart 3.03.D of this Section.

2. Four coupon specimens, each 1-inch wide, shall be cut from the trial seam sample by the Geosynthetics Installer using a die cutter to ensure precise 1-inch wide coupons. The coupons shall be tested, by the Geosynthetic Installer, with the CQA Site Manager present, in peel (both the outside and inside track) and in shear using an electronic readout field tensiometer in accordance with ASTM D 6392, at a strain rate of 2 inches/minute. The samples shall not exhibit failure in the seam, i.e., they shall exhibit a Film Tear Bond (FTB), which is a failure (yield) in the parent material. The required peel and shear seam strength values are listed in Table 02770-3. At no time shall specimens be soaked in water.

3. If any coupon specimen fails, the trial seam shall be considered failing and the entire operation shall be repeated. If any of the additional coupon specimens fail, the seaming apparatus and seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved.

J. Nondestructive Seam Continuity Testing:

1. The Geosynthetic Installer shall nondestructively test for continuity on all field seams over their full length. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming. The Geosynthetic Installer shall complete any required repairs in accordance with Subpart 3.03.K of this Section. The following procedures shall apply:

a. Vacuum testing in accordance with ASTM D 5641.

b. Air channel pressure testing for double-track fusion seams in accordance with ASTM D 5820 and the following:

i. Insert needle, or other approved pressure feed device, from pressure gauge and inflation device into the air channel at one end of a double track seam.

ii. Energize the air pump and inflate air channel to a pressure between 25 and 30 pounds per square inch (psi). Close valve and sustain the pressure for not less than 5 minutes.

iii. If loss of pressure exceeds 3 psi over 5 minutes, or if the pressure does not stabilize, locate the faulty area(s) and repair seam in accordance with Subpart 3.03.K of this Section.

iv. After 5 minutes, cut the end of air channel opposite from the end with the pressure gauge and observe release of pressure to ensure air channel is not blocked. If the channel does not depressurize, find and repair the portion of the seam containing the blockage per Subpart 3.03.K of this Section. Repeat the air pressure test on the resulting segments of the original seam created by the repair and the ends of the seam. Repeat the process until the entire length of seam has successfully passed pressure testing or contains a repair. Repairs shall also be non-destructively tested per Subpart 3.03.K.5 of this Section.

v. Remove needle, or other approved pressure feed device, and seal repair in accordance with Subpart 3.03.K of this Section.

c. Spark test seam integrity verification shall be performed in accordance with ASTM D 6365 if the seam cannot be tested using other nondestructive methods.

K. Destructive Testing:

1. Destructive seam tests shall be performed on samples collected from selected locations to evaluate seam strength and integrity. Destructive tests shall be carried out as the seaming work progresses, not at the completion of all field seaming.

2. Sampling:

a. Destructive test samples shall be collected at a minimum average frequency of one test location per 500 feet of total seam length. If after a total of 50 samples have been tested and no more than 1 sample has failed, the frequency can be increased to one per 1,000 feet. Test locations shall be determined during seaming, and may be prompted by suspicion of excess crystallinity, contamination, offset seams, or any other potential cause of imperfect seaming. The CQA Site Manager will be responsible for choosing the locations. The Geosynthetic Installer shall not be informed in advance of the locations where the seam samples will be taken. The CQA Site Manager reserves the right to increase the sampling frequency if observations suggest an increased frequency is warranted.

b. The CQA Site Manager shall mark the destructive sample locations. Samples shall be cut by the Geosynthetic Installer at the locations designated by the CQA Site Manager as the seaming progresses in order to obtain laboratory test results before the geomembrane is covered by another material. Each sample shall be numbered and the sample number and location identified on the Panel Layout Drawing. All holes in the geomembrane resulting from the destructive seam sampling shall be immediately repaired in accordance with the repair procedures described in Subpart 3.03.K of this Section. The continuity of the new seams associated with the repaired areas shall be tested according to Subpart 3.03.I of this Section.

c. Two coupon strips of dimensions 1-inch wide and 12-inches long with the seam centered parallel to the width shall be taken from any side of the sample location. These samples shall be tested in the field in accordance with Subpart 3.03.J.3 of this Section. If these samples pass the field test, a laboratory sample shall be taken. The laboratory sample shall be at least 1-foot wide by 3.5-feet long with the seam centered along the length. The sample shall be cut into three parts and distributed as follows:

    i. One portion 12-inches long to the Geosynthetic Installer.

    ii. One portion 18-inches long to the Geosynthetic CQA Laboratory for testing.

    iii. One portion 12-inches long to the Owner for archival storage.

3. Field Testing:

    a. The two 1-inch wide strips shall be tested in the field tensiometer in the peel mode on both sides of the double track fusion welded sample. The CQA Site Manager has the option to request an additional test in the shear mode. If any field test sample fails to meet the requirements in Table 02770-3, then the procedures outlined in Subpart 3.03.J.5 of this Section for a failing destructive sample shall be followed.

4. Laboratory Testing:

    a. Testing by the Geosynthetics CQA Laboratory will include "Seam Strength" and "Peel Adhesion" (ASTM D 6392) with 1-inch wide strips tested at a rate of 2 inches/minute. At least 5 specimens will be tested for each test method (peel and shear). Four of the five specimens per sample must pass both the shear strength test and peel adhesion test when tested in accordance with ASTM D 6392. The minimum acceptable values to be obtained in these tests are indicated in Table 02770-3. Both the inside and outside tracks of the dual track fusion welds shall be tested in peel.

5. Destructive Test Failure:

    a. The following procedures shall apply whenever a sample fails a destructive test, whether the test is conducted by the Geosynthetic CQA's laboratory, the Geosynthetic Installer laboratory, or by a field tensiometer. The Geosynthetic Installer shall have two options:

        i. The Geosynthetic Installer can reconstruct the seam (e.g., remove the old seam and reseam) between any two laboratory-passed destructive test locations created by that seaming apparatus. Trial welds do not count as a passed destructive test.

        ii. The Geosynthetic Installer can trace the welding path in each direction to an intermediate location, a minimum of 10 feet from the location of the failed test, and take a small sample for an additional field test at each location. If these additional samples pass the field tests, then full laboratory samples shall be taken. These full laboratory samples shall be tested in accordance with Subpart 3.03.J.4 of this Section. If these laboratory samples pass the tests, then the seam path between these locations shall be reconstructed and nondestructively (at a minimum) tested. If a sample fails, then the process shall be repeated, i.e. another destructive sample shall be obtained and tested at a distance of at least 10 more feet in the seaming path from the failed sample. The seam path between the ultimate passing sample locations shall be reconstructed and nondestructively (at a minimum) tested. In cases where repaired seam lengths exceed 150 feet, a destructive sample shall be taken from the repaired seam and the above procedures for destructive seam testing shall be followed.

b. Whenever a sample fails destructive or non-destructive testing, the CQA Consultant may require additional destructive tests be obtained from seams that were created by the same seamer and/or seaming apparatus during the same time shift.

L. Defects and Repairs:

1. The geomembrane will be inspected before and after seaming for evidence of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. The surface of the geomembrane shall be clean at the time of inspection. The geomembrane surface shall be swept or washed by the Installer if surface contamination inhibits inspection.

2. At observed suspected flawed location, both in seamed and non-seamed areas, shall be nondestructively tested using the methods described Subpart 3.03.I of this Section, as appropriate. Each location that fails nondestructive testing shall be marked by the CQA Site Manager and repaired by the Geosynthetic Installer.

3. When seaming of a geomembrane is completed (or when seaming of a large area of a geomembrane is completed) and prior to placing overlying materials, the CQA Site Manager shall identify all excessive geomembrane wrinkles. The Geosynthetic Installer shall cut and reseam all wrinkles so identified. The seams thus produced shall be tested as per all other seams.

4. Repair Procedures:

a. Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, shall be repaired by the Geosynthetic Installer. Several repair procedures are acceptable. The final decision as to the appropriate repair procedure shall be agreed upon between the Design Engineer and the Geosynthetic Installer. The procedures available include:

i. Patching – extrusion welding a patch to repair holes larger than 1/16 inch, tears, undispersed raw materials, and contamination by foreign matter;

ii. Abrading and reseaming – applying an extrusion seam to repair very small sections of faulty extruded seams;

iii. Spot seaming – applying an extrusion bead to repair minor, localized flaws such as scratches and scuffs;

iv. Capping – extrusion welding a geomembrane cap over long lengths of failed seams; and

v. Strip repairing – cutting out bad seams and replacing with a strip of new material seamed into place on both sides with fusion welding.

b. In addition, the following criteria shall be satisfied:

i. surfaces of the geomembrane that are to be repaired shall be abraded no more than 20 minutes prior to the repair;

ii. the grind depth around the repair shall not exceed ten percent of the core geomembrane thickness;

iii. all surfaces must be clean and dry at the time of repair;

iv. all seaming equipment used in repair procedures must be approved by trial seaming;

v. any other potential repair procedures shall be approved in advance, for the specific repair, by the Design Engineer;

vi. patches or caps shall extend at least 6 inches beyond the edge of the defect, and all corners of patches and holes shall be rounded with a radius of at least 3 inches;

vii. extrudate shall extend a minimum of 3 inches beyond the edge of the patch at fusion welded seam overlaps.

5. Repair Verification:

a. Repairs shall be nondestructively tested using the methods described in Subpart 3.03.I of this Section, as appropriate. Repairs that pass nondestructive testing shall be considered acceptable repairs. Repairs that failed nondestructive or destructive testing will require the repair to be reconstructed and retested until passing test results are observed. At the discretion of the CQA Consultant, destructive testing may be required on any caps.

3.04 MATERIALS IN CONTACT WITH THE GEOMEMBRANE

A. The Geosynthetic Installer shall take all necessary precautions to ensure that the geomembrane is not damaged during its installation. During the installation of other components of the liner system by the Contractor, the Contractor shall ensure that the geomembrane is not damaged. Any damage to the geomembrane caused by the Contractor shall be repaired by the Geosynthetic Installer at the expense of the Contractor.

B. Soil and aggregate materials shall not be placed over the geomembranes at ambient temperatures below 32°F or above 122°F, unless otherwise specified.

C. All attempts shall be made to minimize wrinkles in the geomembrane.

D. Construction loads permitted on the geomembrane are limited to foot traffic and all terrain vehicles with a contact pressures at or lower than 7 pounds per square inch.

3.05 CONFORMANCE TESTING

A. Samples of the geomembrane will be removed by the CQA Site Manager and sent to a Geosynthetic CQA Laboratory for testing to ensure conformance with the requirements of this Section. The CQA Consultant may collect samples at the manufacturing plant or from the rolls delivered to the site. The Geosynthetic Installer shall assist the CQA Site Manager in obtaining conformance samples from any geomembrane rolls sampled at the site. The Geosynthetic Installer and Contractor shall account for this sampling and testing requirement in the installation schedule, including the turnaround time for laboratory results. Only materials that meet the requirements of Subpart 2.02 of this Section shall be installed.

B. Samples will be selected by the CQA Consultant in accordance with this Section and with the procedures outlined in the CQA Plan.

C. Samples will be taken at a minimum frequency of one sample per 100,000 square feet excluding the splash pads. If the Geomembrane Manufacturer provides material that requires sampling at a frequency (due to lot size, shipment size, etc.) resulting in one sample per less than 90 percent of 100,000 square feet (90,000 square feet), then the Geosynthetic Installer shall pay the cost for all additional testing.

D. The CQA Consultant may increase the frequency of sampling in the event that test results do not comply with the requirements of Subpart 2.02 of this Section.

E. The following tests will be performed by the CQA Consultant:

Test	**Procedure**
Thickness	ASTM D 5199 or ASTM D 5944
Specific Gravity	ASTM D 792
Tensile Properties	ASTM D 6693
Carbon Black	ASTM D 4218
Carbon Black Dispersion	ASTM D 5596

F. Any geomembrane that is not certified in accordance with Subpart 1.06.C of this Section, or that conformance testing indicates does not comply with Subpart 2.02 of this Section, shall be rejected. The Geosynthetic Installer shall replace the rejected material with new material.

3.06 GEOMEMBRANE ACCEPTANCE

A. The Geosynthetic Installer shall retain all ownership and responsibility for the geomembrane until accepted by the Owner.

B. The geomembrane will not be accepted by the Owner before:

1. the installation is completed;

2. all documentation is submitted;

3. verification of the adequacy of all field seams and repairs, including associated testing, is complete; and

4. all warranties are submitted.

3.07 PROTECTION OF WORK

A. The Geosynthetic Installer and Contractor shall use all means necessary to protect all work of this Section.

B. In the event of damage, the Geosynthetic Installer shall make all repairs and replacements necessary, to the satisfaction of the Construction Manager.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for 60-mil, smooth, textured, and Drain Liner™ HDPE geomembrane will be measured as in-place square feet (SF), as measured by the surveyor, including geomembrane in the anchor trench to the limits shown on the Drawings, and payment will be based on the unit price provided on the Bid Schedule.

B. The following are considered incidental to the Work:

- Submittals.
- Quality Control.
- Shipping, handling, and storage.
- Deployment.
- Layout survey.
- Mobilization.
- Rejected material.
- Rejected material removal, handling, re-testing, and repair.
- Overlaps and seaming.
- Temporary anchorage.
- Pipe boots.
- Cleaning seam area.

TABLE 02770-1
REQUIRED HDPE GEOMEMBRANE PROPERTIES

PROPERTIES	QUALIFIERS	UNITS	SMOOTH HDPE SPECIFIED VALUES	TEXTURED HDPE SPECIFIED VALUES	TEST METHOD
Physical Properties					
Thickness	Average Minimum	mils mils	60 54	60 54	ASTM D 5199 or ASTM D 5944
Specific Gravity	Minimum	N/A	0.94	0.94	ASTM D 792 Method A or ASTM D 1505
Mechanical Properties Tensile Properties (each direction) 1. Tensile (Break) Strength 2. Elongation at Break 3. Tensile (Yield) Strength 4. Elongation at Yield	Minimum	lb/in % lb/in %	228 700 126 12	90 100 126 12	ASTM D 6693
Puncture	Minimum	lb	108	90	ASTM D 4833
Environmental Properties					
Carbon Black Content	Range	%	2-3	2	ASTM D 4218
Carbon Black Dispersion	N/A	none	Note 1	Note 1	ASTM D 5596
Environmental Stress Crack	Minimum	hr	300	300	ASTM D 5397
Liner System Properties					
Interface Shear Strength – Textured Geomembrane and Geotextile	Minimum	psf	N/A	53, 106, 213	ASTM D5321[2]
Interface Shear Strength – Smooth Geomembrane to Geonet	Minimum	degrees	N/A	11	ASTM D 5321[2]
Interface Shear Strength – Smooth Geomembrane to Drain Liner™ HDPE geomembrane	Minimum	degrees	N/A	11	ASTM D 5321[2]

Notes: (1) Minimum 9 of 10 in Categories 1 or 2; 10 in Categories 1, 2, or 3.
(2) Interface shear strength testing shall be performed, by the CQA Consultant, in accordance with part 2.03.1 of this Section.

TABLE 02770-2
REQUIRED HDPE DRAIN LINER™ GEOMEMBRANE PROPERTIES

PROPERTIES	QUALIFIERS	UNITS	SPECIFIED VALUES	TEST METHOD
Physical Properties				
Thickness	Average Minimum	mils mils	60 54	ASTM D 5994
Specific Gravity	Minimum	N/A	0.94	ASTM D 792
Drainage Stud Height	Average Minimum	mils	130	ASTM D 7466
Mechanical Properties Tensile Properties (each direction) 1. Tensile (Break) Strength 2. Elongation at Break 3. Tensile (Yield) Strength 4. Elongation at Yield	Minimum	lb/in % lb/in %	132 13 132 300	ASTM D 6693
Puncture	Minimum	lb lb	95 72	ASTM D 4833
Environmental Properties				
Carbon Black Content	Range	%	2	ASTM D 4218
Carbon Black Dispersion	N/A	none	Note 1	ASTM D 5596
Environmental Stress Crack	Minimum	hr	300	ASTM D 5397
Liner System Properties				
Interface Shear Strength	Minimum	degrees	11	ASTM D5321[2]

Notes: (1) Minimum 9 of 10 in Categories 1 or 2; 10 in Categories 1, 2, or 3.
(2) Interface shear strength testing shall be performed, by the CQA Consultant, in accordance with part 2.03.3 of this Section.

TABLE 02770-3
REQUIRED GEOMEMBRANE SEAM PROPERTIES

PROPERTIES	QUALIFIERS	UNITS	SPECIFIED VALUES(3)	TEST METHOD
Shear Strength(1)				
Fusion	minimum	lb/in	120	ASTM D 6392
Extrusion	minimum	lb/in	120	ASTM D 6392
Peel Adhesion				
FTB(2)				Visual Observation
Fusion	minimum	lb/in	91	ASTM D 6392
Extrusion	minimum	lb/in	78	ASTM D 6392

Notes: (1) Also called "Bonded Seam Strength".
(2) FTB = Film Tear Bond means that failure is in the parent material, not the seam. The maximum seam separation is 25 percent of the seam area.
(3) Four of five specimens per destructive sample must pass both the shear and peel strength tests.

[END OF SECTION]

SECTION 02771

GEOTEXTILE

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary for the installation of the geotextile. The work shall be carried out as specified herein and in accordance with the Drawings and the Construction Quality Assurance (CQA) Plan.

B. The work shall include, but not be limited to, delivery, offloading, storage, placement, and seaming of the various geotextile components of the project.

C. Nonwoven cushion geotextile shall be used between the Drainage Aggregate and Geomembrane as shown on the Drawings. Woven geotextile shall be used overlying the cushion geotextile/drainage aggregate and as a substitute for sand bags, as shown on the Drawings.

1.02 RELATED SECTIONS

Section 02200 – Earthwork

Section 02225 – Drainage Aggregate

Section 02616 – Polyvinyl Chloride (PVC) Pipe

Section 02770 – Geomembrane

Section 02773 – Geonet

1.03 REFERENCES

A. Drawings

B. Site CQA Plan

C. Latest version of ASTM International (ASTM) standards:

ASTM D 4355 Standard Test Method for Deterioration of Geotextile from Exposure to Ultraviolet Light and Water

ASTM D 4439 Terminology for Geosynthetics

ASTM D 4491 Standard Test Method for Water Permeability of Geotextile by Permittivity

ASTM D 4533 Standard Test Method for Trapezoid Tearing Strength of Geotextile

ASTM D 4632 Standard Test Method for Breaking Load and Elongation of Geotextile (Grab Method)

ASTM D 4751 Standard Test Method for Determining Apparent Opening Size of a Geotextile

ASTM D 6241 Standard Test Method for the Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe

ASTM D 5261 Standard Test Method for Measuring Mass Per Unit Area of Geotextile

1.04 SUBMITTALS

A. The Contractor shall submit the following information regarding the proposed geotextile to the Construction Manager for approval at least 7 days prior to geotextile delivery:

1. manufacturer and product name;

2. minimum property values of the proposed geotextile and the corresponding test procedures;

3. projected geotextile delivery dates; and

4. list of geotextile roll numbers for rolls to be delivered to the site.

B. At least 7 days prior to geotextile placement, the Contractor shall submit to the Construction Manager the Manufacturing Quality Control (MQC) certificates for each roll of geotextile. The certificates shall be signed by responsible parties employed by the geotextile manufacturer (such as the production manager). The MQC certificates shall include:

1. lot, batch, and/or roll numbers and identification;

2. MQC test results, including a description of the test methods used; and

3. Certification that the geotextile meets or exceeds the required properties of the Drawings and this Section.

1.05 CQA MONITORING

A. The Contractor shall be aware of and accommodate all monitoring and conformance testing required by the CQA Plan. This monitoring and testing, including random conformance testing of construction materials and completed work, will be performed by the CQA Consultant. If nonconformances or other deficiencies are found in the Contractor's materials or completed work, the Contractor will be required to repair the deficiency or replace the deficient materials at no additional expense to the Owner.

PART 2 – PRODUCTS

2.01 GEOTEXTILE PROPERTIES

A. The Geotextile Manufacturer shall furnish materials that meet or exceed the criteria specified in Table 02771-1 in accordance with the minimum average roll value (MARV), as defined by ASTM D 4439.

B. The cushion geotextile shall be nonwoven materials, suitable for use in filter/separation and cushion applications.

2.02 MANUFACTURING QUALITY CONTROL (MQC)

A. The geotextile shall be manufactured with MQC procedures that meet or exceed generally accepted industry standards.

B. The Geotextile Manufacturer shall sample and test the geotextile to demonstrate that the material conforms to the requirements of these Specifications.

C. Any geotextile sample that does not comply with this Section shall result in rejection of the roll from which the sample was obtained. The Contractor shall replace any rejected rolls.

D. If a geotextile sample fails to meet the MQC requirements of this Section the Geotextile Manufacturer shall additionally sample and test, at the expense of the Manufacturer, rolls manufactured in the same lot, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established to define the bounds of the failed roll(s). All the rolls pertaining to the failed rolls shall be rejected.

E. Additional sample testing may be performed, at the Geotextile Manufacturer's discretion and expense, to identify more closely the extent of non-complying rolls and/or to qualify individual rolls.

F. Sampling shall, in general, be performed on sacrificial portions of the geotextile material such that repair is not required. The Geotextile Manufacturer shall sample and test the geotextile to demonstrate that the geotextile properties conform to the values specified in Table 02771-1.

1. At a minimum, the following MQC tests shall be performed on the geotextile (results of which shall meet the requirements specified in Table 02271):

Test	Procedure	Frequency
Grab strength	ASTM D 4632	130,000 ft^2
Mass per Unit Area	ASTM D 5261	130,000 ft^2
Tear strength	ASTM D 4533	130,000 ft^2
Puncture strength	ASTM D 4833	130,000 ft^2
Permittivity	ASTM D 4491	540,000 ft^2
A.O.S.	ASTM D 4751	540,000 ft^2

G. The Geotextile Manufacturer shall comply with the certification and submittal requirements of this Section.

2.03 INTERFACE SHEAR TESTING

A. Interface shear test(s) shall be performed on the proposed geosynthetic components in accordance with Section 02270, Part 2.03.A

2.04 PACKING AND LABELING

A. Geotextile shall be supplied in rolls wrapped in relatively impervious and opaque protective covers.

B. Geotextile rolls shall be marked or tagged with the following information:

1. manufacturer's name;
2. product identification;
3. lot or batch number;
4. roll number; and
5. roll dimensions.

2.05 TRANSPORTATION, HANDLING, AND STORAGE

A. The Geosynthetic Manufacturer shall be liable for any damage to the geotextile incurred prior to and during transportation to the site.

B. The geotextile shall be delivered to the site at least 14 days prior to the planned deployment date to allow the CQA Consultant adequate time to perform conformance testing on the geotextile samples as described in Subpart 3.06 of this Section.

C. Handling, unloading, storage, and care of the geotextile at the site, prior to and following installation, are the responsibility of the Contractor. The Contractor shall be liable for any damage to the materials incurred prior to final acceptance by the Owner.

D. The Contractor shall be responsible for offloading and storage of the geotextile at the site.

E. The geotextile shall be protected from sunlight, puncture, or other damaging or deleterious conditions. The geotextile shall be protected from mud, dirt, and dust. Any additional storage procedures required by the geotextile Manufacturer shall be the responsibility of the Contractor.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work described in this Section, the Contractor shall become thoroughly familiar with the site, the site conditions, and all portions of the work falling within this Section.

B. If the Contractor has any concerns regarding the installed work of other Sections or the site, the Construction Manager shall be notified, in writing, prior to commencing the work. Failure to notify the Construction Manager or commencing installation of the geotextile will be construed as Contractor's acceptance of the related work of all other Sections.

3.02 PLACEMENT

A. Geotextile installation shall not commence over other materials until CQA conformance evaluations, by the CQA Consultant, of underlying materials are complete, including evaluations of the Contractor's survey results to confirm that the previous work was constructed to the required grades, elevations, and thicknesses. Should the Contractor begin the work of this Section prior to the completion of CQA evaluations for underlying materials or this material, this shall be at the risk of removal of these materials, at the Contractor’s expense, to remedy the non-conformances. The Contractor shall account for the CQA conformance evaluations in the construction schedule.

B. The Contractor shall handle all geotextile in such a manner as to ensure it is not damaged in any way.

C. The Contractor shall take any necessary precautions to prevent damage to underlying materials during placement of the geotextile.

D. After unwrapping the cushion geotextile from its opaque cover, the geotextile shall not be left exposed for a period in excess of 15 days unless a longer exposure period is approved in writing by the Geotextile Manufacturer.

E. The Contractor shall take care not to entrap stones, excessive dust, or moisture in the geotextile during placement.

F. The Contractor shall anchor or weight all geotextile with sandbags, or the equivalent, to prevent wind uplift.

G. The Contractor shall examine the entire geotextile surface after installation to ensure that no foreign objects are present that may damage the geotextile or adjacent layers. The Contractor shall remove any such foreign objects and shall replace any damaged geotextile.

3.03 SEAMS AND OVERLAPS

A. On slopes steeper than 10 horizontal to 1 vertical, geotextiles shall be continuous down the slope; that is, no horizontal seams are allowed. Horizontal seams shall be considered as any seam having an alignment exceeding 45 degrees from being perpendicular to the slope contour lines, unless otherwise approved by the Design Engineer. No horizontal seams shall be allowed within 5 feet of the top or toe of the slopes.

B. Nonwoven geotextile seams shall be overlapped and continuously sewn. Thread shall by polymeric with chemical and ultraviolet resistance properties equal or exceeding those of the geotextile.

C. Woven geotextile shall be overlapped and continuously sewn.

3.04 REPAIR

A. Any holes or tears in the geotextile shall be repaired using a patch made from the same geotextile. If a tear exceeds 50 percent of the width of a roll, that roll shall be removed and replaced.

3.05 PLACEMENT OF SOIL MATERIALS

A. The Contractor shall place soil materials on top of the geotextile in such a manner as to ensure that:

1. the geotextile and the underlying materials are not damaged;
2. minimum slippage occurs between the geotextile and the underlying layers during placement; and
3. excess stresses are not produced in the geotextile.

B. Equipment shall not be driven directly on the geotextile.

3.06 CONFORMANCE TESTING

A. Conformance samples of the geotextile materials will be removed by the CQA Site Manager after the material has been received at the site and sent to a Geosynthetic CQA Laboratory for testing to ensure conformance with the requirements of this Section and the CQA Plan. This testing will be carried out, in accordance with the CQA Plan, prior to the start of the work of this Section.

B. Samples of each geotextile will be taken, by the CQA Site Manager, at a minimum frequency of one sample per 260,000 square feet (minimum of one).

C. The CQA Consultant may increase the frequency of sampling in the event that test results do not comply with requirements of Subpart 2.01 of this Section until passing conformance test results are obtained for all material that is received at the site. This additional testing shall be performed at the expense of the Contractor.

D. The following conformance tests will be performed (results of which shall meet the requirements specified in Table 02771):

Test	Cushion Geotextile Procedure	Woven Geotextile Procedure
Grab strength	ASTM D 4632	ASTM D 4632
Mass per Unit Area	ASTM D 5261	N/A
Puncture strength	ASTM D 4833	ASTM D 4833

Test	Cushion Geotextile Procedure	Woven Geotextile Procedure
Permittivity	ASTM D 4491	ASTM D 4491
A.O.S.	ASTM D 4751	ASTM D 4751

E. Any geotextile that is not certified in accordance with Subpart 1.04 of this Section, or that conformance testing results do not comply with Subpart 2.01 of this Section, will be rejected. The Contractor shall replace the rejected material with new material. All other rolls that are represented by failing test results will also be rejected, unless additional testing is performed to further determine the bounds of the failed material.

3.07 PROTECTION OF WORK

A. The Contractor shall protect all work of this Section.

B. In the event of damage, the Contractor shall make repairs and replacements to the satisfaction of the Construction Manager at the expense of the Contractor.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for Geotextile will be incidental to PVC Pipe, and payment will be based on the unit price provided for PVC Pipe on the Bid Schedule.

B. The following are considered incidental to the work:

- Submittals.
- Quality Control.
- Shipping, handling, and storage.
- Layout survey.
- Mobilization.
- Rejected material.
- Overlaps and seaming.
- Rejected material removal, handling, re-testing, and repair.
- Temporary anchorage.

TABLE 02771-1
REQUIRED PROPERTY VALUES FOR GEOTEXTILE

PROPERTIES	QUALIFIERS	UNITS	NONWOVEN CUSHION GEOTEXTILE SPECIFIED VALUES	WOVEN GEOTEXTILE SPECIFIED VALUES	TEST METHOD
Physical Properties					
Mass per unit area	Minimum	oz/yd^2	16	N/A	ASTM D 5261
Apparent opening size (O_{95})	Maximum	mm	0.21	0.43	ASTM D 4751
Permittivity	Minimum	s^{-1}	0.5	0.05	ASTM D 4491
Grab strength	Minimum	lb	390	200	ASTM D 4632
Tear strength	Minimum	lb	150	N/A	ASTM D 4533
Puncture strength	Minimum	lb	1,120	700	ASTM D 6241
Ultraviolet Resistance @ 500 hours	Minimum	%	70	70	ASTM D 4355

[END OF SECTION]

SECTION 02772
GEOSYNTHETIC CLAY LINER (OPTION B ONLY)

PART 1 – GENERAL

1.01 SCOPE

A. The Geosynthetic Installer shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary for installation of the geosynthetic clay liner (GCL). The work shall be carried out as specified herein and in accordance with the Drawings and Construction Quality Assurance (CQA) Plan.

B. The work shall include, but not be limited to, delivery, offloading, storage, placement, anchorage, and seaming of the GCL.

1.02 RELATED SECTIONS

Section 02220 – Subgrade Preparation

Section 02770 – Geomembrane

1.03 REFERENCES

A. Drawings

B. Site CQA Plan

C. Latest Version American Society of Testing and Materials (ASTM) Standards:

ASTM D 5887	Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens using a Flexible Wall Permeameter
ASTM D 5888	Guide for Storage and Handling of Geosynthetic Clay Liners
ASTM D 5890	Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners
ASTM D 5891	Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners
ASTM D 5993	Test Method for Measuring Mass per Unit Area of Geosynthetic Clay Liners

1.04 QUALIFICATIONS

A. GCL Manufacturer:

1. The Manufacturer shall be a well-established firm with more than five (5) years of experience in the manufacturing of GCL.

2. The GCL Manufacturer shall be responsible for the production of GCL rolls and shall have sufficient production capacity and qualified personnel to provide material meeting the requirements of this Section and the construction schedule for this project.

B. GCL Installer:

1. The Geosynthetic Installer shall install the GCL and shall meet the requirements of Section 02770 Subpart 1.04. B and this Section.

2. The Geosynthetics Installer shall be responsible and shall provide sufficient resources for field handling, deploying, temporarily restraining (against wind), and other aspects of the deployment and installation of the GCL and other geosynthetic components of the project.

1.05 SUBMITTALS

A. At least 7 days before transporting any GCL to the site, the Manufacturer shall provide the following documentation to the Construction Manager for approval.

1. list of material properties, including test methods utilized to analyze/confirm properties.

2. projected delivery dates for this project.

3. Manufacturing quality control certificates for each shift's production for which GCL for the project was produced, signed by responsible parties employed by the Manufacturer (such as the production manager).

4. Manufacturer Quality Control (MQC) certificates, including:

a. roll numbers and identification; and

b. MQC results, including description of test methods used, outlined in Subpart 2.02 of this Section.

5. Certification that the GCL meets all the properties outlined in Subpart 2.01 of this Section.

B. During installation, the Geosynthetic Installer shall be responsible for the timely submission to the Construction Manager of:

1. Quality control documentation; and

2. Subgrade Acceptance Certificates, signed by the Geosynthetic Installer, for each area of subgrade to be covered by geosynthetic clay liner.

1.06 CONSTRUCTION QUALITY ASSURANCE (CQA) MONITORING

A. The Geosynthetic Installer shall be aware of all monitoring and conformance testing required by the CQA Plan. This monitoring and testing, including random conformance testing of construction materials and completed work, will be performed by the CQA Consultant. If nonconformances or other deficiencies are found in the materials or completed work, the Geosynthetic Installer will be required to repair the deficiency or replace the deficient materials at no additional cost to the Owner.

PART 2 – PRODUCTS

2.01 MATERIAL PROPERTIES

A. The flux of the bentonite portion of the GCL shall be no greater than 1×10^{-8} m^3/m^2-sec, when measured in a flexible wall permeameter in accordance with ASTM D 5887 under an effective confining stress of 5 pounds per square inch (psi).

B. The GCL shall have the following minimum dimensions:

1. the minimum roll width shall be 15 feet; and

2. the linear length shall be long enough to conform with the requirements specified in this Section.

C. The bentonite component of the GCL shall be applied at a minimum concentration of 0.75 pound per square foot (psf), when measured at a water content of 0 percent.

D. The GCL shall meet or exceed all required property values listed in Table 02772-1.

E. The bentonite will be adhered to the backing material(s) in a manner that prevents it from being dislodged when transported, handled, and installed in a manner prescribed by the Manufacturer. The method used to hold the bentonite in place shall not be detrimental to other components of the lining system.

F. The geotextile components of the GCL shall be woven and nonwoven and have a combined mass per unit area of 9 ounces per square yard (oz./SY).

G. The GCL shall be needle punched.

2.02 INTERFACE SHEAR TESTING

A. Interface shear testing requirements and results shall be in accordance with Section 02770 2.03A.

2.03 MANUFACTURING QUALITY CONTROL (MQC)

A. The GCL shall be manufactured with quality control procedures that meet or exceed generally accepted industry standards.

B. The Manufacturer shall sample and test the GCL to demonstrate that the material complies with the requirements of this Section.

C. Any GCL sample that does not comply with this Section will result in rejection of the roll from which the sample was obtained. The Manufacturer shall replace any rejected rolls.

D. If a GCL sample fails to meet the quality control requirements of this Section, the Construction Manager will require that the Manufacturer sample and test, at the expense of the Manufacturer, rolls manufactured in the same lot, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established to determine the bounds of the failed roll(s). All rolls pertaining to failed tests shall be rejected.

E. Additional sample testing may be performed, at the Manufacturer's discretion and expense, to more closely identify the extent of any non-complying rolls and/or to qualify individual rolls.

F. Sampling shall, in general, be performed on sacrificial portions of the GCL material such that repair is not required. The Manufacturer shall sample and test the GCL to demonstrate that its properties conform to the requirements stated herein. At a minimum, the following (MQC) tests shall be performed by the Manufacturer: dry mass per unit area (ASTM D5993) and index flux at frequencies of at least one per 50,000 square feet and one per 200,000 square feet, respectively.

G. The Manufacturer shall comply with the certification and submittal requirements of this Section.

2.04 PACKING AND LABELING

A. GCL shall be supplied in rolls wrapped in impervious and opaque protective covers.

B. GCL shall be marked or tagged with the following information:

1. Manufacturer's name;
2. product identification;
3. lot number;
4. roll number; and
5. roll dimensions.

2.05 TRANSPORTATION, HANDLING AND STORAGE

A. The Geosynthetic Manufacturer shall be liable for any damage to the GCL incurred prior to and during transportation to the site.

B. Handling, storage, and care of the GCL at the site prior to and following installation, are the responsibility of the Geosynthetic Installer, until final acceptance by the Owner.

C. The GCL shall be stored and handled in accordance with ASTM D 5888.

D. The Geosynthetic Installer shall be liable for all damage to the materials incurred prior to and during transportation to the site including hydration of the GCL prior to placement.

E. The GCL shall be on-site at least 14 days prior to the scheduled installation date to allow for completion of conformance testing described in Subpart 3.07 of this Section.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work described in this Section, the Geosynthetic Installer shall carefully inspect the installed work of all other Sections and verify that all work is complete to the point where the installation of this Section may properly commence without adverse impact.

B. If the Geosynthetic Installer has any concerns regarding the installed work of other Sections, he should notify the Construction Manager in writing prior to commencing the work. Failure to notify the Construction Manager or commencing installation of the GCL will be construed as Geosynthetic Installer's acceptance of the related work of all other Sections.

C. A pre-installation meeting shall be held to coordinate the installation of the GCL with the installation of other components of the lining system.

3.02 SURFACE PREPARATION

A. The Geosynthetics Installer shall provide certification in writing that the surface on which the GCL will be installed is acceptable. This certification of acceptance shall be given to the Construction Manager prior to commencement of geosynthetics installation in the area under consideration. Special care shall be taken to maintain the prepared soil surface.

B. Special care shall be taken to maintain the prepared soil surface. The subgrade shall be moisture conditioned prior to installation of the GCL. GCL subgrade shall be moisture conditioned the day before installation such that the surface is workable but not dry to a depth of more than 1 inch from subgrade surface.

C. No GCL shall be placed onto an area that has been softened by precipitation or that has cracked due to desiccation. The soil surface shall be observed daily to evaluate the effects of desiccation cracking and/or softening on the integrity of the prepared subgrade.

D. Subgrade protrusions shall not exceed 0.7 inch.

3.03 HANDLING AND PLACEMENT

A. The Geosynthetic Installer shall handle all GCL in such a manner that it is not damaged in any way.

B. In the presence of wind, all GCL shall be sufficiently weighted with sandbags to prevent their movement.

C. Any GCL damaged by stones or other foreign objects, or by installation activities, shall be repaired in accordance with Subpart 3.06 by the Geosynthetic Installer, at the expense of the Geosynthetic Installer.

D. All GCL shall be hydrated by the Geosynthetic Installer once in place by direct spraying with water. Hydrated GCL shall be defined as greater than 50% moisture content when tested in accordance with ASTM D 2216. To monitor the hydration process, small, shallow, flat bottom containers shall be deployed on the GCL surface by the CQA Site Manager during water spraying to measure the amount (depth) of water applied. Minimum depth of water will be 1/8-inch. During hot, dry periods, additional water may be required. Upon completion of the direct spraying with water, the GCL shall be covered with the overlying secondary geomembrane within 2 hours. Samples of the hydrated GCL will be obtained by the CQA Site Manager from locations of destructive tests in the secondary geomembrane. GCL sample holes shall be repaired in accordance with Part 3.06 of this Section.

E. The GCL shall be installed with the woven geotextile facing up (against the overlying geomembrane).

3.04 OVERLAPS

A. On slopes steeper than 10:1 (horizontal:vertical), all GCL shall be continuous down the slope, i.e., no horizontal seams shall be allowed on the slope. Horizontal seams shall be considered as any seam having an alignment exceeding 30 degrees from being perpendicular to the slope contour lines, unless otherwise approved by the Construction Manager.

B. All GCL shall be overlapped in accordance with the Manufacturer's recommended procedures. At a minimum, along the length (i.e., the sides) of the GCL placed on slopes steeper than 10:1 (horizontal:vertical), the overlap shall be 12 inches, and along the width (i.e., the ends) the overlap shall be 24 inches.

C. At a minimum, along the length (i.e., the sides) of the GCL placed on non-sloped areas (i.e. slopes no steeper than 10:1), the overlap shall be 6-inches, and along the width (i.e., the ends) the overlap shall be 12-inches.

3.05 MATERIALS IN CONTACT WITH THE GCL

A. Installation of other components of the liner system shall be carefully performed to avoid damage to the GCL.

B. Construction Manager approved low ground pressure equipment may be driven directly on the GCL.

C. Installation of the GCL in appurtenant areas, and connection of the GCL to appurtenances shall be made according to the Drawings. The Geosynthetic Installer shall ensure that the GCL is not damaged while working around the appurtenances.

3.06 REPAIR

A. Any holes or tears in the GCL shall be repaired by placing a GCL patch over the defect. On slopes steeper than 10 percent, the patch shall overlap the edges of the hole or tear by a minimum of 2 feet in all directions. On slopes 10 percent or flatter, the patch shall overlap the edges of the hole or tear by a minimum of 1 foot in all directions. The patch shall be secured with a Manufacturer recommended water-based adhesive.

B. Care shall be taken to remove any soil, rock, or other materials, which may have penetrated the torn GCL.

C. The patch shall not be nailed or stapled.

3.07 CONFORMANCE TESTING

A. Samples of the GCL will be removed by the CQA Site Manager and sent to a Geosynthetic CQA Laboratory for testing to ensure conformance with the requirements of this Section and the CQA Plan. The Geosynthetic Installer shall assist the CQA Site Manager in obtaining conformance samples. The Geosynthetic Installer shall account for this testing in the installation schedule.

B. At a minimum, the following conformance tests will be performed at a minimum frequency rate of one sample per 100,000 square feet: mass per unit area (ASTM D 5993) and bentonite moisture content (ASTM D 5993). At a minimum, the following conformance tests will be performed at a frequency of one sample per 400,000 square feet: index flux (ASTM D 5887). If the GCL Manufacturer provides material that requires sampling at a frequency (due to lot size, shipment size, etc.) resulting in one sample per less than 90 percent of 100,000 square feet (90,000 square feet), then the Geosynthetic Installer shall pay the cost for all additional testing.

C. The CQA Consultant may increase the frequency of sampling in the event that test results do not comply with the requirements of Subpart 2.01 of this Section until passing conformance test results are obtained for all material that is received at the site. This additional testing shall be performed at the expense of the Geosynthetic Installer.

D. Any GCL that is not certified by the Manufacturer in accordance with Subpart 1.05 of this Section or that does not meet the requirements specified in Subpart 2.01 shall be rejected and replaced by the Geosynthetic Installer, at the expense of the Geosynthetic Installer.

3.08 PROTECTION OF WORK

A. The Geosynthetic Installer shall protect all work of this Section.

B. In the event of damage, the Geosynthetic Installer shall immediately make all repairs and replacements necessary to the approval of the Construction Manager, at the expense of the Geosynthetic Installer.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for GCL will be measured as in-place square feet (SF), as measured by the surveyor, to the limits shown on the Drawings, and payment will be based on the unit price provided on the Bid Schedule.

B. The following are considered incidental to the Work:

- Submittals.
- Quality Control.
- Shipping, handling and storage.
- Overlaps and seaming.
- Hydration.
- Layout survey.
- Mobilization.
- Rejected material.
- Rejected material removal, handling, re-testing, and repair.
- Overlaps and seaming.
- Temporary anchorage.
- Visqueen.

TABLE 02772-1
REQUIRED GCL PROPERTY VALUES

PROPERTIES	QUALIFIERS	UNITS	SPECIFIEDVALUES	TEST METHOD
GCL Properties				
Bentonite Content[2]	minimum	lb/ft^3	0.75	ASTM D 5993
Bentonite Swell Index	minimum	mL/2g	24	ASTM D 5890
Bentonite Fluid Loss	maximum	mL	18	ASTM D 5891
Hydraulic Index Flux	maximum	m^3/m^2-s	1×10^{-8}	ASTM D 5887[1]

Notes: (1) Hydraulic flux testing shall be performed under an effective confining stress of 5 pounds per square inch.
(2) Measured at a moisture content of 0 percent; also known as mass per unit area

[END OF SECTION]

SECTION 02773

GEONET

PART 1 – GENERAL

1.01 SCOPE

A. The Geosynthetic Installer shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary for installation of the geonet. The work shall be carried out as specified herein and in accordance with the Drawings and Construction Quality Assurance (CQA) Plan.

B. The work shall include, but not be limited to, delivery, offloading, storage, placement, anchorage, and seaming of the geonet.

C. 300-mil geonet shall be installed above the secondary geomembrane to form the primary leak detection system. 200-mil geonet shall be installed overlying the butt seams of the tertiary Drain Liner™ geomembrane, if applicable.

1.02 RELATED SECTIONS

Section 02220 – Subgrade Preparation

Section 02225 – Drainage Aggregate

Section 02616 – Polyvinyl Chloride (PVC) Pipe

Section 02770 – Geomembrane

Section 02771 – Geotextile

1.03 REFERENCES

A. Drawings

B. Site CQA Plan

C. Latest Version ASTM International (ASTM) Standards:

ASTM D792	Standard Test Methods for Specific Gravity and Density of Plastics by Displacement
ASTM D1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique
ASTM D1603	Standard Test Method for Carbon Black in Olefin Plastics
ASTM D4218	Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by Muffle-Furnace Technique
ASTM D4716	Standard Test Method for Constant Head Hydraulic Transmissivity (In-Place Flow) of Geotextiles and Geotextile Related Products
ASTM D5199	Standard Test Method for Measuring Nominal Thickness of Geosynthetics

1.04 QUALIFICATIONS

A. Geonet Manufacturer:

1. The Manufacturer shall be a well-established firm with more than five (5) years of experience in the manufacturing of geonet.

2. The Manufacturer shall be responsible for the production of geonet rolls and shall have sufficient production capacity and qualified personnel to provide material meeting the requirements of this Section and the construction schedule for this project.

B. Geonet Installer:

1. The Geosynthetic Installer shall meet the requirements of Subpart 1.04. B of Section 02770, and this Section.

2. The Geosynthetics Installer shall be responsible and shall provide sufficient resources for field handling, deploying, temporarily restraining (against wind and re-curling), and other aspects of the deployment and installation of the geonet and other geosynthetic components of the project.

1.05 SUBMITTALS

A. At least 7 days before transporting any geonet to the site, the Manufacturer shall provide the following documentation to the Construction Manager for approval.

1. list of material properties, including test methods utilized to analyze/confirm properties.

2. projected delivery dates for this project.

3. Manufacturing Quality Control (MQC) certificates for each shift's production for which geonet for the project was produced, signed by responsible parties employed by the Manufacturer (such as the production manager). MQC certificates shall include:

a. roll numbers and identification; and

b. MQC results, including description of test methods used, outlined in Subpart 2.01 of this Section.

c. Certification that the geonet meets all the properties outlined in Subpart 2.01 of this Section.

1.06 CONSTRUCTION QUALITY ASSURANCE (CQA)

A. The Geosynthetic Installer shall ensure that the materials and methods used for producing and handling the geonet meet the requirements of the Drawings and this Section. Any material or method that does not conform to these documents, or to alternatives approved in writing by the Design Engineer, will be rejected and shall be repaired or replaced, at the Geosynthetic Installer’s expense.

B. The Geosynthetic Installer shall be aware of all monitoring and conformance testing required by the CQA Plan. This monitoring and testing, including random conformance testing of construction materials and completed work, will be performed by the CQA Consultant. If nonconformances or other deficiencies are found in the materials or completed work, the Geosynthetic Installer will be required to repair the deficiency or replace the deficient materials at no additional cost to the Owner.

PART 2 – PRODUCTS

2.01 GEONET PROPERTIES

A. The Manufacturer shall furnish geonet having properties that comply with the required property values shown on Table 02773-1.

B. In addition to documentation of the property values listed in Table 02773-1, the geonet shall contain a maximum of one percent by weight of additives, fillers, or extenders (not including carbon black) and shall not contain foaming agents or voids within the ribs of the geonet.

2.02 MANUFACTURING QUALITY CONTROL (MQC)

A. The geonet shall be manufactured with MQC procedures that meet or exceed generally accepted industry standards.

B. Any geonet sample that does not comply with the Specifications will result in rejection of the roll from which the sample was obtained. The Geonet Manufacturer shall replace any rejected rolls at no additional cost to Owner.

C. If a geonet sample fails to meet the MQC requirements of this Section, then the Geonet Manufacturer shall sample and test each roll manufactured, in the same lot, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established.

D. Additional sample testing may be performed, at the Geonet Manufacturer's discretion and expense, to more closely identify any non-complying rolls and/or to qualify individual rolls.

E. Sampling shall, in general, be performed on sacrificial portions of the geonet material such that repair is not required. The Manufacturer shall sample and test the geonet, at a minimum, once every 100,000 square feet to demonstrate that its properties conform to the values specified in Table 02773-1.

F. At a minimum, the following MQC tests shall be performed:

Test	Procedure
Density	ASTM D 792 or D 1505
Thickness	ASTM D 5199
Carbon Black Content	ASTM D 1603

G. The hydraulic transmissivity test (ASTM D 4716) in Table 02773-1 need not be performed at a frequency of one per 100,000 square feet. However, the Geonet Manufacturer will certify that this test has been performed on a sample of geonet identical to the product that will be delivered to the Site. The Geonet Manufacturer shall provide test results as part of MQC documentation.

H. The Geonet Manufacturer shall comply with the certification and submittal requirements of this Section.

2.03 LABELING

A. Geonet shall be supplied in rolls labeled with the following information:

1. manufacturer's name;
2. product identification;
3. lot number;
4. roll number; and
5. roll dimensions.

2.04 TRANSPORTATION

A. Transportation of the geonet shall be the responsibility of the Geonet Manufacturer. The Geonet Manufacturer shall be liable for all damages to the materials incurred prior to and during transportation to the site.

B. Geonet shall be delivered to the site at least 7 days before the scheduled date of deployment to allow the CQA Site Manager adequate time to inventory the geonet rolls and obtain additional conformance samples, if needed. The Geosynthetic Installer shall notify the Construction Manager a minimum of 48 hours prior to any delivery.

2.05 HANDLING AND STORAGE

A. The Geosynthetic Manufacturer shall be responsible for handling, off-loading, storage, and care of the geonet prior to and following installation at the Site. The Geosynthetic Installer shall be liable for all damages to the materials incurred prior to final acceptance of the geonet drainage layer by the Owner.

B. The geonet shall be stored off the ground and out of direct sunlight, and shall be protected from mud and dirt. The Geosynthetic Installer shall be responsible for implementing any additional storage procedures required by the Geonet Manufacturer.

2.06 CONFORMANCE TESTING

A. Conformance testing, if required, shall be performed in accordance with the CQA Plan. The Geosynthetics installer shall assist the CQA Site Manager in obtaining conformance samples, if requested. The CQA Consultant has the option of collecting samples at the manufacturing facility.

B. Passing conformance testing results, if applicable, are required before any geonet is deployed.

C. Samples shall be taken at a minimum frequency of one sample per 200,000 square feet with a minimum of one sample per lot. If the Geonet Manufacturer provides material that requires sampling at a frequency (due to lot size, shipment size, etc.) resulting in one sample per less than 90 percent of 200,000 square feet (180,000 square feet), then the Geosynthetic Installer shall pay the cost for all additional testing.

D. The CQA Consultant may increase the frequency of sampling in the event that test results do not comply with the requirements of Subpart 2.01 of this Section until passing conformance test results are obtained for all material that is received at the Site. This additional testing shall be performed at the expense of the Geosynthetic Installer.

E. Any geonet that are not certified in accordance with Subpart 1.05 of this Section, or that conformance testing indicates do not comply with Subpart 2.01 of this Section, will be rejected by the CQA Consultant. The Geonet Manufacturer shall replace the rejected material with new material at no additional cost to the Owner.

PART 3 – EXECUTION

3.01 HANDLING AND PLACEMENT

A. The geonet shall be handled in such a manner as to ensure it is not damaged in any way.

B. Precautions shall be taken to prevent damage to underlying layers during placement of the geonet.

C. The geonet shall be installed in a manner that minimizes wrinkles.

D. Care shall be taken during placement of geonet to prevent dirt or excessive dust in the geonet that could cause clogging and/or damage to the adjacent materials.

3.02 JOINING AND TYING

A. Adjacent panels of geonet shall be overlapped by at least 4 inches. These overlaps shall be secured by tying with nylon ties.

B. Tying shall be achieved by plastic fasteners or polymer braid. Tying devices shall be white or yellow for easy inspection. Metallic devices shall not be used.

C. Tying shall be performed at a minimum interval of every 5 feet along the geonet roll edges and 2 feet along the geonet roll ends.

3.03 REPAIR

A. Any holes or tears in the geonet shall be repaired by placing a patch extending 1 foot beyond the edges of the hole or tear. The patch shall be secured to the original geonet by tying every 6 inches with approved tying devices. If the hole or tear width across the roll is more than 50 percent of the width of the roll, then the damaged area shall be cut out and the two portions of the geonet shall be joined in accordance with the requirements of Subpart 3.02 of this Section.

3.04 PRODUCT PROTECTION

A. The Geosynthetics Installer shall use all means necessary to protect all prior work, and all materials and completed work of other Sections.

B. In the event of damage to the geonet, the Geosynthetic Installer shall immediately make all repairs per the requirements of this Section.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for geonet will be measured as in-place square feet (SF), as measured by the surveyor, to the limits shown on the Drawings, and payment will be based on the unit price provided on the Bid Schedule.

B. The following are considered incidental to the Work:

- Submittals.
- Quality Control.
- Shipping, handling, and storage.
- Overlaps and seaming.
- Layout survey.
- Offloading.
- Mobilization.
- Rejected material.

- Rejected material removal, handling, re-testing, and repair.
- Temporary anchorage.

TABLE 02773-1
REQUIRED GEONET PROPERTY VALUES

PROPERTIES	QUALIFIERS	UNITS	300-MIL GEONET SPECIFIED(1) VALUES	200-MIL GEONET SPECIFIED(1) VALUES	TEST METHOD
Resin Density	Minimum	g/cc	0.94	0.94	ASTM D792 or D1505
Carbon Black Content	Range	%	2.0 – 3.0	2.0 – 3.0	ASTM D1603 or D4218
Thickness	Minimum	mils	300	200	ASTM D5199
Transmissivity(2)	Minimum	m^2 / sec	8×10^{-3}	1×10^{-3}	ASTM D4716

Notes: (1) All values (except transmissivity) represent average roll values.
(2) Transmissivity shall be measured using water at 68°F with a gradient of 0.1 under a confining pressure of 7,000 lb/ft^2. The geonet shall be placed in the testing device between 60-mil HDPE smooth geomembrane. Measurements are taken one hour after application of confining pressure.
(3) Interface shear strength testing shall be performed, by the CQA Consultant, in accordance with Part 2.03 of this Section.

[END OF SECTION]

SECTION 03400

CAST-IN-PLACE CONCRETE

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, transportation and equipment necessary to construct a cast-in-place spillway crossing as shown on the Drawings and as specified herein.

B. The Work shall include, but not be limited to, procurement, delivery, subgrade preparation, formwork, concrete placement, control joints, surface treatment, and curing.

1.02 RELATED SECTIONS

None.

1.03 REFERENCES

A. Drawings

B. Construction Quality Assurance (CQA) Plan

C. Latest version of American Concrete Institute (ACI) standards:

ACI 117	Tolerances for Concrete Construction and Materials
ACI 211.1	Selecting Proportions for Normal, Heavyweight, and Mass Concrete
ACI 301	Structural Concrete for Buildings
ACI 304R	Measuring, Mixing, Transporting, and Placing Concrete
ACI 308	Standard Practice for Curing Concrete
ACI 318	Building Code Requirements for Reinforced Concrete
ACI 347R	Formwork for Concrete

D. Latest version of the ASTM International (ASTM) standards:

ASTM A 615	Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
ASTM C 33	Concrete Aggregates
ASTM C 39	Compressive Strength of Cylindrical Concrete Specimens
ASTM C 94	Ready- Mixed Concrete
ASTM C 127	Specific Gravity and Adsorption of Coarse Aggregate
ASTM C 128	Specific Gravity and Adsorption of Fine Aggregate
ASTM C 143	Slump of Hydraulic Cement Concrete
ASTM C 150	Portland Cement

ASTM C 171	Sheet Materials for Curing Concrete
ASTM C 192	Making and Curing Concrete Test Specimens in the Laboratory
ASTM C 309	Liquid Membrane - Forming Compounds for Curing Concrete
ASTM C 403	Time of Setting of Concrete Mixtures by Penetration Resistance
ASTM C 494	Chemical Admixtures for Concrete
ASTM C 618	Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete

1.04 SUBMITTALS

A. At least 7 days prior to construction of the concrete, Contractor shall submit a mix design for the type of concrete. Submit a complete list of materials including types, brands, sources, amount of cement, fly ash, pozzolans, retardants, and admixtures, and applicable reference specifications for the following:

1. Slump design based on total gallons of water per cubic yard.

2. Type and quantity of cement.

3. Brand, type, ASTM designation, active chemical ingredients, and quantity of each admixture.

4. Compressive strength based on 28-day compression tests.

B. Delivery Tickets:

1. Provide duplicate delivery tickets with each load of concrete delivered, one for Contractor's records and one for the Construction Manager, with the following information:

a. Date and serial number of ticket.
b. Name of ready-mixed concrete plant, operator, and job location.
c. Type of cement, admixtures, if any, and brand name.
d. Cement content, in bags per cubic yard (CY) of concrete, and mix design.
e. Truck number, time loaded, and name of dispatcher.
f. Amount of concrete (CY) in load delivered.
g. Gallons of water added at job, if any, and slump of concrete after water was added.

C. Delivery

1. The Concrete Manufacturer shall be liable for all damage to the materials incurred prior to and during transportation to the Site.

1.05 MANUFACTURER QUALITY CONTROL (MQC)

A. Aggregates shall be sampled and tested in accordance with ASTM C 33.

B. Concrete test specimens shall be made, cured, and stored in conformity with ASTM C 192 and tested in conformity with ASTM C 39.

C. Slump shall be determined in accordance with ASTM C 143.

1.06 LIMITING REQUIREMENTS

A. Unless otherwise specified, each concrete mix shall be designed and concrete shall be controlled within the following limits:

1. Concrete slump shall be kept as low as possible, consistent with proper handling and thorough compaction. Unless otherwise authorized by the Construction Manager, slump shall not exceed 5 inches.

2. The admixture content, batching method, and time of introduction to the mix shall be in accordance with the manufacturer's recommendations for minimum shrinkage and for compliance with this Section. A water-reducing admixture may be included in concrete.

PART 2 – PRODUCTS

2.01 PROPORTIONING AND DESIGN MIXES

A. Concrete shall have the following properties.

1. 3,000 pounds per square inch (psi), 28-day compressive strength.

2. Slump range of 1 to 5 inches.

3. Coarse Aggregate Gradation, ASTM C 33, Number 57 or 67.

B. Retarding admixture in proportions recommended by the manufacturer to attain additional working and setting time from 1 to 5 hours.

2.02 CONCRETE MATERIALS

A. Cement shall conform to ASTM C 150 Type II.

B. Water shall be fresh and clean, free from oils, acids, alkalis, salts, organic materials, and other substances deleterious to concrete.

C. Aggregates shall conform to ASTM C 33. Aggregates shall not contain any substance which may be deleteriously reactive with the alkalis in the cement, and shall not possess properties or constituents that are known to have specific unfavorable effects in concrete.

D. The Contractor may use a water reducing chemical admixture. The water reducing admixture shall conform to ASTM C 494, Type A. The chemical admixture shall be approved by the Construction Manager.

2.03 REINFORCING STEEL

A. The reinforcing steel shall be Grade 60 in accordance with ASTM A 615.

B. Unless otherwise noted on the Drawings, all reinforcement bars shall be No. 3 (3/8-inch diameter) in accordance with ASTM A 615 and welded wire fabric shall be sized as 6 x 6, W1.4 x W1.4.

PART 3 – EXECUTION

3.01 BATCHING, MIXING, AND TRANSPORTING CONCRETE

A. Batching shall be performed according to ASTM C 94, ACI 301, and ACI 304R, except as modified herein. Batching equipment shall be such that the concrete ingredients are consistently measured within the following tolerances: 1 percent for cement and water, 2 percent for aggregate, and 3 percent for admixtures. Concrete Manufacturer shall furnish mandatory batch ticket information for each load of ready mix concrete.

B. Machine mixing shall be performed according to ASTM C 94 and ACI 301. Mixing shall begin within 30 minutes after the cement has been added to the aggregates. Concrete shall be placed within 90 minutes of either addition of mixing water to cement and aggregates or addition of cement to aggregates. Additional water may be added, provided that both the specified maximum slump and water-cement ratio are not exceeded. When additional water is added, an additional 30 revolutions of the mixer at mixing speed is required. Dissolve admixtures in the mixing water and mix in the drum to uniformly distribute the admixture throughout the batch.

C. Transport concrete from the mixer to the forms as rapidly as practicable. Prevent segregation or loss of ingredients. Clean transporting equipment thoroughly before each batch. Do not use aluminum pipe or chutes. Remove concrete which has segregated in transporting and dispose of as directed.

3.02 SUBGRADE PREPARATION

A. Subgrade shall be graded to the lines and elevations as shown on the Drawings.

B. Standing water, mud, debris, and foreign matter shall be removed before concrete is placed.

3.03 PLACING CONCRETE

A. Place concrete in accordance with ACI 301, ACI 318, and ACI 304R. Place concrete as soon as practicable after the forms and the reinforcement have been approved by the CQA Site Manager. Do not place concrete when weather conditions prevent proper placement and consolidation, in uncovered areas during periods of precipitation, or in standing water. Prior to placing concrete, remove dirt, construction debris, water, snow, and ice from within the forms. Deposit concrete as close as practicable to the final position in the forms. Place concrete in one continuous operation from one end of the structure towards the other

B. Ensure reinforcement is not disturbed during concrete placement.

C. Do not allow concrete temperature to decrease below 50 °F while curing. Cover concrete and provide sufficient heat to maintain 50 °F minimum adjacent to both the formwork and the structure while curing. Limit the rate of cooling to 5 °F in any 1 hour and 50 °F per 24 hours after heat application.

D. Do not spread concrete with vibrators. Concrete shall be placed in final position without being moved laterally more than 5 feet.

E. When placing of concrete is temporarily halted or delayed, provide construction joints.

F. Concrete shall not be dropped a distance greater than 5 feet.

G. Place concrete with aid of internal mechanical vibrator equipment capable of 9,000 cycles/minute. Transmit vibration directly to concrete.

H. Hot Weather:

1. Comply with ACI 304R.

2. Concrete temperature shall not exceed 90°F.

3. At air temperatures of 80°F or above, keep concrete as cool as possible during placement and curing. Cool forms by water wash.

4. Evaporation reducer shall be used in accordance with manufacturer recommendations (Subpart 2.02).

3.04 CURING AND PROTECTION

A. Immediately after placement, protect concrete from premature drying, excessively hot or cold temperatures, and mechanical injury in accordance with ACI 308.

B. Immediately after placement, protect concrete from plastic shrinkage by applying evaporation reducer in accordance with manufacturer recommendations (Subpart 2.02).

C. Maintain concrete with minimal moisture loss at relatively constant temperature for period necessary for hydration of cement and hardening of concrete (Subpart 2.02).

D. Protect from damaging mechanical disturbances, particularly load stresses, heavy shock, and excessive vibration.

E. Membrane curing compound shall be spray applied at a coverage of not more than 300 square feet per gallon. Unformed surfaces shall be covered with curing compound within 30 minutes after final finishing. If forms are removed before the end of the specified curing period, curing compound shall be immediately applied to the formed surfaces before they dry out.

F. Curing compound shall be suitably protected against abrasion during the curing period.

G. Film curing will not be allowed.

3.05 FORMS

A. Formwork shall prevent leakage of mortar and shall conform to the requirements of ACI 347R.

B. Do not disturb forms until concrete is adequately cured.

C. Form system design shall be the Contractor's responsibility.

3.06 CONTROL JOINTS

A. Control joints shall consist of plastic strips set flush with finished surface or ¼-inch wide joints formed with a trowel immediately after pouring or cut with a diamond saw within 12 hours after pouring.

B. Control joints shall be installed in a 15 foot by 15 foot grid spacing along the slab unless otherwise approved by the Design Engineer. Control joints shall be no greater than 1 ½ inches below the surface.

3.07 SLAB FINISHES

A. Unformed surfaces of concrete shall be screeded and given an initial float finish followed by additional floating, and troweling where required.

B. Concrete shall be broom finished.

3.08 SURVEY

A. The Surveyor shall locate the features of the concrete structure. The dimensions, locations and elevations of the features shall be presented on the Surveyor's Record Drawings.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for Cast-In-Place Concrete will be measured as lump sum (LS) and payment will be based on the unit price provided on the Bid Schedule.

B. The following are considered incidental to the work:

- Mobilization.
- Submittals.
- Quality Control.
- Excavation.
- Subgrade preparation.
- Concrete batching, mixing, and delivery.
- Layout and as-built Record Survey.
- Subgrade preparation.
- Reinforcing steel.
- Formwork.
- Concrete placement and finishing.
- Saw cutting and control joints.
- Rejected material removal, handling, re-testing, repair, and replacement.

[END OF SECTION]

APPENDIX D

Design Calculations

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF**	Project: **White Mesa Mill – Cells 5A-5B**	Project/ Proposal No.: Task No.	**SC0634**

Title of Computations **ACTION LEAKAGE RATE**

Computations by:	Signature	[signature]	12/18/12 Date
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	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature	[signature]	12/20/12 Date
	Printed Name	Keaton Botelho	
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Computations backchecked by: (originator)	Signature	[signature]	12/18/12 Date
	Printed Name	Rebecca Flynn	
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Approved by: (pm or designate)	Signature	[signature]	12/18/12 Date
	Printed Name	Gregory T. Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	12/09/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A & 5B	Project/ Proposal No.:	SC0634	Task No.:	

CALCULATION OF ACTION LEAKAGE RATE THROUGH THE LEAKAGE DETECTION SYSTEM UNDERLYING A GEOMEMBRANE LINER.

OBJECTIVE

In accordance with Part 254.302 of the USEPA Code of Federal Regulations, determine the action leakage rate (ALR) that a leak detection system (LDS) can remove, and not allow the maximum fluid head on the bottom liner to exceed 1 foot. The ALR shall be given as an average daily flow rate in gallons per day per acre for the sumps associated with the primary and secondary LDS. The calculation shall include a margin of safety sufficient to allow for design uncertainties, operational changes, and material characteristics.

On the cell floors, the triple liner systems for Cells 5A and 5B will be comprised of the following from top to bottom (Attachment A):

- Primary Liner: 60-mil smooth high density polyethylene (HDPE) geomembrane;
- 300-mil HDPE geonet;
- Secondary Liner: 60-mil HDPE geomembrane; and
- Tertiary Liner: 60-mil HDPE Drain Liner™ geomembrane with 130-mil asperities.

On the cell slopes, the triple liner systems for Cells 5A and 5B will be comprised of the following from top to bottom (Attachment A):

- Primary Liner: 60-mil smooth high density polyethylene (HDPE) geomembrane;
- Secondary Liner: 60-mil HDPE Drain Liner™ geomembrane with 130-mil asperities; and
- Tertiary Liner: 60-mil HDPE Drain Liner™ geomembrane with 130-mil asperities.

Cells 5A and 5B will have primary and secondary LDSs with surface areas of approximately 42 acres. On the cell floor, the primary LDS will consist of a 300-mil geonet above a 60-mil HDPE geomembrane while the secondary LDS will consist of a Drain Liner™ geomembrane. Both systems will include collection trenches that contain

4-inch diameter perforated PVC pipe, drainage aggregate, and a cushion geotextile (Attachment A). Pipes are spaced at the mid-points of the cells in the north-south and east-west directions, as well as the toes of the 2H:1V side slopes along the lowest portions of the cell floor. There is one sump associated with each LDS. On the slopes, the primary and secondary LDSs will consist of 130-mil Drain Liner™ geomembrane.

In order to evaluate flow through the LDS with geonet and Drain Liner™ deployed in any direction, the flow will be evaluated for the conservatively lowest possible drainage gradient which is the north-south direction. The drainage gradient is reduced in this scenario from 1.75% to 1.1% in Cell 5A and from 1.75% to 1.2% in Cell 5B. This ALR calculation evaluates the "worst-case scenario" of drainage assuming 1.1% slope in Cell 5A along a distance of 563 ft (Attachment B).

In addition, Drain Liner™ panels have smooth sides for seaming, while the ends of each panel will have the studs removed to allow seaming. As a result, flow is inhibited at the sides and ends of deployed panels. A 200-mil thick piece of geonet will be installed above the smooth seam at the butt-ends of the panels to allow liquid to drain along the length of each panel (machine direction) to the LDS collection trench. On the side seams, it is assumed no liquid will pass as there are no "studs" on the surface of the Drain Liner™ and the overlying geomembrane will immediately contact the underlying seam area thereby inhibiting flow (see Attachment A).

The method outlined by Giroud, et al. (1997) will be employed to calculate the ALR and confirm the maximum expected head for each collection layer (Attachment C).

PRIMARY LDS ANALYSIS

Liquid flow through defect in primary geomembrane

Liquid migration through a liner occurs essentially through defects in the geomembrane. According to Giroud, et al. (1997) (see Attachment C, 3/6) the rate of liquid migration through a defect in the geomembrane is given by the following:

$$Q = (2/3)d^2\sqrt{gh_{prim}} \qquad \text{Equation (1)}$$

where:

- Q = flow rate through one geomembrane defect, m^3/s
- d = defect diameter, m
- g = acceleration due to gravity, 9.81 m/sec^2
- h_{prim} = head of liquid on top of primary liner, m

According to the EPA, common practice is to assume that the diameter of a leak in the geomembrane is equal to the thickness of the geomembrane (i.e. 60 mil, 0.0015 m).

Cell Bottom

Based on the proposed grading for Cells 5A (Attachment B) and the operational constraint of maintaining 3 feet of freeboard within the cells, the height of the liquid on primary geomembrane along the critical flow path is 30 feet (9.1 m). Placing the above values into Equation 1 results in the following maximum flow rate per defect:

$$Q = \left(\frac{2}{3}\right)(0.0015m)^2\sqrt{(9.81\ \frac{m}{s^2})(9.1m)}$$

$$Q = 1.42 \text{ x } 10^{-5} \text{ m}^3/\text{sec}$$

$$= 1.23 \text{ m}^3/\text{day}$$

$$= 322 \text{ gal/day}$$

Side Slopes

Based on the proposed grading for Cells 5A and 5B (Attachment B) and the operational constraint of maintaining 3 feet of freeboard within the cells, the height of the liquid on primary geomembrane along the side slope critical flow path is 1 foot (0.3048 m). Placing the above values into Equation 1 results in the following maximum flow rate per defect:

$$Q = \left(\frac{2}{3}\right)(0.0015m)^2\sqrt{(9.81\ \frac{m}{s^2})(0.3048m)}$$

$$Q = 2.59\text{x}10^{-6} \text{ m}^3/\text{sec}$$

$$= 0.22 \text{ m}^3/\text{day}$$

$$= 59.2 \text{ gal/day}$$

Maximum flow rate on Secondary Geomembrane, Cell Bottom

According to Giroud, et al. (1997) (see Attachment C, p. 2/6) the maximum flow rate within the leak detection layer geonet is given by the following:

$Q_{full} = k\ t_{LCL}^2$ Equation (2)

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Where:

Q_{full} = maximum flow rate within the geonet *to be determined, m^3/sec*
k = hydraulic conductivity of geonet; *see below, m/sec*
t_{LCL} = thickness of leak detection layer; *300 mil, 0.0076 m*

Hydraulic conductivity of Cell Bottom Geonet, k

Attachment D shows a permeability curve for a 300 mil thick geonet with an HDPE geomembrane with a normal load of 10,000 psf. Based on the site grading (Attachment B), a maximum thickness of waste material (tailings/slimes) will result in the following normal stresses in Cells 5A and 5B:

Cell 5A	Cell 5B
Total Height of Material: 41 ft of tailings + 9 ft of cover	Total Height of Material: 43 ft of tailings + 9 ft of cover
Normal Stress: 50 ft x 125 lb/ft* = 6,250 pounds per square foot (psf)	Normal Stress: 52 ft x 125 lb/ft* = 6,500 pounds per square foot (psf)

*Assumed

Normal stresses of approximately 6,250 psf and 6,500 psf will be exerted on the geosynthetics in Cells 5A and 5B, respectively. The loading to be exerted on the deployed geonet is less than the 10,000 psf normal load during transmissivity testing; therefore, utilizing the results of transmissivity data is conservative for this loading condition.

Graphing the permeability data for the 300 mil geonet under a normal stress of approximately 10,000 psf (Attachment D), results in the following equation of the line:

$$k = 0.0854i^{-0.406} \qquad \text{Equation (3)}$$

This equation accounts for intrusion (RF_{IN}), creep (RF_{CR}), chemical clogging (RF_{CC}), and biological clogging (RF_{BC}), Koerner (Attachment E, 3/3) suggests the following partial factor of safety values for leak detection systems:

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RF_{IN}	1.5 to 2.0	use 1.0 (no geotextiles on either side to intrude, test data accounts for geomembrane intrusion)
RF_{CR}	1.4 to 2.0	use 1.2 (low normal stress)
RF_{CC}	1.5 to 2.0	use 2.0 (very low pH)
RF_{BC}	1.5 to 2.0	use 1.0 (very low pH should preclude biological activity)

The hydraulic gradient is based on the longest, critical drainage path (563 feet), slope of the geonet (1.1%), and height of liquid above the liner system at the deepest point along the flow path (5,585-5,555 = 30 feet, which accounts for the 3 foot freeboard, Attachment B). Based on this information, the hydraulic gradient can be estimated as follows:

$$i = (30 \text{ ft} + 563 \text{ ft} \times 0.011) / 563 \text{ ft} = 0.064$$

Placing the estimated hydraulic gradient of 0.064 into Equation 3 results in a hydraulic conductivity of 0.26 m/sec.

Placing the geonet hydraulic conductivity and thickness into Equation 2 results in the following:

$$Q_{liner} = (0.26 \text{ m/sec}) \times (0.0076 \text{ m})^2 = \mathbf{1.5 \times 10^{-5}\ m^3/sec > 1.42 \times 10^{-5}\ m^3/sec}$$

The flow through the geonet is greater than the flow through the defect; therefore, the geonet is appropriate as a leak detection layer on the cell bottom.

Maximum flow rate on Secondary Geomembrane, Side Slopes

According to Giroud, et al. (1997) (see Attachment C, p. 2/6) the maximum flow rate within the side slope leak detection layer Drain Liner™ is given by the following:

$$Q_{full} = k\, t_{LCL}^{2} \qquad \text{Equation (2)}$$

Where:

Q_{full} = maximum flow rate within the Drain Liner™ *to be determined, m³/sec*
k = hydraulic conductivity of Drain Liner™; *see below, m/sec*
t_{LCL} = thickness of leak detection layer; 130 *mil, 0.0033 m*

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Hydraulic conductivity of Side Slope Drain Liner™, k

Attachment F shows a hydraulic conductivity curve for a 130 mil thick Drain Liner™ geomembrane with an HDPE geomembrane under a normal load of 15,000 psf.

As calculated previously, normal stresses of 6,250 psf and 6,500 psf will be exerted on the Drain Liner™ geomembrane in Cells 5A and 5B, respectively; therefore, utilizing the hydraulic conductivity of the Drain Liner™ under a normal load of 15,000 psf is conservative.

Graphing the permeability data for the 130 mil thick Drain Liner™ under a normal stress of approximately 15,000 psf (Attachment F), results in the following equation of the line:

$$k = 0.2388i^{-0.413}$$ Equation (3)

This equation accounts for intrusion (RF_{IN}), creep (RF_{CR}), chemical clogging (RF_{CC}), and biological clogging (RF_{BC}), Koerner (Attachment E) suggests the following partial factor of safety values for leak detection systems:

RF_{IN}	1.5 to 2.0	use 1.0 (no geotextiles on either side to intrude, test data accounts for geomembrane intrusion)
RF_{CR}	1.4 to 2.0	use 1.2 (low normal stress)
RF_{CC}	1.5 to 2.0	use 2.0 (very low pH)
RF_{BC}	1.5 to 2.0	use 1.0 (very low pH should preclude biological activity)

The hydraulic gradient is based on the longest, critical drainage path (92 feet), slope of the Drain Liner™ (50%), and height of liquid above the liner system at the point furthest from the collection pipe, 1 ft (Attachment B). Based on this information, the hydraulic gradient can be estimated as follows:

$$i = (1 \text{ ft} + 92 \text{ ft} \times 0.50) / 92 \text{ ft} = 0.511$$

Placing the estimated hydraulic gradient of 0.511 into Equation 3 results in a hydraulic conductivity of 0.32m/sec.

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Placing the Drain Liner™ hydraulic conductivity and thickness into Equation 2 results in the following:

$Q_{liner} = (0.32 \text{ m/sec}) \times (0.0033 \text{ m})^2 = \mathbf{3.4 \times 10^{-6}\ m^3/sec} > \mathbf{2.59 \times 10^{-6}\ m^3/sec}$

The flow through the Drain Liner™ is greater than the flow through the defect; therefore, the Drain Liner™ is appropriate as a leak detection layer on the side slopes.

Action Leakage Rate (ALR)

The number of defects in a geomembrane is given by Giroud, et al (Attachment C, 4/6), as the following:

$$N = (F)(A_{LCL}) \qquad \text{Equation (4)}$$

where:

- N = number of defects
- F = frequency of defects (per m^2 of geomembrane)
- A_{LCL} = area of leakage collection layer; *42 acres, 169,970 m^2*

Using an assumed F = 1/2,500 m^2 (Attachment A, 4/6), the number of defects assumed in the primary geomembrane is as follows:

$$N = \frac{1 \text{ defect}}{2{,}500 \text{ m}^2} \times (169{,}970\text{m}^2) = 68 \text{ (rounded up to nearest whole number)}$$

$$\text{ALR} = (Q)(N)/\text{acre}$$

$$= \frac{(1.23\text{m}^3/\text{day})(68)}{42 \text{ acres}} = 1.99 \text{ m}^3/\text{day/acre}$$

$$= \mathbf{526\ gal/day/acre}$$

Q = flow through defect on the cell bottom, 1.23 m^3/day, *conservatively high for entire cell since side slopes defects flows are lower.*

Both Cells 5A and 5B are the same size, 42 acres; therefore, the ALR of 526 gal/day/acre is valid for both cells.

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Maximum flow rate to sump

Based on the area of the liner systems, the following maximum flow rate to the sump is anticipated:

Q_{sump} = (526 gal/day/acre) (42 acres) = 22,100 gal/day = 15.3 gpm

A sump pump capable of a minimum flow rate of 20 gallons per minute at the head conditions present (approximately 46 vertical feet plus piping losses [Cell 5B conditions, conservative for Cell 5A], Attachment B) will be utilized to remove liquids from the LDS.

Time of travel

According to Giroud, et al. (1997) (see Attachment C, 6/6) the travel time for the liquid to reach the LDS piping system from the defect in the primary geomembrane is given by the following:

$$t_{travel} = (nx) / (k \sin\beta \cos\beta)$$

The time of travel is evaluated for the worst-case scenario, when the Cell 5A liner system is deployed in north-south orientation and assuming the longest drainage path to the sump (1050 ft, 320m); actual deployment direction will be determined by the Contractor.

$$t_{travel} = (nx) / (k \sin\beta \cos\beta)$$

where:

t_{travel} = time for liquid to travel from defect in primary geomembrane to the LDS piping; *to be determined, sec*

n = porosity of geonet, 0.8

x = maximum distance from defect in primary geomembrane to LDS piping; 1050 *ft, 320 m*

k = hydraulic conductivity of the geonet; *0.26 m/sec from above*

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β = slope of floor; *1.1%, 0.011 radians*

t_{travel} = (0.80) (320m) / (0.26 m/sec) (sin 0.011) (cos 0.011)
= 89,521 sec
= **24.9 hours**

Therefore, the leak detection system geonet will allow for timely detection of liquids.

Head Above Secondary Liner, Cell Bottom (h):

Knowing the maximum potential flow rate through a specific defect in the primary geomembrane, and assuming a worst case condition where the liner defect is located at the higher end of the leakage collection layer slope, liquid head build-up on the secondary geomembrane is calculated using the following equation from Giroud, et al. (1997) (see Attachment A, 5/6):

$$t_{avgworst} = \frac{NQ}{kiB} \qquad \text{Equation (6)}$$

where:

$t_{avg\ worst}$ = average thickness of liquid above secondary (bottom) geomembrane under worst case scenario; *to be determined, m*
N = total number of defects in primary geomembrane; *68*
Q = flow rate through one defect in primary geomembrane; *1.42×10^{-5} m³/sec*
k = hydraulic conductivity of geonet; *0.26 m/sec from above*
i = hydraulic gradient in leakage collection layer; *0.064 from above*
B = width of leakage collection layer; *563 feet, 172 m (Attachment B)*

Placing the estimated geonet hydraulic conductivity, average thickness of liquid in the LDS, and the thickness of the leak detection layer geonet into Equation 6 results in the following:

$$t_{avgworst} = \frac{(68)(1.42x10^{-5})}{(2.6x10^{-1}\,\text{m/sec})(0.064)(172\text{m})} \qquad t_{avgworst} = 0.00034\ \text{m} = 0.34\ \text{mm}$$

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The head on the secondary does not exceed 0.34 mm (13.4 mil), much less than the 300 mil geonet thickness.

Head Above Secondary Liner, Side Slope Drain Liner™ (h):

The head above the liner is evaluated to determine if the side slope liner system is flowing full. In this evaluation, the 22 ft wide Drain Liner™ strip is evaluated for Cell 5A. This results in a drainage area of 2,992 sf (assuming a panel length equivalent to the slope length, 136 ft, and a panel width of 22 ft). Using the same defect evaluation identified for the ALR calculation, this would result in no more than 1 defects per strip.

Knowing the maximum potential flow rate through a specific defect in the primary geomembrane, and assuming a worst case condition where the 1 primary liner defect is located at the higher end of the leakage collection layer slope, liquid head build-up on the secondary geomembrane is calculated using the following equation from Giroud, et al. (1997) (see Attachment C, 5/6):

$$t_{avgworst} = \frac{NQ}{kiB} \qquad \text{Equation (6)}$$

where:

$t_{avg\ worst}$	= average thickness of liquid above secondary (bottom) geomembrane under worst case scenario; *to be determined, m*
N	= total number of defects in primary geomembrane; *1*
Q	= flow rate through one defect in primary geomembrane; *2.59×10^{-6} m³/sec*
k	= hydraulic conductivity of primary Drain Liner™ geomembrane; *0.32m/sec from above*
i	= hydraulic gradient in leakage collection layer; *0.511 from above*
B	= width of leakage collection layer; *22 feet, 6.7 m (Attachment A)*

Placing the estimated Drain Liner™ hydraulic conductivity, average thickness of liquid in the LDS, and the thickness of the leak detection layer Drain Liner™ into Equation 6 results in the following:

$$t_{avgworst} = \frac{(1)(2.59x10^{-6})}{(0.32m/sec)(0.511)(6.7m)} \qquad t_{avgworst} = 2.36x10^{-6}\ m = 0.0024\ mm$$

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The head on the secondary liner does not exceed 0.0024 mm (0.09 mil), much less than the 130-mil Drain Liner™ asperity height; therefore, the assumption that the drainage collection layer is not flowing full is valid.

SECONDARY LDS ANALYSIS

Liquid flow through defect in secondary geomembrane

Using Equation 1, defined previously, the rate of liquid migration through a defect in the secondary geomembrane is given by the following:

$$Q = (2/3)d^2\sqrt{gh_{prim}} \qquad \text{Equation (1)}$$

where:

- Q = flow rate through one geomembrane defect, m^3/s
- d = defect diameter, m
- g = acceleration due to gravity, 9.81 m/sec^2
- h_{prim} = head of liquid on top of primary liner, m

Based on the thickness of the primary leak detection, 300-mil, the head on the secondary liner will not be greater than 300-mil. Because this condition is the same for both Cells bottoms and conservative for cell side slopes, this evaluation is only performed once. Placing this value into Equation 1 results in the following maximum flow rate per defect:

$$Q = \left(\frac{2}{3}\right)(0.0015m)^2\sqrt{(9.81\ \frac{m}{s^2})(7.6 \times 10^{-3}m)}$$

$$Q = 4.10 \text{ x } 10^{-7}\ m^3/sec$$

$$= 3.5x10^{-2}\ m^3/day$$

$$= 9.25 \text{ gal/day}$$

Maximum flow rate on Drain Liner™

According to Giroud, et al. (1997) (see Attachment C, p. 2/6) the maximum flow rate within the leak detection layer Drain Liner™ is given by the following:

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$Q_{full} = k\ t_{LCL}^{2}$ Equation (2)

Where:

Q_{full} = maximum flow rate within the Drain Liner™; *to be determined, m^3/sec*
k = hydraulic conductivity of Drain Liner™; *see below, m/sec*
t_{LCL} = thickness of leak detection layer; *130 mil, 0.0033 m*

Hydraulic conductivity of Drain Liner™, k

The hydraulic conductivity of the Drain Liner™ was evaluated under a normal load of 15,000 psf for the primary side slope LDS. The following equation was identified for determining the hydraulic conductivity based on the gradient with appropriate factors of safety.

$k = 0.2388 i^{-0.413}$ Equation (3)

Similar to the primary leak detection system analysis, the hydraulic gradient is based on the longest, critical drainage path (563 feet), slope of the geonet (1.1%), and height of liquid above the liner system at the deepest point along the flow path based on the geonet thickness, 300 mil (Attachment B). Based on this information, the hydraulic gradient can be estimated as follows:

$i = (0.025 \text{ ft} + 563 \text{ ft} \times 0.011) / 563 \text{ ft} = 0.011$

Placing the estimated hydraulic gradient of 0.011 into Equation 3 results in a hydraulic conductivity of 1.54 m/sec.

Placing the Drain Liner™ hydraulic conductivity and thickness into Equation 2 results in the following:

$\mathbf{Q_{liner}} = (1.54 \text{ m/sec}) \times (0.0033 \text{ m})^2 = \mathbf{1.68 \times 10^{-5}\ m^3/sec}$

Action Leakage Rate (ALR)

The number of defects in a geomembrane is given by Giroud, et al (Attachment C), as the following:

$N = (F)(A_{LCL})$ Equation (4)

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where:

N = number of defects
F = frequency of defects (per m^2 of geomembrane)
A_{LCL} = area of leakage collection layer; *42 acres, 169,970 m^2*

Using an assumed F = 1/2,500 m^2 (Attachment C, 4/6), the number of defects assumed in the primary geomembrane is as follows:

$$N = \frac{1 \text{ defect}}{2{,}500 \text{ m}^2} \times (169{,}970 \text{m}^2) = 68 \text{ (rounded up to nearest whole number)}$$

ALR = $(Q)(N)$/acre

$$= \frac{(3.5 \times 10^{-2})(68)}{42} = \frac{0.057 \frac{m^3}{day}}{acre}$$

= 15.1 gal/day/acre

Both Cells 5A and 5B are the same size, 42 acres; therefore, the ALR of 15.1 gal/day/acre is valid for both cells.

Maximum flow rate to sump

Based on the area of the liner systems, the following maximum flow rate to the sump is anticipated:

Q_{sump} = (15.1 gal/day/acre) (42 acres) = 634 gal/day = 0.44 gpm

A sump pump capable of a minimum flow rate of 1 gallon per minute at the head conditions present (approximately 46 vertical feet plus piping losses [Cell 5B conditions, conservative for Cell 5A], Attachment B) will be utilized to remove liquids from the LDS.

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Time of travel

According to Giroud, et al. (1997) (see Attachment C, 6/6) the travel time for the liquid to reach the LDS piping system from the defect in the secondary geomembrane is given by the following:

$$t_{travel} = (nx) / (k \sin \beta \cos \beta)$$

t_{travel} = (0.97) (320 m) / (1.54 m/sec) (sin 0.63) (cos 0.63)
= 18,332 sec
= **5.09 hours**

where:

t_{travel} = time for liquid to travel from defect in primary geomembrane to the LDS piping; *to be determined, sec*

n = porosity of Drain Liner™, 97% (Attachment G)

x = distance from defect in secondary geomembrane to LDS piping; *1050ft, 320 m* (Assumed worst-case if panels are oriented NE to SW)

k = hydraulic conductivity of the geonet; *1.54 m/sec from above*

β = slope of floor; *1.1%, 0.63 degrees, 0.011 radians*

Therefore, the leak detection system Drain Liner™ will allow for timely detection of liquids.

Head Above Tertiary Liner, (h):

Knowing the maximum potential flow rate through a specific defect in the primary geomembrane, and assuming a worst case condition where the 68 tertiary liner defects are located at the higher end of the leakage collection layer slope, liquid head build-up on the secondary geomembrane is calculated using the following equation from Giroud, et al. (1997) (see Attachment C, 5/6):

$$t_{avgworst} = \frac{NQ}{kiB} \qquad \text{Equation (6)}$$

where:

$t_{avg\ worst}$ = average thickness of liquid above secondary (bottom) geomembrane under worst case scenario; *to be determined, m*

N = total number of defects in primary geomembrane; *68*

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Q = flow rate through one defect in secondary geomembrane; *2.7 x 10^{-7} m^3/sec*
k = hydraulic conductivity of primary Drain Liner™ geomembrane; *1.54 m/sec from above*
i = hydraulic gradient in leakage collection layer; *0.011 from above*
B = width of leakage collection layer; *563 feet, 172 m (Attachment B)*

Placing the estimated Drain Liner™ hydraulic conductivity, average thickness of liquid in the LDS, and the thickness of the leak detection layer Drain Liner™ into Equation 6 results in the following:

$$t_{avgworst} = \frac{(68)(4.1x10^{-7})}{(1.54\text{m}/\text{sec})(0.011)(172\text{m})} \qquad t_{avgworst} = 9.57\text{x}10^{-6}\text{ m} = 0.0096\text{ mm}$$

The head on the secondary does not exceed 0.0096 mm (0.4 mil), much less than the 130-mil Drain Liner™ asperity height; therefore, the assumption that the drainage collection layer is not flowing full is valid.

SUMMARY AND CONCLUSIONS

- Using the method outlined by Giroud, et al. (1997), and an N = 68, the ALR was calculated to be 526 gal/day/acre for the primary LDS system and 15.1 gal/day/acre for the secondary LDS.
- Liquids entering the LDS layers will take approximately one day or less to travel from the leak to the LDS piping systems.
- Assuming worst case scenarios for the primary cell bottom, primary side slopes, and secondary cell bottoms, the liquid head on the secondary and tertiary liners do not exceed the thickness of the drainage collection layer.
- The Drain Liner™ and 300-mil Geonet provides sufficient flow rate to accommodate the ALR.

REFERENCES

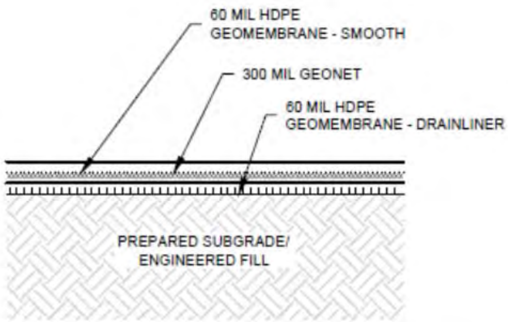
AGRU America, High Density Polyethylene Drain Liner™ Product Data, 2009 - 2011 *(Attachment F)*

Giroud, J.P., Gross, B.A., Bonaparte, R., and McKelvey, J.A. (1997), "Leachate Flow in Leakage Collection Layers Due to Defects in Geomembrane Liners," Geosynthetic International, Vol. 4, No. 3-4, pp. 215-292. *(Attachment C)*

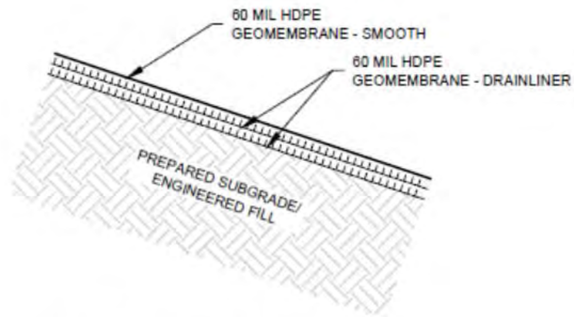
GSE, 2012. Drainage Design Manual. Available online at: www.gseworld.com *(Attachment D)*

Koerner, R. M., Designing with Geosynthetics, Prentice Hall, Upper Saddle River, NJ, 1998. *(Attachment E)*

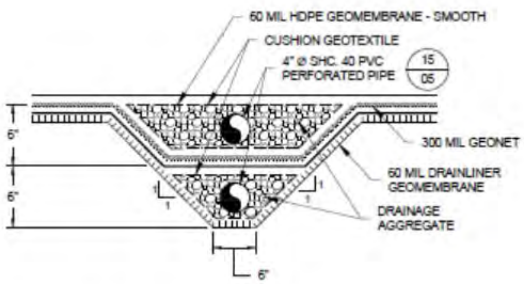
Attachment A – Liner System Details



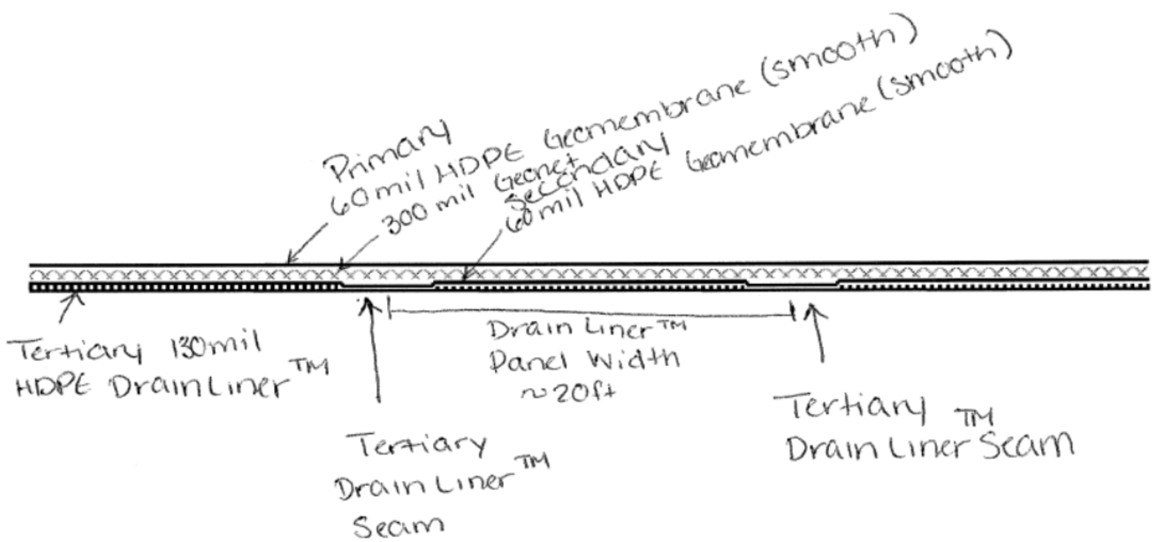
DETAIL
BASE LINER SYSTEM



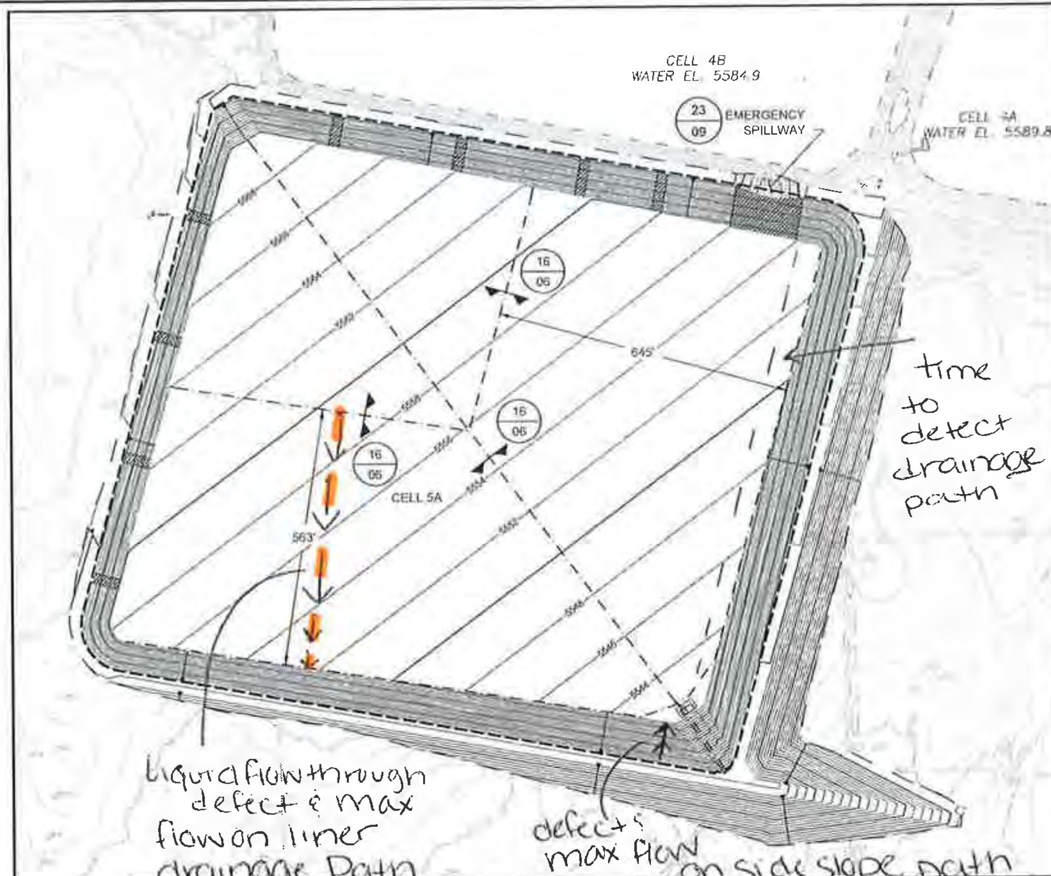
DETAIL
SIDE SLOPE LINER SYSTEM



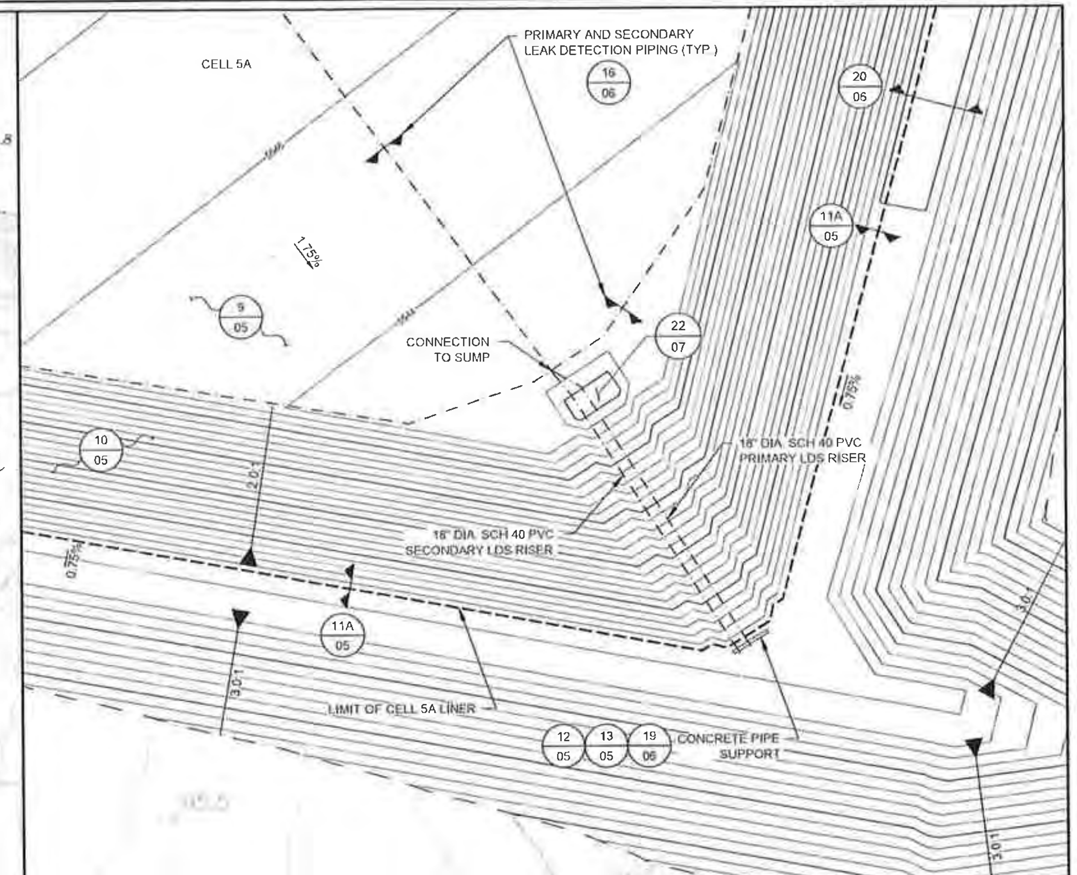
DETAIL
LEAK DETECTION SYSTEM TRENCHES



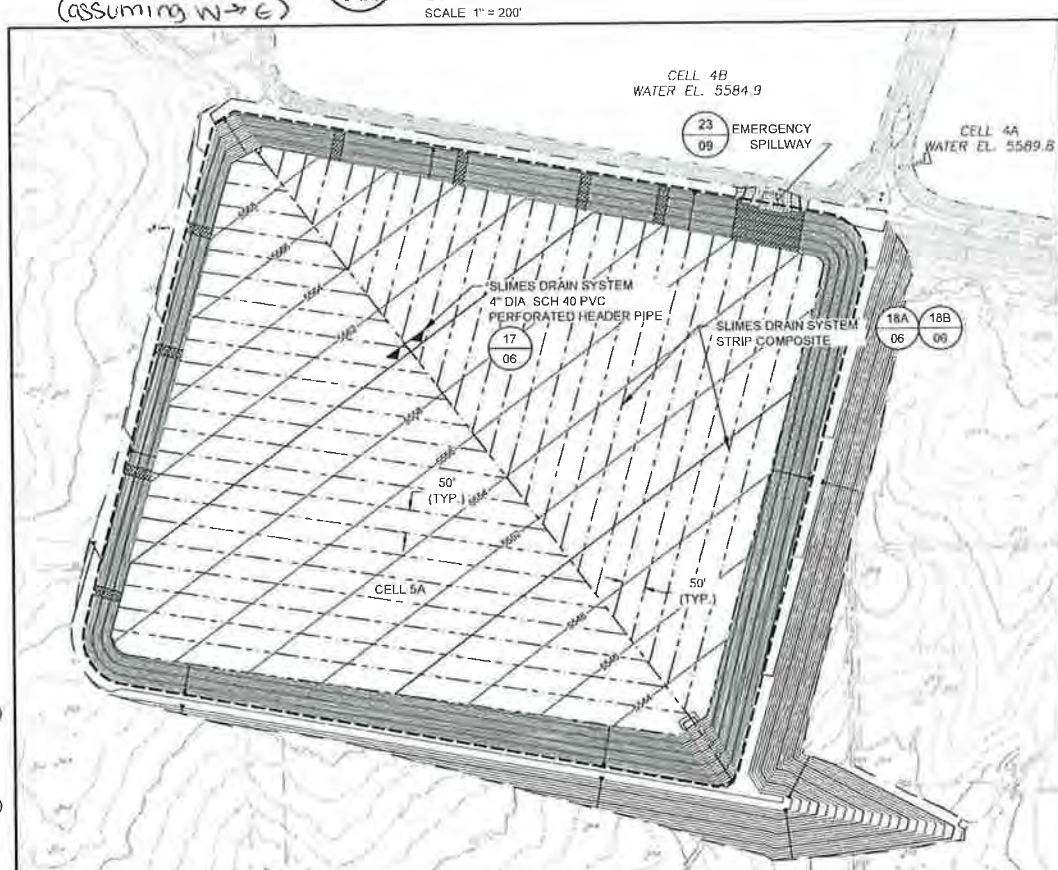
Detail
TERTIARY DRAIN LINER TM PANEL WIDTH



1 / 04A PLAN
CELL 5A LEAK DETECTION SYSTEM
SCALE 1" = 200'

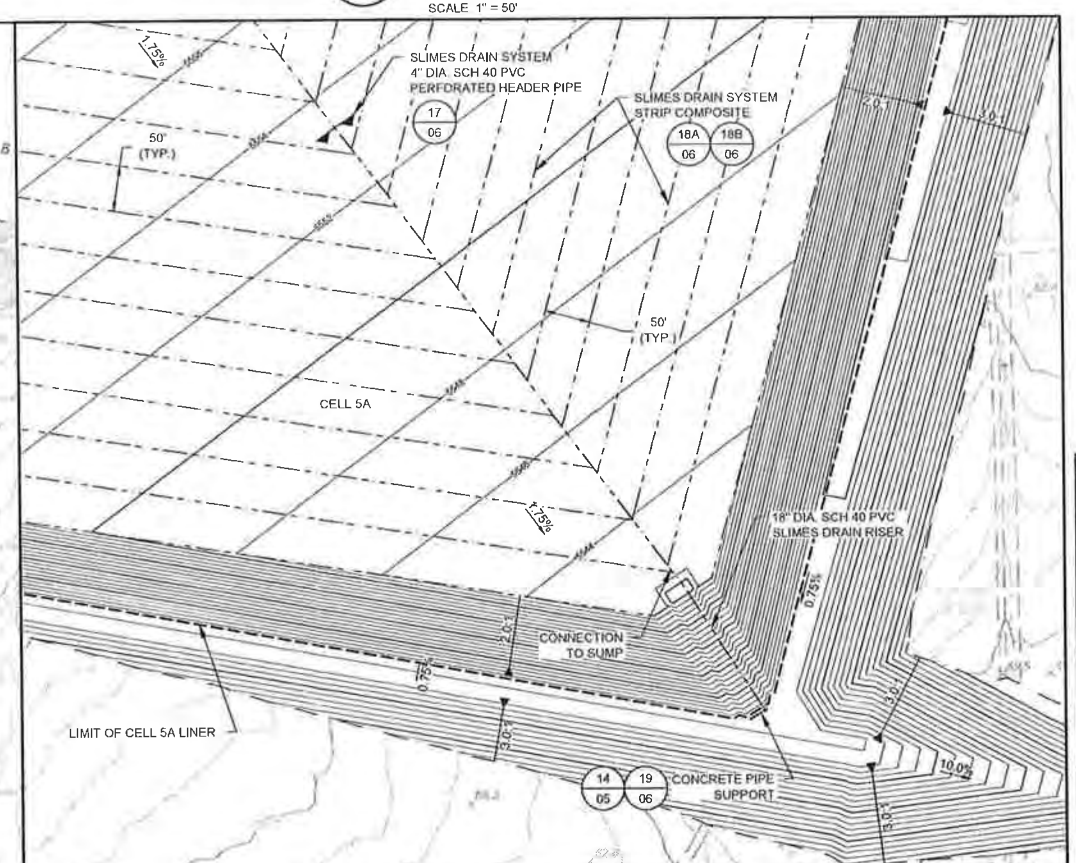


3 / 04A DETAIL
CELL 5A LEAK DETECTION SYSTEM
SCALE 1" = 50'



2 / 04A PLAN
CELL 5A SLIMES DRAIN SYSTEM
SCALE 1" = 200'

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



4 / 04A DETAIL
CELL 5A SLIMES DRAIN SYSTEM
SCALE 1" = 100'

LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- 5602 — PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- LIMIT OF LINER SYSTEM
- PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- SPLASH PAD (21/06)

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858.674.6559

EF Energy Fuels Resources (USA) Inc.

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5A

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL, BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION UNLESS SEALED

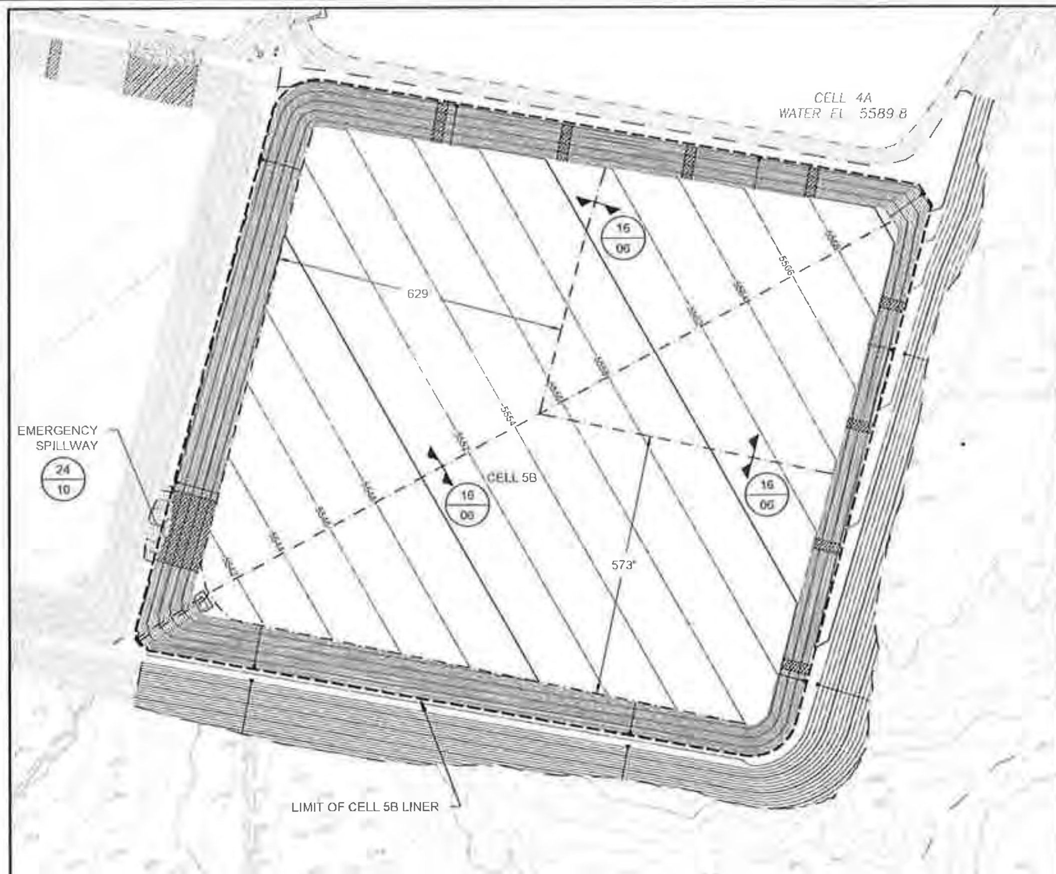
SIGNATURE

DATE

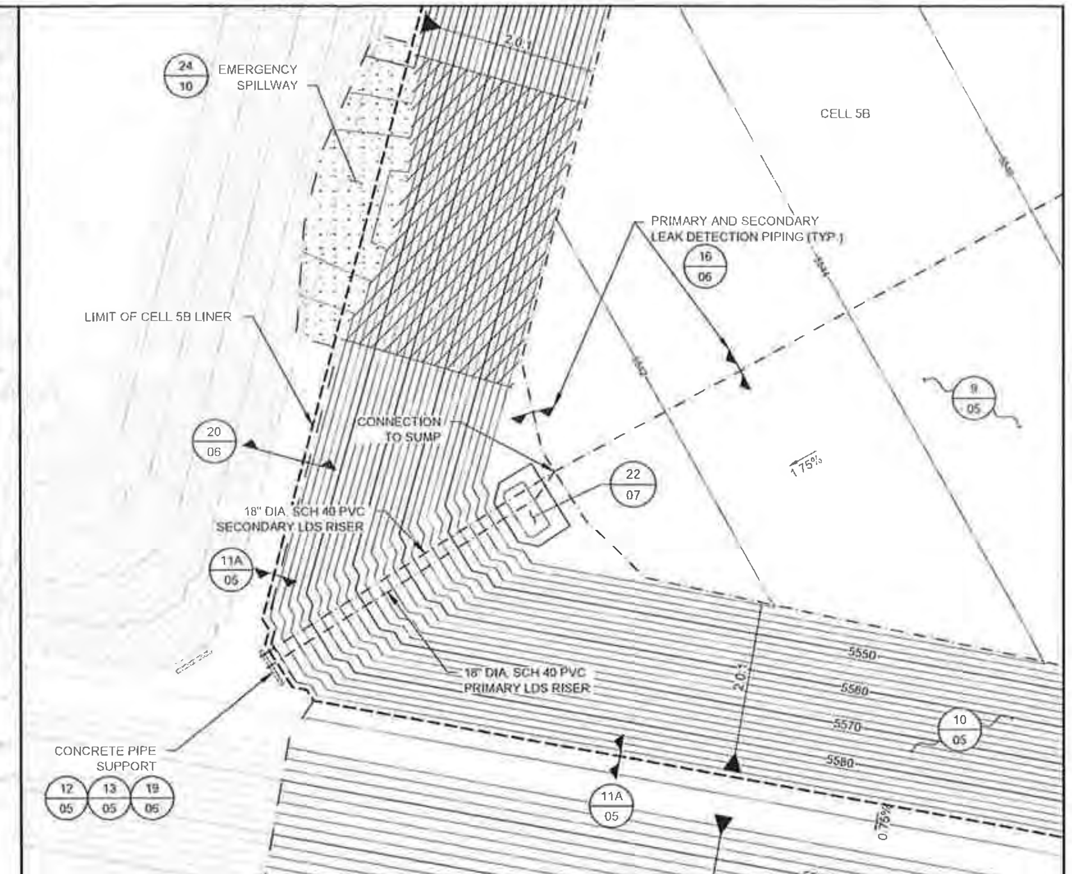
DESIGN BY:	GTC	DATE:	JANUARY 2013
DRAWN BY:	MMC	PROJECT NO.:	SC0634
CHECKED BY:	RBF	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	04A OF 12	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

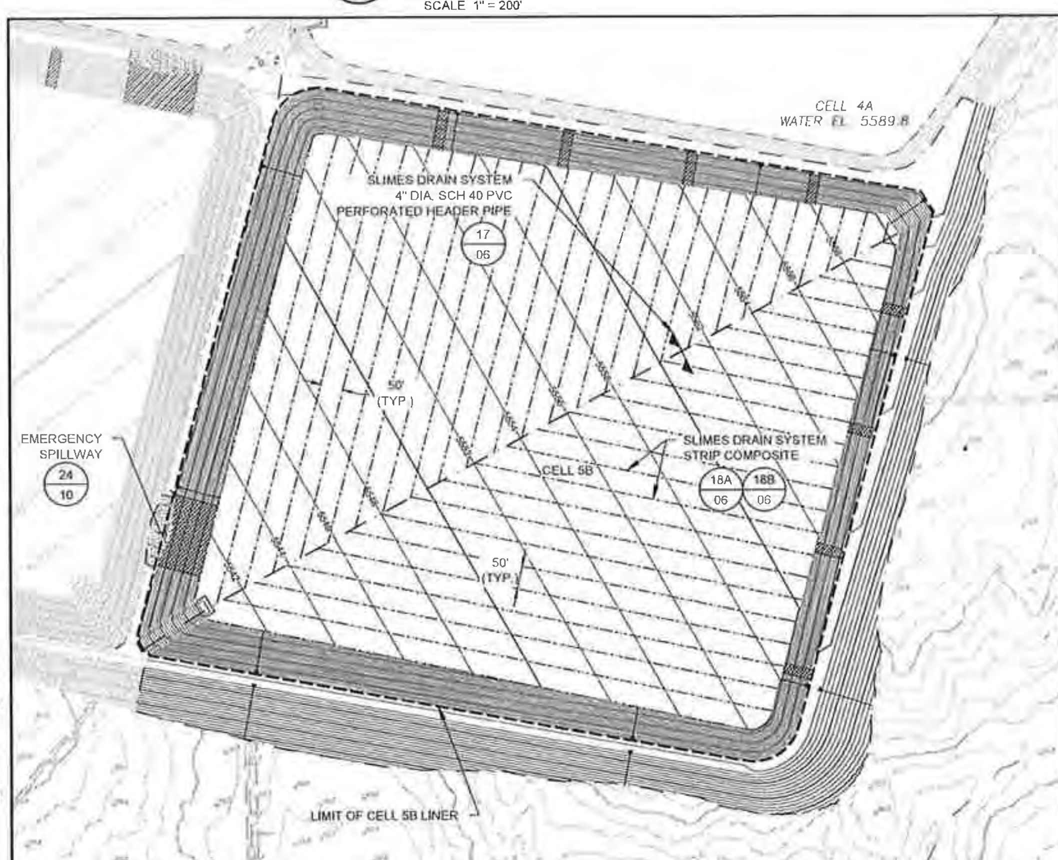
Attachment B(13)



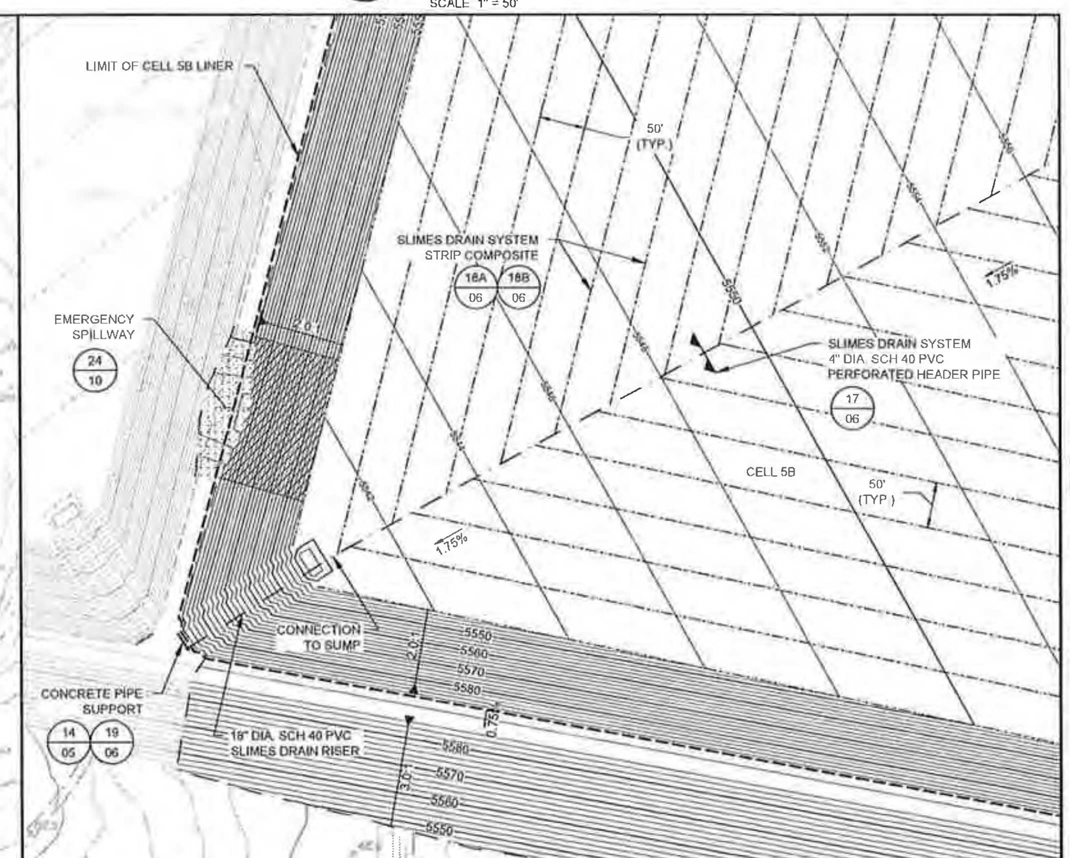
21 / 04B PLAN
CELL 5B LEAK DETECTION SYSTEM
SCALE 1" = 200'



6 / 04B DETAIL
CELL 5B LEAK DETECTION SYSTEM
SCALE 1" = 50'



7 / 04B PLAN
CELL 5B SLIMES DRAIN SYSTEM
SCALE 1" = 200'



8 / 04B DETAIL
CELL 5B SLIMES DRAIN SYSTEM
SCALE 1" = 100'

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

LEGEND

- JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- LIMIT OF LINER SYSTEM
- PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- SPLASH PAD 21/06

NOTES

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PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUTE 200
SAN DIEGO, CA 92127
PHONE 858 674 6559

Energy Fuels Resources (USA) Inc

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5B

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL, BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION UNLESS SEALED

SIGNATURE

DATE

DESIGN BY:	GTC	DATE:	JANUARY 2013
DRAWN BY	MMC	PROJECT NO.:	SC0634
CHECKED BY:	RBF	FILE:	SC0634 - 03A-04B
REVIEWED BY	GTC	DRAWING NO.:	04B OF 12
APPROVED BY:	GTC		

Attachment B (2/3)

Geosyntec consultants

Written by: J. GRIFFIN Date: 19/12/12 (DD MM YY) Reviewed by: G. CORCORAN Date: __/__/__ (DD MM YY)

Client: EF Project: CELLS 5A & 5B Project/Proposal No. SC0634 Task No. 02

FLOOR GRADE SLOPES: CELL 5A

NORTH - SOUTH

5559.25' - 5553' = 6.25'

$\frac{6.25'}{563'} = 0.011$

(0.011)(100) = **1.1 %**

EAST - WEST

5558.5' - 5549.75' = 8.75'

$\frac{8.75'}{645'} = 0.0135$

(0.0135)(100) = **1.35 %**

FLOOR GRADE SLOPES: CELL 5B

NORTH - SOUTH

5558.5 - 5551.5' = 7.0'

$\frac{7.0'}{573'} = 0.0122$

(0.0122)(100) = **1.2 %**

EAST - WEST

5557.5' - 5549' = 8.5'

$\frac{8.5'}{629} = 0.0135$

(0.0135)(100) = **1.4 %**

ATTACHMENT B (3/3)

vledge the support of GeoSyntec Consultants for the preparation of and express my gratitude to its Chief Executive Officer and Presi-, and its Principals, T.R. Sanglerat, J.F. Beech, R.C. Bachus, T.N. a, R.J. Dunn, E. Kavazanjian and D.M. Hendron. I also want to say of this issue would not have been possible without the contribution T.D. King, from Tesoro Petroleum Company, and the others from tants: K. Badu-Tweneboah (2 papers), R. Bonaparte, B.A. Gross, T. Khire (3 papers), J.A. McKelvey (3 papers), N.S. Rad, T.R. Sang-erman (3 papers). It is certainly very rewarding for me to work with is caliber. Finally, I am grateful to S.L. Berdy who produced the ex- K. Holcomb who ensured flawless word processing, with the help N. Pierce for several of the papers. I also want to acknowledge the e by the unknown soldiers of *Geosynthetics International*, the anon-who reviewed the papers and provided so many valuable comments. I express my gratitude to T.S. Ingold, Editor, and R.J. Bathurst, Co-etics International for giving me the opportunity of grouping these same issue published as a Special Issue, and to K. Labinaz, Produc-synthetics International, who provided two rounds of editing, with , to ensure not only the correctness of each paper, but, also, the con-cial Issue.

J.P.G.

Technical Paper by J.P. Giroud, B.A. Gross, R. Bonaparte and J.A. McKelvey

Leachate Flow in Leakage Collection Layers Due to Defects in Geomembrane Liners

ABSTRACT: This paper provides analytical and graphical solutions related to the flow of leachate in a leakage collection layer due to defects in the overlying liner (i.e. the primary liner of a double liner system). The defects are assumed to be small (e.g. holes in geomembrane liners). It is shown that leachate flows in a zone of the leakage collection layer (the wetted zone) that is limited by a parabola. A simple relationship is established between the rate of leachate migration through the defect and the maximum thickness of leachate in the leakage collection layer; this relationship depends on the hydraulic conductivity (but not on the slope) of the leakage collection layer. Equations are provided to calculate the average head of leachate on top of the liner underlying the leakage collection layer (i.e. the secondary liner of a double liner system), which is useful for calculating the rate of leachate migration through that liner. Finally, the case of several leaks randomly distributed is considered, and equations for the surface area of the wetted zone and the average head are given for this case. Parametric analyses and design examples provide useful comparisons between the three types of materials used in leakage collection layers: gravel, sand and geonets.

KEYWORDS: Geomembrane, Defect, Leachate migration, Leachate collection, Leakage, Leakage collection, Liner system, Double liner, Geosynthetic leakage collection layer.

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PUBLICATION: *Geosynthetics International* is published by the Industrial Fabrics Association International, 345 Cedar St., Suite 800, St. Paul, Minnesota 55101-1088, USA, Telephone: 1/612-222-2508, Telefax: 1/612-222-8215. *Geosynthetics International* is registered under ISSN 1072-6349.

DATES: Original manuscript received 1 March 1997 and accepted 19 April 1997. Discussion open until 1 March 1998.

REFERENCE: Giroud, J.P., Gross, B.A., Bonaparte, R. and McKelvey, J.A., 1997, "Leachate Flow in Leakage Collection Layers Due to Defects in Geomembrane Liners", *Geosynthetics International*, Vol. 4, Nos. 3-4, pp. 215-292.

It appears that, when the leakage collection layer is not full, there is an extremely sim-le relationship between the rate of leachate migration through the primary liner defect, ?, and the thickness of leachate in the leakage collection layer beneath the defect, t_o. t is interesting to note that this relationship does not depend on the size of the defect 1 the primary liner or on the slope of the leakage collection layer.

An approximation that was made to establish Equations 9 and 10 was to assume that 1e downslope flow line from A (i.e. AB in Figure 4a) is parallel to the liner. This as-umption is close to reality as discussed in Section 2.2. However, the actual flow line rom A is below Line AB as the flow thickness decreases in the downslope direction, s discussed at the end of Section 5.1.2. Therefore, t_o should only be regarded as the flow 1ickness at a primary liner defect, and it is the maximum flow thickness.

Since the simple relationship expressed by Equations 9 and 10 was demonstrated for 1e case when the leakage collection layer is not full, the condition expressed by Equa-ion 1 must be met for Equations 9 and 10 to be valid. Combining Equations 1 and 10 ives the following equation, which is another way to express the condition that should e met to ensure that the leakage collection layer is not full:

$$t_{LCL} \geq t_{LCLfull} = \sqrt{\frac{Q}{k}} \tag{11}$$

vhere $t_{LCLfull}$ is the *minimum* thickness that a leakage collection layer with a hydraulic onductivity k should have to contain, without being full at any location, the leachate low which results from a defect in the primary liner.

The following equation, derived from Equation 11, is another way to express the con-lition that should be met to ensure that the leakage collection layer is not full:

$$Q \leq Q_{full} = k\, t_{LCL}^2 \tag{12}$$

vhere Q_{full} is the *maximum* steady-state rate of leachate migration through a defect in he primary liner that a leakage collection layer, with a thickness t_{LCL} and a hydraulic onductivity k, can accommodate without being filled with leachate.

It is important to remember that the subscript *full* corresponds to a *minimum* thickness of the leakage collection layer and to a *maximum* rate of leachate migration (which is ilso the *maximum* flow rate in the leakage collection layer). It is noteworthy that the ninimum thickness of the leakage collection layer, $t_{LCLfull}$, and the maximum flow rate, Q_{full}, which are required to ensure that the leakage collection layer can contain, without being full, the flow that results from a defect in the primary liner, do not depend on the slope of the leakage collection layer.

It is not impossible to design a leakage collection layer with a thickness less than the value $t_{LCLfull}$ given by Equation 11, i.e. where the flow rate is greater than Q_{full} defined by Equation 12. In this case, the leakage collection layer is filled with leachate in a cer-ain area around the defect of the primary liner (i.e. "the leachate collection layer is full"). This case is discussed in Section 3.2.

2/5

3.2 Rate of Leachate Flow When the Leachate Collection Layer is Fu

If the thickness of the leakage collection layer is less than $t_{LCLfull}$ expressed tion 11 (or if the rate of leachate migration through a primary liner defect is gre Q_{full} expressed by Equation 12, which is equivalent), the leakage collectior filled with leachate in a certain area around the defect. Following the appr scribed in Section 2.2, it may then be assumed that the leachate phreatic surfa leakage collection layer is a truncated cone (Figure 5). The virtual apex of the t cone, A′, is above the leakage collection layer (i.e. above the primary liner, the upper boundary of the leakage collection layer). The virtual leachate depth the virtual leachate thickness, t_o, are related to the actual leachate head, h_o; Equation 4, and the virtual leachate thickness t_o is greater than the thickness o chate collection layer:

$$t_o > t_{LCL}$$

The surface area of the vertical cross section of the flow in the leakage collect (Figure 5) is expressed by:

$$S = \frac{D_o^2}{\tan\beta} - \frac{(D_o - D_{LCL})^2}{\tan\beta} = \frac{D_{LCL}(2D_o - D_{LCL})}{\tan\beta}$$

where D_{LCL} is the depth of the leakage collection layer.

The depth is measured vertically whereas the thickness is measured perpenc to the slope, hence, in accordance with Equation 3:

$$t_{LCL} = D_{LCL} \cos\beta$$

Using the demonstration presented in Section 2.2, i.e. combining Equations 8, 14 and 15, gives:

$$Q = k\, t_{LCL}(2t_o - t_{LCL})$$

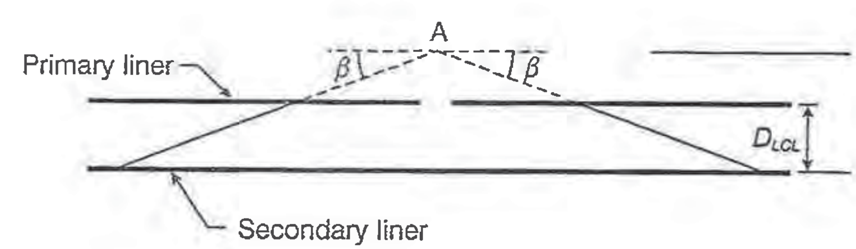


Figure 5. Vertical cross section of the assumed phreatic surface in the leakage co layer in the case where the leakage collection layer is filled with leachate in a certa around the primary liner defect.

ring (or assuming) the leachate head, h_o, on top of the secondary liner vertically the primary liner defect, one may derive the virtual leachate thickness, t_o, using n 4. Then, knowing t_o, t_{LCL} and k, one may use Equation 16 to calculate the rate ate flow through a defect that the leakage collection layer can convey.

ollowing equation can be derived from Equation 16:

$$t_o = \frac{t_{LCL}}{2}\left(1 + \frac{Q}{k\, t_{LCL}^2}\right) \quad (17)$$

ollowing equation can be derived from Equations 13 and 16:

$$t_{LCL} = t_o\left(1 - \sqrt{1 - \frac{Q}{k\, t_o^2}}\right) \quad (18)$$

ion 18 is valid only if the following condition is met:

$$Q \le k\, t_o^2 \quad (19)$$

uld be noted that if $t_{LCL} = t_o$, i.e. if the leakage collection layer is filled with lea- only one point, i.e. at the location of the primary liner defect, Equation 16 is ent to Equation 9.

Parametric Study

the equations presented in Sections 3.1 and 3.2 it is possible to compare the pacity of different leakage collection layers in case of a defect in the primary Table 1, three different leakage collection layers are compared:

net with a thickness of 5 mm and a hydraulic transmissivity resulting in a hy- ic conductivity (obtained by dividing the hydraulic transmissivity by the thick- of 1×10^{-1} m/s;

vel layer with a thickness of 300 mm and a hydraulic conductivity of 1×10^{-1} and

l layer with a thickness of 300 mm and a hydraulic conductivity of 1×10^{-3} m/s.

irst two leakage collection layers have the same hydraulic conductivity and the have the same thickness. In the case of the geonet, the virtual leachate thick- considered in Table 1 is greater than, or equal to, the thickness of the leachate on layer, t_{LCL}; therefore, in all cases considered in Table 1, the geonet is filled chate over a certain area around the defect (this area being zero for t_o = 5 mm). ase of the gravel and sand layers, the leachate thicknesses considered in Table ss than, or equal to, the thickness of the leakage collection layer; therefore, in s considered in Table 1, the gravel and sand layer are not filled (or just filled) chate, and for these two materials the leachate thicknesses, t_o, shown in Table tual (not virtual) thicknesses.

Table 1. Rate of leachate flow in three different leachate collection layers resulting from a defect in the primary liner.

Leachate thickness (actual or virtual)		Leakage collection layer material: Geonet t_{LCL} = 5 mm, $k = 1 \times 10^{-1}$ m/s		Gravel t_{LCL} = 300 mm, $k = 1 \times 10^{-1}$ m/s		Sand t_{LCL} = 300 mm, $k = 1 \times 10^{-3}$ m/s	
t_o		Q		Q		Q	
(m)	(mm)	(m³/s)	(lpd)	(m³/s)	(lpd)	(m³/s)	(lpd)
0.005	5	2.5×10^{-6}	216	2.5×10^{-6}	216	2.5×10^{-8}	2.16
0.01	10	7.5×10^{-6}	648	1.0×10^{-5}	864	1.0×10^{-7}	8.64
0.05	50	4.75×10^{-5}	4,104	2.5×10^{-4}	21,600	2.5×10^{-6}	216
0.1	100	9.75×10^{-5}	8,424	1.0×10^{-3}	86,400	1.0×10^{-5}	864
0.3	300	2.975×10^{-4}	25,704	9.0×10^{-3}	777,600	9.0×10^{-5}	7,776

Notes: The leachate thickness, t_o, can be derived from the leachate head on top of the secondary liner using Equation 4. The leachate thickness, t_o, is the actual leachate thickness if $t_o < t_{LCL}$ and a virtual leachate thickness if $t_o > t_{LCL}$. The tabulated values of the rate of leachate flow, Q, were calculated using Equation 9 when $t_o < t_{LCL}$ and Equation 16 when $t_o > t_{LCL}$. Units: 1 m³/s = 86,400,000 liters per day (lpd).

It appears from Table 1, that for a given value of t_o, i.e. a given value of the head of leachate on top of the secondary liner, h_o (see Equation 4), the gravel and the geonet can convey significantly more leachate than the sand. It is interesting to compare the flow rates of Table 1 with rates of leachate migration through defects of geomembranes used alone (i.e. not part of a composite liner) calculated using Bernoulli's equation, which is expressed as follows:

$$Q = 0.6\,a\sqrt{2\,g\,h_{prim}} = 0.6\,\pi(d^2/4)\sqrt{2\,g\,h_{prim}} \approx (2/3)\,d^2\sqrt{g\,h_{prim}} \quad (20)$$

where: a = defect area; d = defect diameter; g = acceleration due to gravity; and h_{prim} = head of leachate on top of the primary liner.

Table 2 gives rates of leachate migration through geomembrane defects calculated using Equation 20. It appears that, with the leachate heads that typically exist on the primary liners of actively operating landfills (i.e. landfills that are receiving waste), and provided that the geomembrane is used alone (i.e. is not part of a composite liner):

- a small geomembrane defect (e.g. 1 to 2 mm diameter), which may occasionally be undetected during construction, results in a rate of leakage on the order of 100 liters per day (lpd);
- a geomembrane defect (e.g. 3 to 5 mm diameter), which may occasionally occur during construction phases where defect detection may not be possible (e.g. placement of granular leachate collection material on geomembrane), results in a rate of leakage on the order of 1000 lpd (1 m³/day); and
- a large geomembrane defect (e.g. 10 mm diameter or more), which may occur under

4 Wetted Fraction

4.1 *Scope of Section 4.4*

To calculate the rate of leakage through the secondary liner, it is useful to know what ıction of the total surface area of the secondary liner is wetted and what is the average ad of leachate over this fraction of the secondary liner. The wetted fraction is deter- ined in Sections 4.4.3 and 4.4.4, and the average head will be determined in Sections 1 and 5.2.

In the preceding sections, only one defect in the primary liner was considered. This no longer the case in Section 4.4 because the wetted fraction depends on the number defects per unit area. In Section 4.4, two scenarios of defect location will be consid- ed: a scenario where the defects are located to give the maximum wetted fraction, and scenario where the defects are at random.

In Section 4.4, a leakage collection layer whose length in the direction of the flow s a horizontal projection L, and whose width in the direction perpendicular is B, is nsidered (Figure 9). The projected surface area of this leakage collection layer is erefore:

$$A_{LCL} = L\,B \qquad (98)$$

4.2 *Definitions*

etted Fraction. The wetted fraction, R_w, is defined as the ratio between the surface ea of the total wetted zone and the surface area of the leakage collection layer:

$$R_w = \frac{\sum_{n=1}^{n=N} A_w}{A_{LCL}} \qquad (99)$$

As shown by the numerator of the fraction, the surface area of the total wetted zone the sum of the surface areas of the wetted zones that correspond to every defect in e primary liner, the number of defects being N.

efect Frequency. The frequency of defects, F, in the primary liner (i.e. the liner over- ing the leakage collection layer) is defined as the ratio of the total number of defects, in the liner and the surface area of the liner, which is equal to the surface area of the akage collection layer:

$$F = \frac{N}{A_{LCL}} \qquad (100)$$

In typical design calculations the frequency of the defects in the primary liner, F, is sumed to be known. For example, if there are four defects per hectare (10,000 m^2), ...

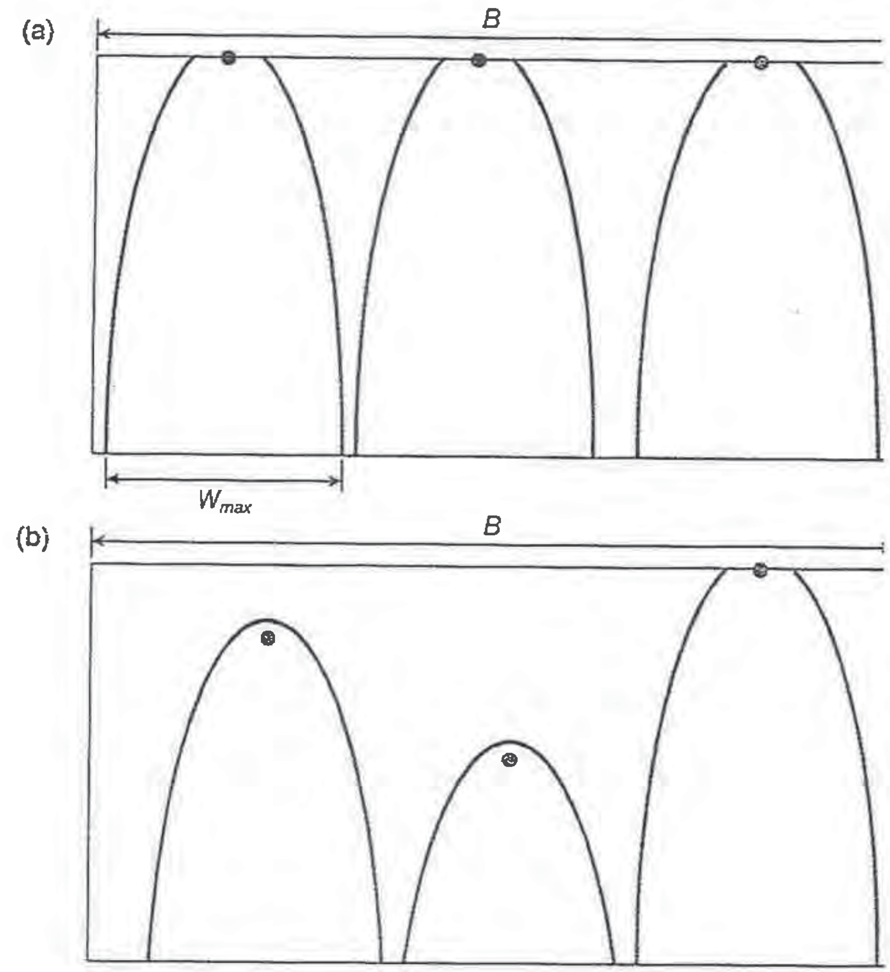


Figure 9. Leakage collection layer zones wetted by leachate migrating through se defects in the primary liner, assuming no overlapping of wetted zones: (a) scenario where all the defects are located at the high end of the leachate collection slope; (b) random scenario where the defects are randomly distributed.

Notes: L is the horizontal projection of the length of the leakage collection layer in the direction of the and B is the width of the leakage collection layer. The dots represent the horizontal projection of the loca of the primary liner defects.

Scenarios. Two defect location scenarios will be considered: (i) the worst sce where all of the defects are at the high end of the leakage collection layer slope (Fi 9a); and (ii) the random scenario where the defects are randomly distributed (Fi 9b). In both scenarios it is assumed that the ...

$$\frac{t_{avg\ rand}\ \lambda_{rand}}{t_{avg\ worst}\ \lambda_{worst}} = \frac{2\ \mu}{9} + \frac{x_{rand}}{L} = \frac{\mu^{5/3}}{\left(10\sqrt{2}\right)^{2/3}} \left[\left(1+\frac{2}{\mu}\right)^{5/2} - 2 \right]^{2/3} - \frac{5\mu}{18} \qquad (192)$$

Equation 192 is valid only for $\mu \leq 1.0696$. Values calculated using Equation 192 are given in Table 6. Values of $t_{avg\ rand}\ \lambda_{rand}/(t_{avg\ worst}\ \lambda_{worst})$ given in Table 6 for $\mu > 1.0696$ were calculated from numerical values of $\lambda_{worst}/\lambda_{rand}$ given in Table 4 and numerical values of $t_{avg\ rand}/t_{avg\ worst}$ given in Table 6.

5.2.4 *Average Leachate Thickness When Wetted Zones Overlap*

The values of the average leachate thickness given in Sections 5.2.2 and 5.2.3 are valid only if there is no overlapping of different wetted zones, i.e. if, as shown in Section 4.4.5:

$$R_{w\ worst} \leq \text{Crit}\,(R_{w\ worst}) \qquad (193)$$

$$R_{w\ rand} \leq \text{Crit}\,(R_{w\ rand}) \qquad (194)$$

If the conditions expressed by Equations 193 and 194 are not satisfied, there is overlapping between adjacent wetted zones. In this case, the best approach, from a practical standpoint, is to assume that the entire area of the leakage collection layer is wetted. Again, the worst scenario and the random scenario are considered. These two scenarios are defined in Section 4.4.2.

Worst Scenario. In the worst scenario all of the primary liner defects are located at the higher end of the leakage collection layer slope. Since the wetted zones have been assumed to overlap, it is approximately correct to consider that the entire leakage collection layer area is wetted. As a result, the leachate thickness is approximately uniform over the entire leakage collection layer area provided that the defects are uniformly distributed at the high end of the leakage collection layer slope. The average leachate thickness is then derived using the classical Darcy's equation, resulting in:

$$t_{avg\ worst} = \frac{N\ Q}{k\ i\ B} \qquad (195)$$

where: N = total number of defects in the primary liner; Q = rate of leachate migration through one defect of the primary liner, all defects being assumed identical and subjected to the same leachate head over the entire surface area of the primary liner; k = hydraulic conductivity of the leakage collection layer material; i = hydraulic gradient in the leakage collection layer; and B = width of the leakage collection layer.

Combining Equations 8 and 195 gives:

$$t_{avg\ worst} = \frac{N\ Q}{k\ B\ \sin\beta} \qquad (196)$$

Combining Equations 98, 100 and 197 gives:

$$t_{avg\ worst} = \frac{F\ L\ Q}{k\ \sin\beta}$$

Equations 195 to 197 are valid only if the leakage collection layer is not the condition expressed by Equation 11 (or Equation 12 which is equivalent) case where the leakage collection layer is *full over its entire surface area* i (i) Equations 16 to 18, which where established for the case where the leak tion layer is *full in a limited area* around the primary liner defect, are not and (ii) assuming that the virtual thickness of leachate is a constant (t_{avg}) ove area of the leakage collection layer allows Darcy's equation to be written :

$$N\ Q = k\ B\ t_{LCL}\ \sin\beta$$

which shows that there is no relationship between Q and t_{avg}. In other words indeterminate. Therefore, no solution is proposed for the average leachate virtual thickness) for the case where the leakage collection layer is filled wit

Random Scenario. In the random scenario, the primary liner defects are at random. In the case where there are enough defects to assume that the ent collection layer area is wetted, the design of a leakage collection layer becor to the design of a leachate collection layer subjected to a uniform rate of lea eration. As shown by Giroud and Houlihan (1995), in most practical cases, value of the leachate thickness is :

$$\frac{t_{avg}}{L} = \frac{\sum Q/(L\ B)}{2\ k\ \sin\beta}$$

With the notations used in this paper, Equation 199 becomes:

$$t_{avg\ rand} = \frac{N\ Q}{2\ k\ B\ \sin\beta}$$

Combining Equations 98, 100 and 200 gives:

$$t_{avg\ rand} = \frac{F\ L\ Q}{2\ k\ \sin\beta}$$

Comparing Equations 197 and 200 shows that the average leachate thickne greater in the worst scenario than in the random scenario. (It should be remen it has been assumed that, in both cases, the entire surface area of the leakage layer is wetted.)

Equations 199 to 201 are valid only if the leakage collection layer is not the condition is expressed by Equation 11 (or Equation 12 which is equivale Also, for the reasons indicated after Equation 197, no solution is proposed f where the leakage collection layer is full.

e of Primary Liner Defect Frequency on Average Leachate Thickness

difference between Sections 5.2.2 and 5.2.3 on one hand, and Section er hand should be noted. Equations for $t_{avg\,worst}$ and $t_{avg\,rand}$ do not depend equency, F, in Sections 5.2.2 and 5.2.3, whereas they depend on F in The reason for that is the following:

.2.2 and 5.2.3, the wetted zones, that correspond to various defects in ner, do not overlap. The average leachate thickness is the same in any idual wetted zones and it is calculated for any of them. Consequently, achate thickness does not depend on the frequency of defects. However, of defects governs the wetted fraction (i.e. the ratio between the total f all wetted zones and the surface area of the leakage collection layer). .4, it is assumed that the entire surface area of the leakage collection l. In other words, it is assumed that the wetted fraction is equal to one. average leachate thickness is a function of all of the defects in the pri- d, consequently, is a function of the defect frequency.

to note that, when the wetted fraction exceeds the critical value (Sec- lesign engineer must assume that the individual wetted zones (i.e. the t correspond to the individual defects in the primary liner) overlap and ations given in Section 5.2.4 to calculate the average leachate thick- when the wetted fraction does not exceed the critical value, the design her use the equations given in Section 5.2.4 or use the equations given and 5.2.3. The approach described in Section 5.2.4 is simpler: it con- that the entire leakage collection layer area is wetted. The approach tions 5.2.2 and 5.2.3 is more complex but closer to reality: only a frac- ge collection layer is wetted and, in addition to calculating the average ss as shown in Sections 5.2.2 and 5.2.3, it is necessary to determine the on using equations provided in Section 4.4. The use of both approaches Example 6 in Section 6.1.

aches give values of the leachate thickness (and head) that are different etted zones do not overlap, only the approach described in Sections ives a correct value of the leachate thickness (or head). However, in age leachate thickness is only calculated as a first step in the calcula- leakage through the secondary liner. In this case, both approaches are pproach described in Section 5.2.4 gives a leachate thickness that is nly distributed over the entire secondary liner, while the approach de- ns 5.2.2 and 5.2.3 gives a greater leachate thickness in the wetted area utside the wetted area. The leakage rates calculated using the leachate ined as indicated in Section 5.2.4 are conservative (i.e. greater than using the leachate thickness determined as indicated in Sections 5.2.2 ltiplied by the wetted fraction) because leakage rates typically vary the head to a power less than one. This will be illustrated quantitative- after Example 6.

5.3 Time Required to Reach Steady-State Flow Conditions

5.3.1 *Equations*

The volume of liquid in a porous medium is less than the volume of porous medium that contains the liquid. As indicated by Equation 143, the volume of leachate in the leakage collection layer is equal to the volume of the leakage collection layer that contains the leachate multiplied by the porosity, n, of the leakage collection layer material. The time required for such a volume to pass through the primary liner defect, $\bar{t}_{req}$, gives a lower boundary of the time required to reach steady-state flow conditions, hence:

$$\bar{t}_{req} > \frac{nV}{Q} \qquad (202)$$

Combining Equations 10, 153 and 202 gives the following equation for the case where the leakage collection layer is not full:

$$\bar{t}_{req} > \frac{n\,x}{k \sin\beta \cos\beta} + \frac{2\,n\,Q^{1/2}}{9 \sin^2\beta \cos\beta \; k^{3/2}} \qquad (203)$$

The last term is generally negligible, because it represents the time required to fill the volume of the leakage collection layer that contains leachate between axes Oy and VY (Figure 6). This volume is either small or reduced by truncation (Figure 8). Therefore:

$$\bar{t}_{req} > \frac{n\,x}{k \sin\beta \cos\beta} \qquad (204)$$

Equation 204 may be written as follows:

$$\bar{t}_{req} > \frac{x / \cos\beta}{k \sin\beta / n} \qquad (205)$$

Combining Equations 8 and 205 gives:

$$\bar{t}_{req} > \frac{x / \cos\beta}{k\,i / n} \qquad (206)$$

where the numerator is the distance between the primary liner defect and the low end of the leakage collection layer slope, and the denominator is the actual liquid velocity derived from Darcy's equation. Therefore, the right hand member of Equation 204 is the travel time, $\bar{t}_{travel}$, i.e. the time required by a drop of leachate to travel from the primary liner defect to the low end of the leakage collection layer, assuming that flow is not hampered by capillarity in the leakage collection layer:

$$\bar{t}_{req} > \bar{t}_{travel} = \frac{n\,x}{k \sin\beta \cos\beta} \qquad (207)$$

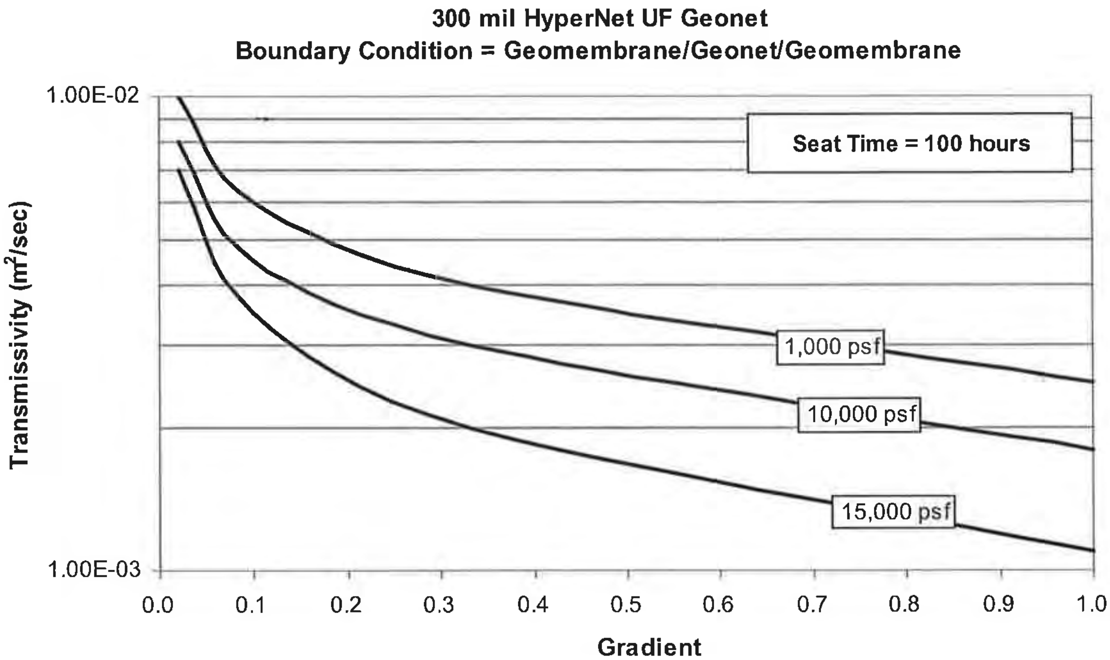


Figure A-7 Performance Transmissivity of a 300 mil HyperNet UF Geonet.

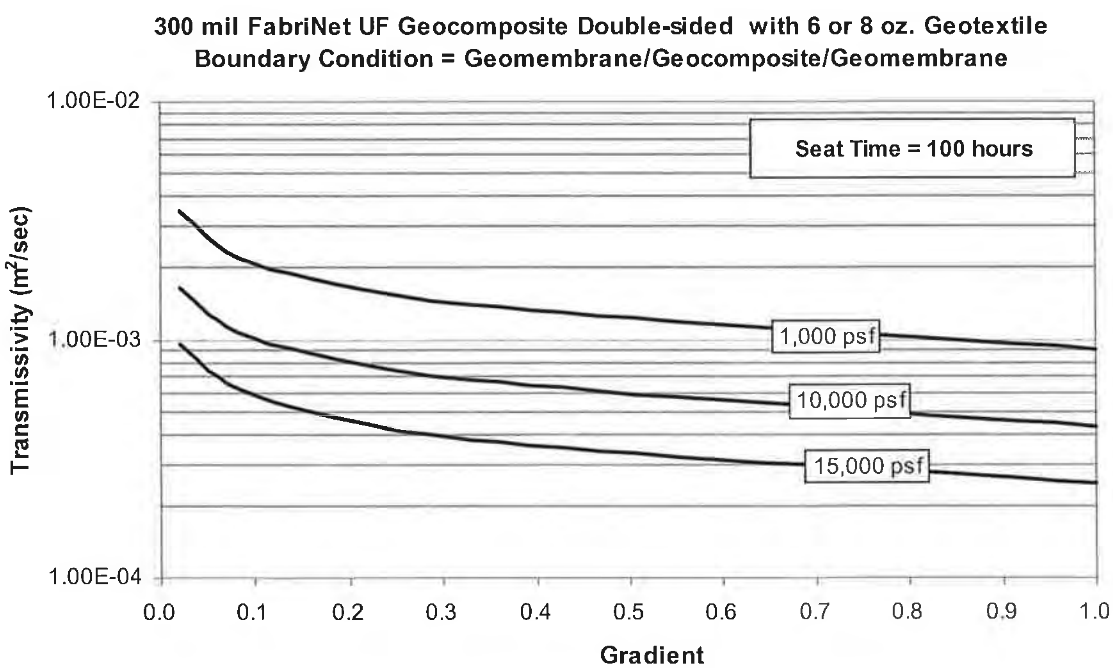


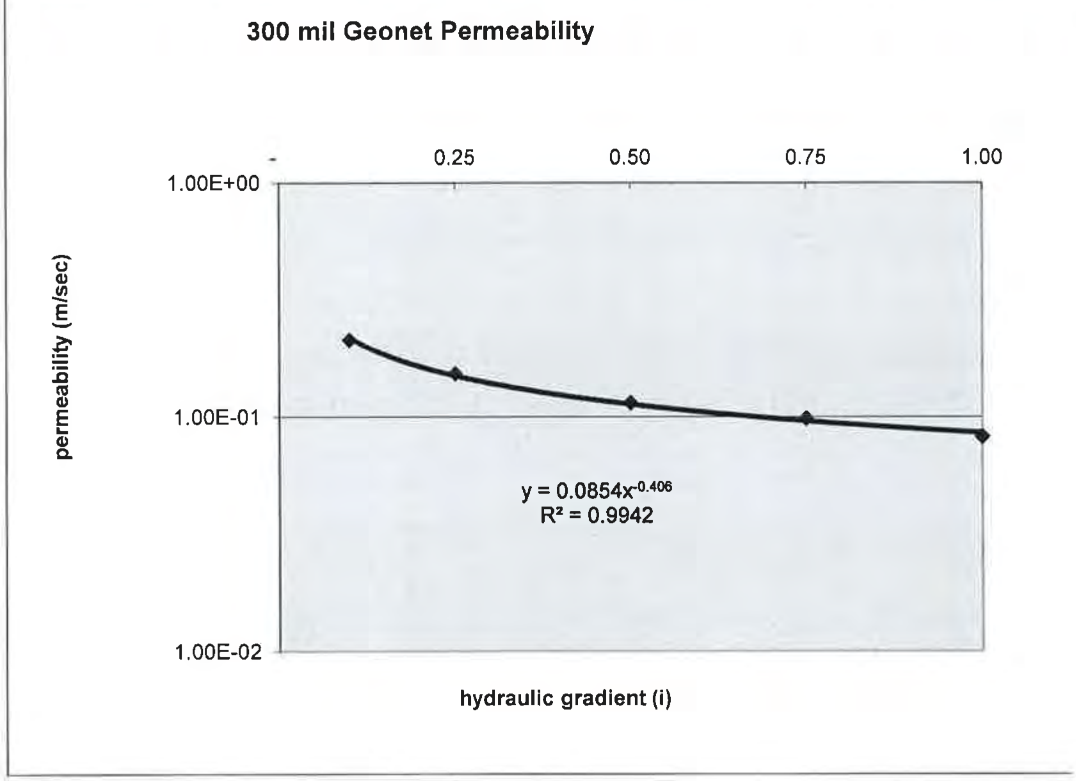
Figure A-8 Performance Transmissivity of a 300 mil FabriNet UF Geocomposite between Plates.

Source: http://www.gseworld.com/Online-Drainage-Design-Manual/Transmissivity/

Attachment D (1/2)

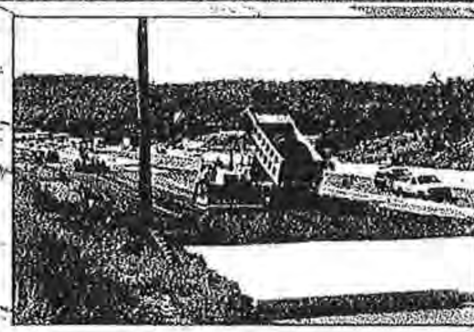
GSE 300 mil HyperNet UF (HDPE/GN/HDPE)

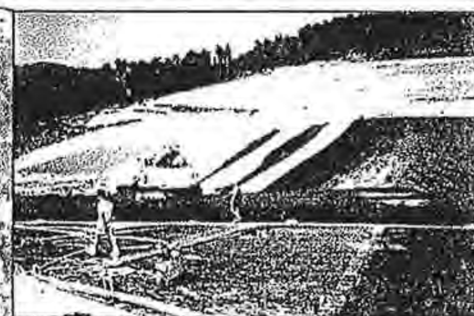
i	Normal Stress (psf)	Transmissivity (m2/sec)	Thickness (mil)	Thickness (mm)	Partial Factor of Safety IN	CR	CC	BC	Permeability (m/sec)
0.10	10,000	3.90E-03	300	7.62	1.0	1.2	2.0	1.0	2.13E-01
0.25	10,000	2.80E-03	300	7.62	1.0	1.2	2.0	1.0	1.53E-01
0.50	10,000	2.10E-03	300	7.62	1.0	1.2	2.0	1.0	1.15E-01
0.75	10,000	1.80E-03	300	7.62	1.0	1.2	2.0	1.0	9.84E-02
1.00	10,000	1.50E-03	300	7.62	1.0	1.2	2.0	1.0	8.20E-02

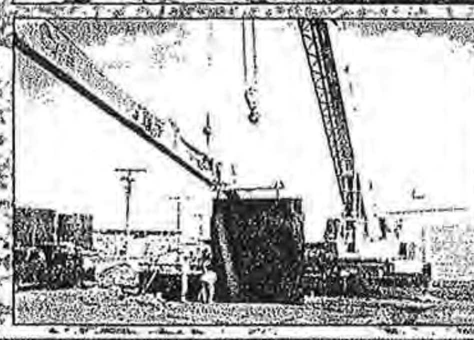


Attachment D 2/2

DESIGNING WITH GEOSYNTHETICS







Fourth Edition

Robert M. Koerner

ATTACHMENT E, 1/3

4.1.6 Allowable Flow Rate

As described previously, the very essence of the design-by-function concept is the establishment of an adequate factor of safety. For geonets, where flow rate is the primary function, this takes the following form.

$$FS = \frac{q_{allow}}{q_{reqd}} \tag{4.3}$$

where

- FS = factor of safety (to handle unknown loading conditions or uncertainties in the design method, etc.),
- q_{allow} = allowable flow rate as obtained from laboratory testing, and
- q_{reqd} = required flow rate as obtained from design of the actual system.

Alternatively, we could work from transmissivity to obtain the equivalent relationship.

$$FS = \frac{\theta_{allow}}{\theta_{reqd}} \tag{4.4}$$

where θ is the transmissivity, under definitions as above. As discussed previously, however, it is preferable to design with flow rate rather than with transmissivity because of nonlaminar flow conditions in geonets.

Concerning the allowable flow rate or transmissivity value, which comes from hydraulic testing of the type described in Section 4.1.3, we must assess the realism of the test setup in contrast to the actual field system. If the test setup does not model site-specific conditions adequately, then adjustments to the laboratory value must be made. This is usually the case. Thus the laboratory-generated value is an ultimate value that must be reduced before use in design; that is,

$$q_{allow} < q_{ult}$$

One way of doing this is to ascribe reduction factors on each of the items not adequately assessed in the laboratory test. For example,

$$q_{allow} = q_{ult}\left[\frac{1}{RF_{IN} \times RF_{CR} \times RF_{CC} \times RF_{BC}}\right] \tag{4.5}$$

or if all of the reduction factors are considered together,

$$q_{allow} = q_{ult}\left[\frac{1}{\Pi RF}\right] \tag{4.6}$$

where

- q_{ult} = flow rate determined using ASTM D4716 or ISO/DIS 12958 for short-term tests between solid platens using water as the transported liquid under laboratory test temperatures,

ATTACHMENT E, 2/3

q_{allow} = allowable flow rate to be used in Eq. (4.3) for final design purposes,
RF_{IN} = reduction factor for elastic deformation, or intrusion, of the adjacent geosynthetics into the geonet's core space,
RF_{CR} = reduction factor for creep deformation of the geonet and/or adjacent geosynthetics into the geonet's core space,
RF_{CC} = reduction factor for chemical clogging and/or precipitation of chemicals in the geonet's core space,
RF_{BC} = reduction factor for biological clogging in the geonet's core space, and
ΠRF = product of all reduction factors for the site-specific conditions.

Some guidelines for the various reduction factors to be used in different situations are given in Table 4.2. Please note that some of these values are based on relatively sparse information. Other reduction factors, such as installation damage, temperature effects, and liquid turbidity, could also be included. If needed, they can be included on a site-specific basis. On the other hand, if the actual laboratory test procedure has included the particular item, it would appear in the above formulation as a value of unity. Examples 4.2 and 4.3 illustrate the use of geonets and serve to point out that high reduction factors are warranted in critical situations.

Example 4.2

What is the allowable geonet flow rate to be used in the design of a capillary break beneath a roadway to prevent frost heave? Assume that laboratory testing was done at the proper design load and hydraulic gradient and that this testing yielded a short-term between-rigid-plates value of 2.5×10^{-4} m^2/s.

Solution: Since better information is not known, average values from Table 4.2 are used in Eq. (4.5).

TABLE 4.2 RECOMMENDED PRELIMINARY REDUCTION FACTOR VALUES FOR EQ. (4.5) FOR DETERMINING ALLOWABLE FLOW RATE OR TRANSMISSIVITY OF GEONETS

Application Area	RF_{IN}	RF_{CR}*	RF_{CC}	RF_{BC}
Sport fields	1.0 to 1.2	1.0 to 1.5	1.0 to 1.2	1.1 to 1.3
Capillary breaks	1.1 to 1.3	1.0 to 1.2	1.1 to 1.5	1.1 to 1.3
Roof and plaza decks	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2	1.1 to 1.3
Retaining walls, seeping rock, and soil slopes	1.3 to 1.5	1.2 to 1.4	1.1 to 1.5	1.0 to 1.5
Drainage blankets	1.3 to 1.5	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2
Surface water drains for landfill covers	1.3 to 1.5	1.1 to 1.4	1.0 to 1.2	1.2 to 1.5
* Secondary leachate collection (landfills)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 2.0
Primary leachate collection (landfills)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 2.0

*These values are sensitive to the density of the resin used in the geonet's manufacture. The higher the density, the lower the reduction factor. Creep of the covering geotextile(s) is a product-specific issue.

ATTACHMENT E, 2/3

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

GEOMEMBRANE TEST RESULTS

TRI Client: Agru America
Project: Product Characterization

Material: Agru Geomembrane - 60 mil HDPE Smooth / 60 mil HDPE Drain Liner
Sample Identification: No Label
TRI Log #: E2231-68-01

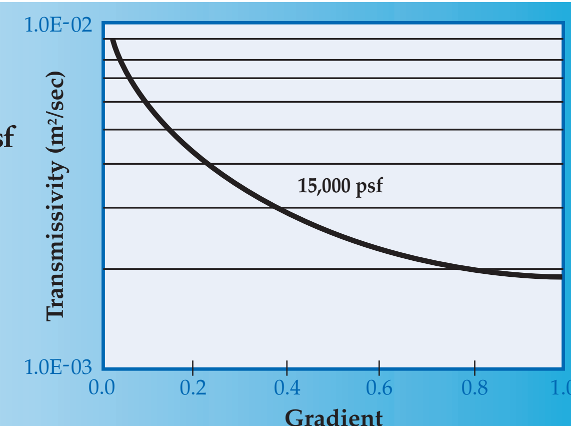
PARAMETER							MEAN	STD. DEV.	PROJ SPEC
Hydraulic Transmissivity (ASTM D 4716)									
Direction Tested: Machine Direction									
Profile (Top to Bottom): Plate/60 mil Smooth HDPE Geomembrane/60 mil Drain Liner HDPE Geomembrane (Studs Up)/Plate									
Permeant: Water									
Compressive Load (psf):	15000								
Hydraulic Gradient:	1.0								
Seat Time (hours):	0.25								
Test Temperature (C)	23								
Flow Rate/Unit Width (GPM/ft width)	9.27	9.45	9.19	10.24	9.99	9.95	9.68	0.397	
Hydraulic Transmissivity (m2/s)	1.8E-03	1.8E-03	1.8E-03	2.0E-03	1.9E-03	1.9E-03	1.9E-03	7.6E-05	8E-04 min
Compressive Load (psf):	15000								
Hydraulic Gradient:	0.5								
Seat Time (hours):	0.25								
Test Temperature (C)	23								
Flow Rate/Unit Width (GPM/ft width)	6.09	6.37	6.16	6.51	6.59	6.68	6.40	0.217	
Hydraulic Transmissivity (m2/s)	2.3E-03	2.5E-03	2.4E-03	2.5E-03	2.5E-03	2.6E-03	2.5E-03	8.3E-05	8E-04 min
Compressive Load (psf):	15000								
Hydraulic Gradient:	0.33								
Seat Time (hours):	0.25								
Test Temperature (C)	23								
Flow Rate/Unit Width (GPM/ft width)	4.95	4.90	5.08	5.39	5.30	5.30	5.16	0.188	
Hydraulic Transmissivity (m2/s)	2.9E-03	2.8E-03	2.9E-03	3.1E-03	3.1E-03	3.1E-03	3.0E-03	1.1E-04	8E-04 min
Compressive Load (psf):	15000								
Hydraulic Gradient:	0.1								
Seat Time (hours):	0.25								
Test Temperature (C)	23								
Flow Rate/Unit Width (GPM/ft width)	2.52	2.52	2.51	2.50	2.66	2.68	2.57	0.076	
Hydraulic Transmissivity (m2/s)	4.9E-03	4.9E-03	4.8E-03	4.8E-03	5.1E-03	5.2E-03	4.9E-03	1.5E-04	8E-04 min

Drain Liner™/Smooth HDPE

Transmissivity under 15,000 psf

Normal stress

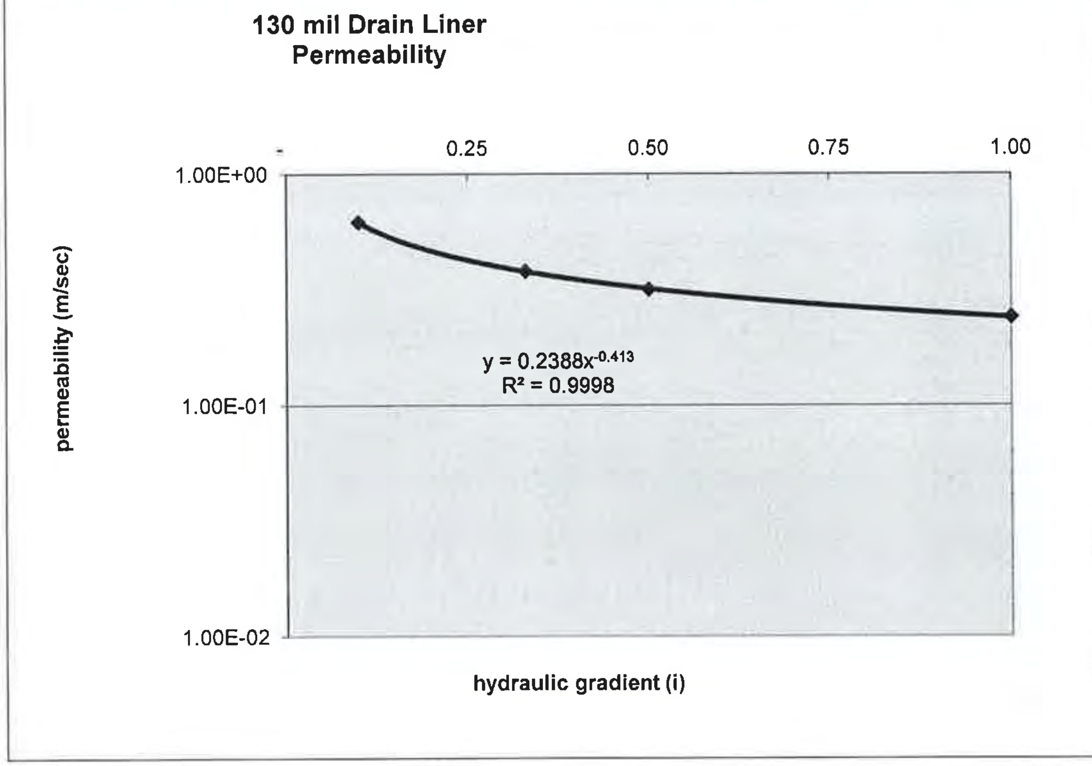
ASTM D4716



Appendix F (2/3)

Agru Drain Liner 130 mil (HDPE/HDPE)

i	Normal Stress (psf)	Transmissivity (m2/sec)	Thickness (mil)	(mm)	Partial Factor of Safety IN	CR	CC	BC	Permeability (m/sec)
0.10	15,000	4.90E-03	130	3.3	1.0	1.2	2.0	1.0	6.18E-01
0.33	15,000	3.00E-03	130	3.3	1.0	1.2	2.0	1.0	3.79E-01
0.50	15,000	2.50E-03	130	3.3	1.0	1.2	2.0	1.0	3.15E-01
1.00	15,000	1.90E-03	130	3.3	1.0	1.2	2.0	1.0	2.40E-01



Attachment F 3/3

Page ___ of ___

Geosyntec consultants

Written by: ______ Date: __/__/__ (DD MM YY) Reviewed by: ______ Date: __/__/__ (DD MM YY)

Client: ______ Project: ______ Project/Proposal No. ______ Task No. ______

SAMPLE

DIMENSIONS: 4" × 6"

AREA: 24 in²

Total Void Volume Assuming H = 130 mil

$V_T = 24\,in^2 \times 0.13\,in = 3.12\,in^3$

STUDS

HEIGHT: 130 mil = 0.13 in

DIAMETER: 0.10 in

Volume: $\left(\frac{0.10}{2}\right)^2 \pi (0.13) = 0.00102\,in^3$

No. Studs on 4"×6" panel: 80

Total Stud Volume, V_s

$80 \times 0.00102\,in^3$

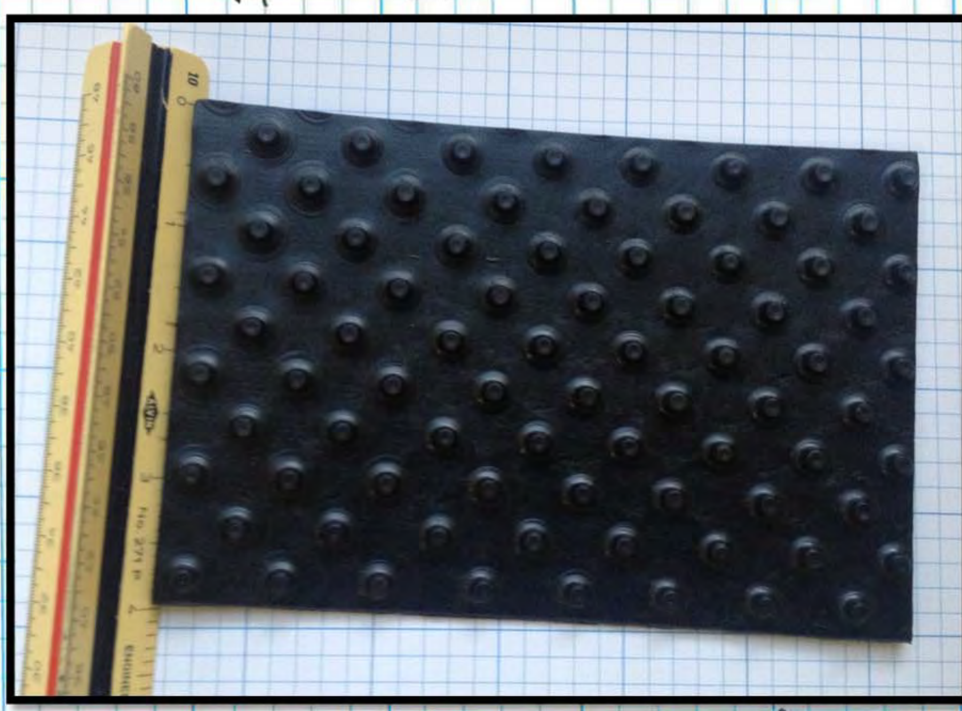
$V_S = 0.0816\,in^3$

Volume of Voids, V_V

$V_V = V_T - V_S = 3.12 - 0.0816 = 3.04\,in^3$

Porosity, ϕ

$\phi = \frac{V_V}{V_T} = \frac{3.04}{3.12} = 0.97 = 97\%$



Attachment G

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF** Project: **White Mesa Mill – Cells 5A and 5B** Project/ Proposal No.: **SC0634A** Task No. **02**

Title of Computations **EVALUATION OF LINER SYSTEM ANCHOR TRENCH CAPACITY – Option B**

Computations by:	Signature	[signature]	6/21/18 Date
	Printed Name	Rebecca Oliver	
	Title	Principal Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature	[signature]	6/21/18 Date
	Printed Name	Keaton Botelho	
	Title	Senior Engineer	
Computations Checked by:	Signature	[signature]	6/21/18 Date
	Printed Name	Keaton Botelho	
	Title	Senior Engineer	
Computations backchecked by: (originator)	Signature	[signature]	6/21/18 Date
	Printed Name	Rebecca Oliver	
	Title	Principal Engineer	
Approved by: (pm or designate)	Signature	[signature]	06/22/2018 Date
	Printed Name	Gregory T. Corcoran	
	Title	Senior Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Oliver	Date:	6/21/18	Reviewed by:	G. Corcoran	Date:	
Client:	EF	Project:	WMM- Cells 5A & 5B	Project/ Proposal No.:	SC0634A	Task No.:	02

EVALUATION OF LINER SYSTEM ANCHOR TRENCH CAPACITY

OPTION B

WHITE MESA MILL

BLANDING, UTAH

OBJECTIVE

The project includes the installation of a double geomembrane with geosynthetic clay liner (GCL) liner system within Cells 5A and 5B at the White Mesa Mill in Blanding, Utah. The proposed liner system and anchor trench is shown in Attachment A. The objective of this calculation package is to evaluate the tensile strength capacity for anchorage of the liner system at termination locations of the liner system with respect to wind uplift forces on the geomembrane. The anchor capacity presented herein is applicable to geomembrane pullout. The anchor trench is evaluated for two conditions: the interim construction condition and the final condition. In the interim condition, the liner is temporarily secured in the anchor trench with 1 ft of soil cover while the remaining liner components are deployed.

METHOD OF ANALYSIS

Anchor trench capacity is evaluated using methods and equations presented by Koerner (1998) and are included as Attachment B.

Koerner (1998) presents design equations developed from static equilibrium to evaluate the allowable geosynthetic tension from an anchor trench (see Attachment B). The equation considers frictional resistance due to (i) overburden pressures, (ii) anchor trench side slopes, and (iii) base of the anchor trench. The proposed design equation for determination of the allowable geomembrane tension from an anchor trench is:

$$T_{ult} = F_U + F_L + F_{AT\text{-}SIDE1} + F_{AT\text{-}SIDE2} + F_{AT\text{-}BASE1} + F_{AT\text{-}BASE2} \quad (3)$$

Where: T_{ult} = Ultimate tensile force in the geomembrane;

F_U = Friction force above the geosynthetics;

F_L = Friction force below the geosynthetics;

F_U, F_L = q tanδ(L_{RO})

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q = surcharge pressure due to soil overburden

= depth of soil in anchor trench × unit weight

$\delta_{1,2}$ = minimum friction angle between liner system interfaces and the soil

L_{RO} = Runout length subjected to overburden

$F_{AT\text{-}SIDE}$ = Friction force due to the side of the anchor trench at each interface;

$F_{AT\text{-}SIDE} = (\sigma_h)_{ave} \times \tan\delta\ (d_{AT})$

$(\sigma_h)_{ave}$ = average horizontal stress in the anchor trench = $K_o(\sigma_v)_{ave}$

K_o = coefficient of earth pressure at rest = $1\text{-}\sin\Phi$

Φ = friction angle of backfill soil

$(\sigma_v)_{ave}$ = vertical overburden stress (depth of soil at mid-point of trench (plus additional overburden) multiplied by the soil unit weight (γ))

d_{AT} = depth of the anchor trench = 1 ft (interim), 1.5 ft (final)

$F_{AT\text{-}BASE}$ = Friction force due to the base of the anchor trench at each interface;

$F_{AT\text{-}BASE} = q \tan\delta_{1,2}(L_{AT})$

L_{AT} = width of the anchor trench = 2 ft

For this site, wind uplift is the only loading considered for the anchor trench design and overburden will not be placed on top of the liner beyond the anchor trench; therefore, the liner system on the slope and slope angle is not considered and $L_{RO} = 0$. So the equation for the allowable geomembrane tension from an anchor trench now becomes:

$$T_{ult} = F_{AT\text{-}SIDE1} + F_{AT\text{-}SIDE2} + F_{AT\text{-}BASE1} + F_{AT\text{-}BASE2}$$

ANALYSIS

Evaluating Variables

Since tension may develop in the geomembrane (see the calculation package Tension due to Wind Uplift) due to wind uplift forces and thermal forces, frictional forces will be mobilized along the geosynthetic and soil interfaces on the side and base of the anchor trench. The 75 percent of the maximum wind speed at the site was used to evaluate the

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interim construction conditions (resulting in 18.75 mph). The load due to the interim wind uplift is 9.2 lb/in. (110 lb/ft). The maximum wind speed at the site with a reduction of 25 percent (%) was used to evaluate the final conditions. The load due to the maximum wind uplift is 17.7 lb/in (212.4 lb/ft) (see the calculation package Geomembrane Tension due to Wind Uplift). The maximum load is used for the final condition. For the analysis presented herein, the following three interfaces are evaluated:

1. A friction angle of 18 degrees will be used to represent the interface friction value between the anchor trench backfill and the smooth geomembrane (Attachment C).
2. A friction angle of 15 degrees will be used to represent the interface friction value between the smooth geomembrane and the drain liner (Attachment D).
3. A friction angle of 11 degrees will be used to represent the interface friction value between the geosynthetic clay liner and geomembrane (Attachment E).

For determination of the surcharge due to soil overburden, q, and the vertical and horizontal overburden stresses, σ_h and σ_v, a unit weight of overburden soil of 125 pounds per cubic foot (pcf) was used. For evaluation of the effective horizontal overburden stress based on the coefficient of earth pressure at rest, a friction angle of 26 degrees was used for the soil. See Slope Stability calculation package for material parameter assumptions.

Interim Condition	Final Condition
From Equation (3): $T_{ult} = F_{AT\text{-}SIDE1} + F_{AT\text{-}SIDE2}$ $F_{AT\text{-}BASE1} + F_{AT\text{-}BASE2}$	From Equation (3): $T_{ult} = F_{AT\text{-}SIDE1} + F_{AT\text{-}SIDE2}$ $F_{AT\text{-}BASE1} + F_{AT\text{-}BASE2}$

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$$F_{AT-SIDE1} = (\sigma_h)_{ave} \tan\delta_1 (d_{AT})$$
$$= K_o(\sigma_{vave}) \tan\delta(d_{AT})$$
$$= (1-\sin 26°)\left(\frac{1}{2}(1\text{ ft})\right)\times$$
$$(125\text{ pcf})\tan 18°(1\text{ ft})$$
$$= 11\text{ lb/ft}$$

$$F_{AT-SIDE2} = (\sigma_h)_{ave} \tan\delta_2 (d_{AT})$$
$$= K_o(\sigma_{vave}) \tan\delta(d_{AT})$$
$$= (1-\sin 26°)\left(\frac{1}{2}(1\text{ ft})\right)\times$$
$$(125\text{ pcf})\tan 11°(1\text{ ft})$$
$$= 7\text{ lb/ft}$$

$$F_{AT-BASE1} = q\tan\delta_1(L_{AT})$$
$$= 1\text{ ft}(125\text{ pcf})\tan 18°(2\text{ ft})$$
$$= 81\text{ lb/ft}$$

$$F_{AT-BASE2} = q\tan\delta_2(L_{AT})$$
$$= 1\text{ ft}(125\text{ pcf})\tan 11°(2\text{ ft})$$
$$= 49\text{ lb/ft}$$

T_{ult} = $F_{AT\text{-}SIDE1}$ + $F_{AT\text{-}SIDE2}$ + $F_{AT\text{-}BASE1}$ + $F_{AT\text{-}BASE2}$

= 11 + 7 + 81 + 49

T_{ult} = 148 lb/ft > 110 lb/ft OK

$$F_{AT-SIDE1} = (\sigma_h)_{ave} \tan\delta_1 (d_{AT})$$
$$= K_o(\sigma_v)_{ave} \tan\delta(d_{AT})$$
$$= (1-\sin 26°)\left(\frac{1}{2}(1.5\text{ ft})\right)\times$$
$$(125\text{ pcf})\tan 18°(1.5\text{ ft})$$
$$= 25\text{ lb/ft}$$

$$F_{AT-SIDE2} = (\sigma_h)_{ave} \tan\delta_2 (d_{AT})$$
$$= K_o(\sigma_v)_{ave} \tan\delta(d_{AT})$$
$$= (1-\sin 26°)\left(\frac{1}{2}(1.5\text{ ft})\right)\times$$
$$(125\text{ pcf})\tan 15°(1.5\text{ ft})$$
$$= 21\text{ lb/ft}$$

$$F_{AT-BASE1} = q\tan\delta_1(L_{AT})$$
$$= 1.5\text{ ft}(125\text{ pcf})\tan 18°(2\text{ ft})$$
$$= 122\text{ lb/ft}$$

$$F_{AT-BASE2} = q\tan\delta_2(L_{AT})$$
$$= 1.5\text{ ft}(125\text{ pcf})\tan 15°(2\text{ ft})$$
$$= 100\text{ lb/ft}$$

T_{ult} = $F_{AT\text{-}SIDE1}$ + $F_{AT\text{-}SIDE2}$ + $F_{AT\text{-}BASE1}$ + $F_{AT\text{-}BASE2}$

= 25 + 21 + 122 + 100

T_{ult} = 268 lb/ft > 212 lb/ft OK

Written by: **R. Oliver** Date: **6/21/18** Reviewed by: **G. Corcoran** Date:

Client: **EF** Project: **WMM- Cells 5A & 5B** Project/ Proposal No.: **SC0634A** Task No.: **02**

CONCLUSIONS

The tensile capacity of the anchorage system as calculated herein exceeds the expected interim and long-term wind uplift tensile loads (from the calculation package entitled *Evaluation of Tension due to Wind Uplift*). The expected tensile load due to wind uplift was evaluated to be 110 and 212 lb/ft for the interim and final conditions, respectively. The capacity of the interim and long-term anchor trenches are 148 and 268 lb/ft, respectively. Therefore, the anchorage design for the geomembrane is adequate.

Based on the methods employed herein, results of analysis indicate that the design anchorage evaluated provides adequate tensile capacity to resist geomembrane tension induced by wind uplift forces.

NOTES TO PROJECT DOCUMENTS

The interim anchor trench shall have a minimum of 1 ft soil cover and a minimum 2 ft in width. The final anchor trench shall be a minimum of 1.5 ft deep and 2 ft. If an interim anchor trench is utilized, the total anchor trench depth shall be 3.5 ft in depth and 2 ft in width. The anchor trench shall be located at least 3 ft from the crest of the slope.

REFERENCES

Koerner, R.M. (1998), "*Designing with Geosynthetics*," 4th Edition. Prentice-Hall Inc.: Upper Saddle River, NJ. (*Attachment B)*

GSE Lining Technology. "*GSE FrictionFlex Application Data*." Technical Note. *(Attachment C)*

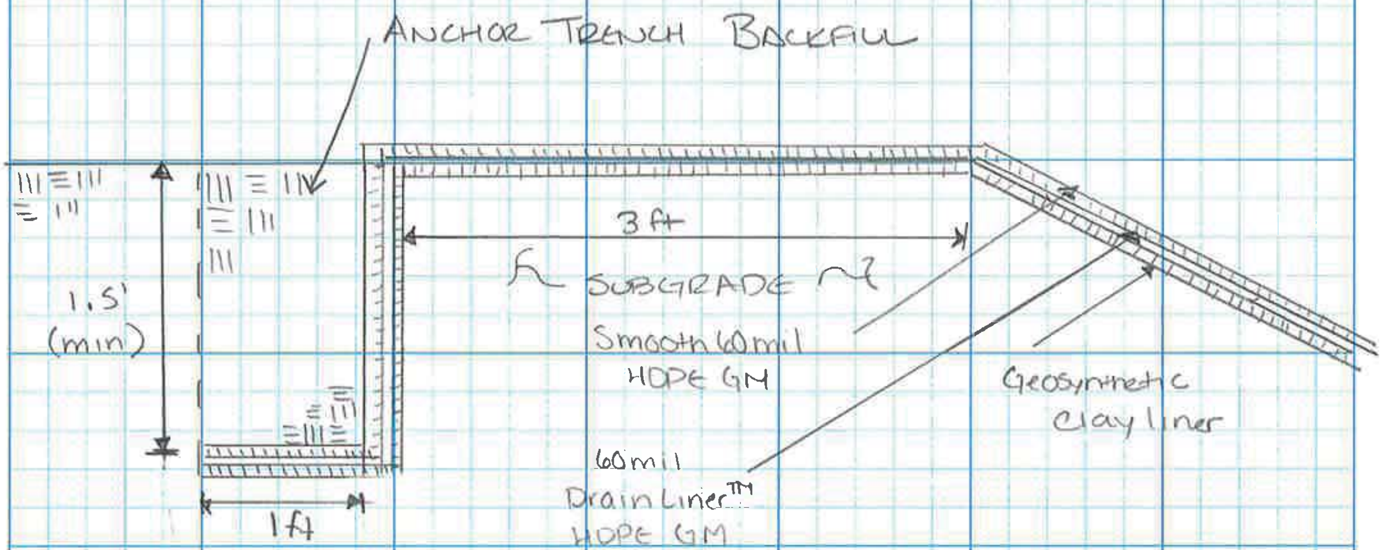
Interface Friction Angle Testing by TRI Environmental carried out in accordance with ASTM D5321. *(Attachment D)*

Hunt, Roy E. (1983). *Geotechnical Engineering Investigation Manual*, McGraw-Hill: New York. *(Attachment F)*

Geosyntec consultants

Written by: R OLIVER Date: 21 / 6 / 18 Reviewed by: ____ Date: __/__/__

Client: EF Project: WMM-5A/B Project/Proposal No. SC0634A Task No. ____



N.T.S. Typ. Anchor Trench

Attachment A
(1/1)

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Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

5.3.6 Runout and Anchor Trench Design

As shown in Figure 5.21 and the subsequent profile sections of geomembrane-lined reservoirs the liner comes up from the bottom of the excavation, covers the side slopes, and then runs over the top a short distance. It often terminates vertically down into an anchor trench. This anchor trench is typically dug by a small backhoe or trenching machine; the liner is draped over the edge, and then the trench is backfilled with the same soil that was there originally. The backfilled soil should be compacted in layers as the backfilling proceeds. Although concrete has been used as an anchorage block, it is rarely justified, at least on the basis of calculations, as will be seen in this section.

Regarding design, two separate cases will be analyzed: one with geomembrane runout only and no anchor trench at all (as is often used with canal liners), and the other as described above, with both runout and anchor trench considerations (as with reservoirs and landfills). Figure 5.30 defines the first situation, together with the forces and stresses involved. Note that the cover soil applies normal stress due to its weight, but does not contribute frictional resistance above the geomembrane. This is due to the fact that the soil moves along with the geomembrane as it deforms and undoubtedly cracks, thereby losing its integrity.

From Figure 5.30, the following horizontal force summation results, which leads to the appropriate design equation.

$$\Sigma F_x = 0$$

$$T_{\text{allow}} \cos \beta = F_{U\sigma} + F_{L\sigma} + F_{LT}$$

Attachment B 1/8

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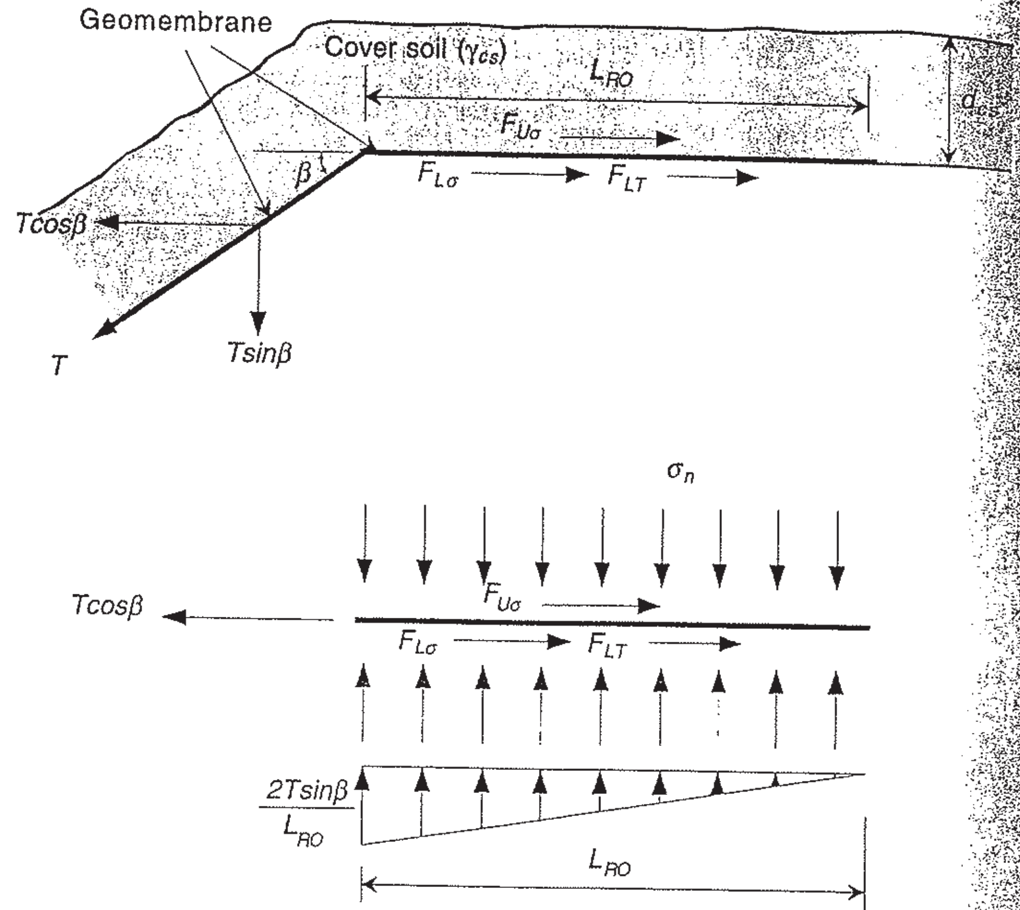

Figure 5.30 Cross section of geomembrane runout section and related stresses and forces involved.

$$= \sigma_n \tan \delta_U(L_{RO}) + \sigma_n \tan \delta_L(L_{RO}) + 0.5\left(\frac{2T_{\text{allow}} \sin \beta}{L_{RO}}\right)(L_{RO}) \tan \delta_L$$

$$L_{RO} = \frac{T_{\text{allow}}(\cos \beta - \sin \beta \tan \delta_L)}{\sigma_n(\tan \delta_U + \tan \delta_L)} \tag{5.25}$$

where

T_{allow} = allowable force in geomembrane stress = $\sigma_{\text{allow}}t$, where
σ_{allow} = allowable stress in geomembrane, and
t = thickness of geomembrane;
β = side slope angle;
$F_{U\sigma}$ = shear force above geomembrane due to cover soil (note that for thin cover soils tensile cracking will occur and this value will be negligible);

Attachment B 2/3

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

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$F_{L\sigma}$ = shear force below geomembrane due to cover soil;
F_{LT} = shear force below geomembrane due to vertical component of T_{allow};
σ_n = applied normal stress from cover soil;
δ = angle of shearing resistance between geomembrane and adjacent material (i.e., soil or geotextile); and
L_{RO} = length of geomembrane runout.

Example 5.13 illustrates the use of the concept and the equations just developed.

Example 5.13

Consider a 1.0 mm thick VLDPE geomembrane with a mobilized allowable stress of 7000 kPa, which is on a $3(H)$ to $1(V)$ side slope. Determine the required runout length to resist this stress without use of a vertical anchor trench. In this analysis use 300 mm of cover soil weighing 16.5 kN/m³ and a friction angle of 30° with the geomembrane.

Solution: From the design equations just presented,

$$T_{allow} = \sigma_{allow} t$$
$$= (7000)(0.001)$$
$$T_{allow} = 7.0 \text{ kN/m}$$

and

$$L_{RO} = \frac{T_{allow}(\cos\beta - \sin\beta\tan\delta_L)}{\sigma_n(\tan\delta_U + \tan\delta_L)}$$
$$= \frac{(7.0)[\cos 18.4 - (\sin 18.4)(\tan 30)]}{(16.5)(0.30)[\tan 0 + \tan 30]}$$
$$= \frac{5.37}{2.86}$$
$$L_{RO} = 1.9 \text{ m}$$

Note that this value is strongly dependent on the value of mobilized allowable stress used in the analysis. To mobilize the failure strength of the geomembrane would require a longer runout length or embedment in an anchor trench. This, however, might not be desirable. Pullout without geomembrane failure might be a preferable phenomenon. It is a site-specific situation.

The situation with an anchor trench at the end of the runout section is illustrated in Figure 5.31. The configuration requires some important assumptions regarding the state of stress within the anchor trench and its resistance mechanism. In order to provide lateral resistance, the vertical distance within the anchor trench has lateral forces acting upon it. More specifically, an active earth pressure (P_A) is tending to destabilize the situation, whereas a passive earth pressure (P_P) is tending to resist pullout. As will

Attachment B 3/8

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

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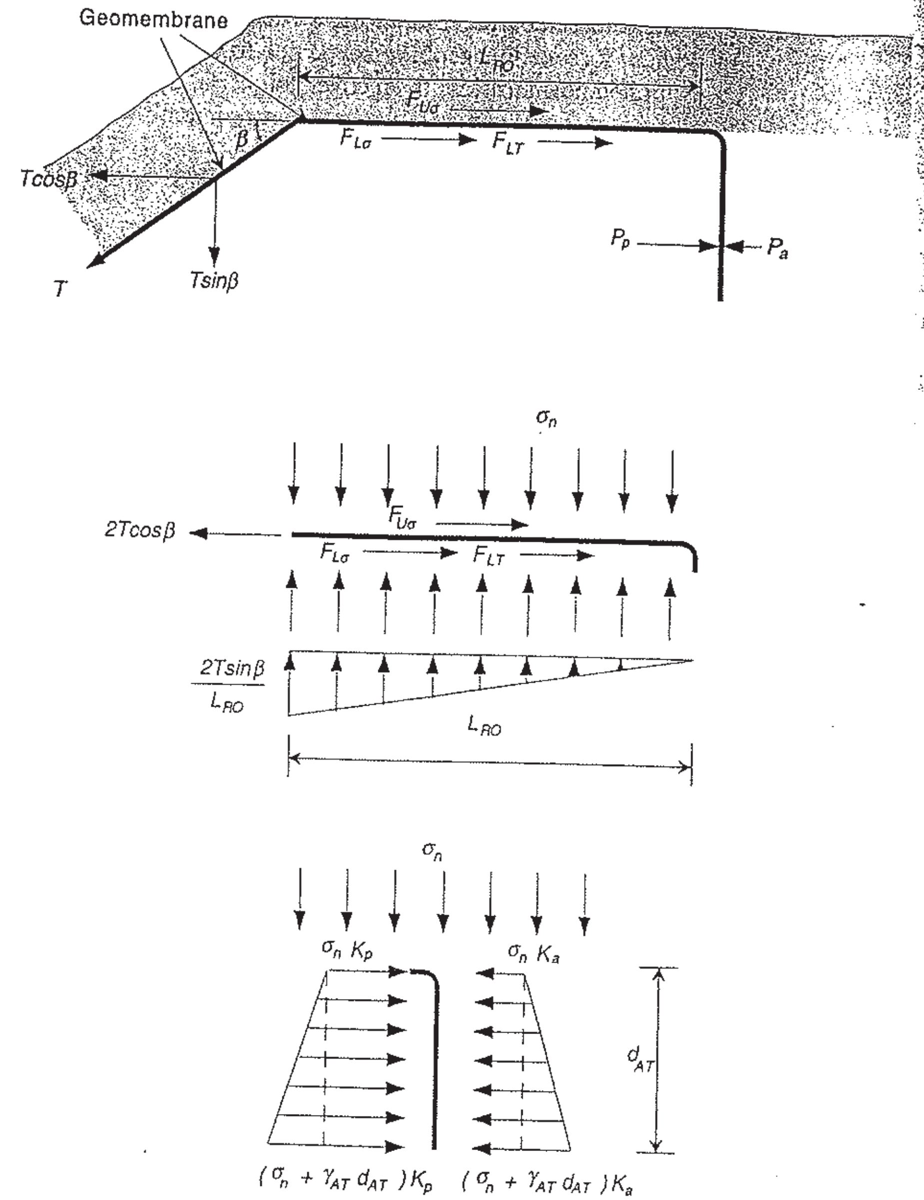

Figure 5.31 Cross section of geomembrane runout section with anchor trench and related stresses and forces involved.

be shown, this passive earth pressure is very effective in providing a resisting force (see Holtz and Kovacs [44]). Using the free-body diagram in Figure 5.31,

$$\Sigma F_x = 0$$

$$* \quad T_{\text{allow}} \cos \beta = F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P \quad * \qquad (5.26)$$

Attachment B 4/8

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

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where

T_{allow} = allowable force in geomembrane = $\sigma_{allow}t$, where
σ_{allow} = allowable stress in geomembrane, and
t = thickness of geomembrane;
β = side slope angle;
$F_{U\sigma}$ = shear force above geomembrane due to cover soil (note that for thin cover soils, tensile cracking will occur, and this value will be negligible);
$F_{L\sigma}$ = shear force below geomembrane due to cover soil;
F_{LT} = shear force below geomembrane due to vertical component of T_{allow};
P_A = active each pressure against the backfill side of the anchor trench; and
P_P = passive earth pressure against the in-situ side of the anchor trench.

The values of $F_{U\sigma}$, $F_{L\sigma}$, and F_{LT} have been defined previously. The values of P_A and P_P require the use of lateral earth pressure theory.

$$P_A = \tfrac{1}{2}(\gamma_{AT}d_{AT})K_A d_{AT} + (\sigma_n)K_A d_{AT}$$

$$P_A = (0.5\gamma_{AT}d_{AT} + \sigma_n)K_A d_{AT} \tag{5.27}$$

$$P_P = (0.5\gamma_{AT}d_{AT} + \sigma_n)K_P d_{AT} \tag{5.28}$$

where

γ_{AT} = unit weight of soil in anchor trench,
d_{AT} = depth of the anchor trench,
σ_n = applied normal stress from cover soil,
K_A = coefficient of active earth pressure = $\tan^2(45 - \phi/2)$,
K_P = coefficient of passive earth pressure = $\tan^2(45 + \phi/2)$, and
ϕ = angle of shearing resistance of respective soil.

This situation results in one equation with two unknowns; thus a choice of either L_{RO} or d_{AT} is necessary to calculate the other. As with the previous situation, the factor of safety is placed on the geomembrane force T, which is used as an allowable value, T_{allow}. Example 5.14 illustrates the procedure.

Example 5.14

Consider a 1.5 mm thick HDPE geomembrane extending out of a facility as shown in Figure 5.31. What depth anchor trench is needed if the runout distance is constrained to 1.0 m? In the solution, use a geomembrane allowable stress of 16,000 kPa on a 3(H) to 1(V) side slope. There are 300 mm of cover soil at 16.5 kN/m³ placed over the geomembrane runout and anchor trench (this is also the unit weight of the anchor trench soil). The friction angle of the geomembrane to the soil is 30° (although assume 0° for the top of the geomembrane under a soil-cracking assumption) and the soil itself is 35°.

Attachment B 5/8

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

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Solution: Using the previously developed design equations based on Figure 5.31:

$$T_{allow} = \sigma_{allow} t$$
$$= 16000(0.0015)$$
$$= 24.0 \text{ kN/m}$$

and

$$F_{U\sigma} = \sigma_n \tan \delta_U (L_{RO})$$
$$= (0.3)(16.5) \tan 0 (L_{RO})$$
$$= 0$$
$$F_{L\sigma} = \sigma_n \tan \delta_L (L_{RO})$$
$$= (0.3)(16.5) \tan 30 (L_{RO})$$
$$= 2.86 L_{RO}$$
$$F_{LT} = T_{allow} \sin \beta \tan \delta_L$$
$$= (24.0) \sin 18.4 \tan 30$$
$$= 4.37 \text{ kN/m}$$
$$P_A = (0.5 \gamma_{AT} d_{AT} + \sigma_n) K_A d_{AT}$$
$$= [(0.5)(16.5) d_{AT} + (0.3)(16.5)] \tan^2 (45 - 35/2)\, d_{AT}$$
$$= [8.25 d_{AT} + 4.95](0.271) d_{AT}$$
$$= 2.24 d_{AT}^2 + 1.34 d_{AT}$$
$$P_P = (0.5 \gamma_{AT} d_{AT} + \sigma_n) K_P d_{AT}$$
$$= [(0.5)(16.5) d_{AT} + (0.3)(16.5)] \tan^2 (45 + 35/2)\, d_{AT}$$
$$= [8.25 d_{AT} + 4.95](3.69) d_{AT}$$
$$= 30.4 d_{AT}^2 + 18.3 d_{AT}$$

This is substituted into the general force equation [Eq. (5.26)] to arrive at the solution in terms of the two variables L_{RO} and d_{AT}.

$$T_{allow} \cos \beta = F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P$$
$$(24.0) \cos 18.4 = 0 + 2.86 L_{RO} + 4.37 - 2.24 d_{AT}^2 - 1.34 d_{AT} + 30.4 d_{AT}^2 + 18.3 d_{AT}$$
$$18.4 = 2.86 L_{RO} + 17.0 d_{AT} + 28.2 d_{AT}^2$$

Attachment B 6/8

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

Since $L_{RO} = 1.0$ m, the equation can be solved for the unknown d_{AT}.

$$d_{AT} = 0.50 \text{ m}$$

Using this formulation we can develop a design chart for a wide range of geomembranes and thicknesses as characterized by different values of T_{allow}. For the specific conditions of Example 5.14,

$$\beta = 18.4°, \text{ which is } 3(H) \text{ to } 1(V)$$

$$\sigma_n = d_{cs}\gamma_{cs}$$

$$= (0.30)(16.5)$$

$$= 4.95 \text{ kN/m}^2$$

$$\delta_U = 0°$$

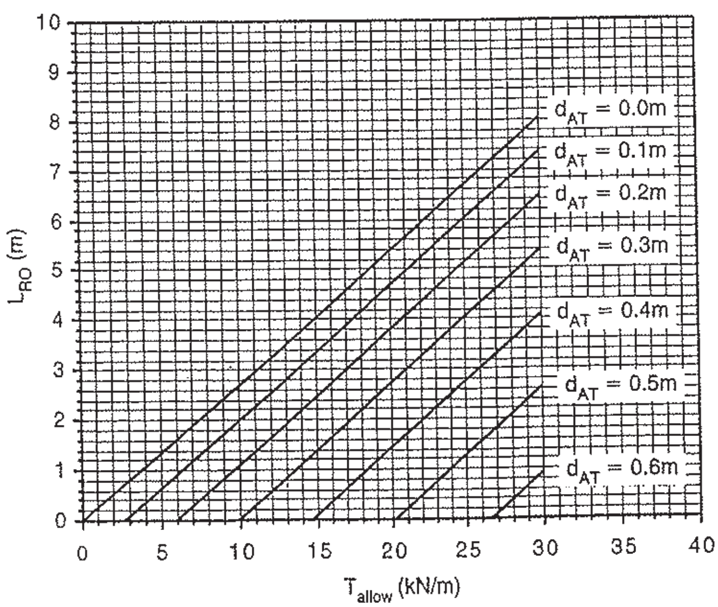
$$\delta_L = 30°$$

$$\phi = 35°$$

$$\gamma_{AT} = 16.5 \text{ kN/m}^3$$

$$\delta_{AT} = 30°$$

the response in terms of the two unknowns L_{RO} and d_{AT} is given in the following figure. Using this figure, Example 5.14 with the 1.5 mm thick HDPE at 24.0 kN/m gives an anchor trench depth of 0.50 m for an assumed runout length of 1.0 m. Other values can be readily selected.



Attachment B 7/8

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

It should be noted that many manufacturers specify 500 mm deep anchor trenches and 1000 mm long runout sections. As seen above, this is very simplistic, for each membrane type and thickness requires its own analysis. By using a model as presented here, any set of conditions can be used to arrive at a solution. Even situations in which geotextiles and/or geonets are used in conjunction with the geomembrane (under, over, or both) and brought into the anchor trench can be analyzed in a similar manner.

5.3.7 Summary

Projects involving liquid containment using geomembranes are often extremely large. With large size come some inherent advantages over smaller projects. Foremost of these advantages is that most parties involved take the project seriously and approve of and enter into a planned and sequential design procedure. This section was laid out with this in mind, so that the design process proceeded step by step. Each element of design that is made leads to a new issue, which is followed by a new design element. Eventually, the quantitative process is concluded and details, often qualitative by nature, must be attended to. These details, such as seam type, seam layout, piping layout, and appurtenance details, are extremely important. They are, however, common to all geomembrane projects and therefore will be handled in Sections 5.10 and 5.11.

Although such large projects obviously warrant a careful design procedure, it does not follow that smaller projects do not deserve the same attention. Indeed, failures of small liner systems can be significant. Many warrant a design effort comparable to that of large projects, as illustrated in this section.

With this section behind us, we can now focus on other applications involving geomembranes. Where a similar analysis is called for, reference will be made back to this section. Thus only new and/or unique features of geomembrane projects will form the basis of the sections to follow.

5.4 COVERS FOR RESERVOIRS

Geomembrane covers are often used above the liquid surface of storage reservoirs. They are of fixed, floating, or suspended types.

5.4.1 Overview

There are a number of important reasons why liquid containment structures should be covered. These include: losses due to evaporation (up to 84% per year; see Cooley [45]), savings on chlorine treatment (for water reservoirs), savings on algae control chemicals (for water reservoirs), reduced air pollution (for reservoirs holding chemicals), reduced need for drainage and cleaning, increased safety against accidental drowning, protection from natural pollution entering the reservoir (e.g., animal excretion), and protection from intentional pollution (i.e., sabotage).

Obviously, a rigid roof structure could be constructed over the reservoir, but the costs involved are usually prohibitively high. At a far lower cost, both during initial construction or in a retrofitted system, is the use of an impermeable liner. All the materials

Attachment B 8/8

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

GSE* TECHNICAL NOTE

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*For environmental lining solutions... the world comes to GSE.**

GSE FrictionFlex* Application Data

GSE's FrictionFlex process provided the geomembrane industry's first textured liner. It is the only geomembrane texturing process ever to be granted a U.S. Patent. The FrictionFlex process begins with smooth GSE membrane that is manufactured to stringent industry standards. After the smooth surfaced sheet passes all GSE's standard quality assurance testing, texturing is added to one or both sides as required. The patented manufacturing process enables GSE to produce a textured liner exhibiting the outstanding mechanical and chemical properties demanded of GSE's premium grades of smooth geomembrane liners.

GSE geomembranes textured by the FrictionFlex process can be utilized to improve the factor of safety on steep slopes. This can increase facility design capacity, service life and ultimately, total revenue potential. GSE's textured geomembranes can be used to improve a number of applications.

GSE FrictionFlex geomembranes have an approximate six inch (15 cm) wide edge that remains smooth. This smooth edge means that GSE's seaming procedures are the same for FrictionFlex textured geomembranes and smooth geomembranes therefore requiring no changes in field quality control.

FrictionFlex liner has many performance benefits when in contact with soils and synthetics:

- High coefficient of friction with soils
- High coefficient of friction with other geosynthetic materials
- Premium grade mechanical and chemical properties
- Excellent narrow *and* wide width tensile elongation

The table below shows typical comparative data for smooth and FrictionFlex textured geomembranes. Testing was performed according to ASTM D 5321. GSE recommends that specific data be developed for all application designs. Shearbox testing of the specific geosynthetic and natural components of the composite is necessary to establish an appropriate design basis. GSE will be pleased to provide material samples for such purposes.

Friction Angle Comparison - Smooth vs. FrictionFlex Textured Geomembranes

	Smooth Geomembrane	GSE FrictionFlex Textured Liner Materials	
Material	Friction Angle (deg.)	Adhesion (lb/ft²)	Friction Angle (deg.)
Sandy Glacial Till	20	27	36
* Sandy Clay	18 *	65	35
Smooth Clay	16	39	32
Ottawa Sand	19	21	30
Non-woven Geotextile	12	133	33

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Attachment C

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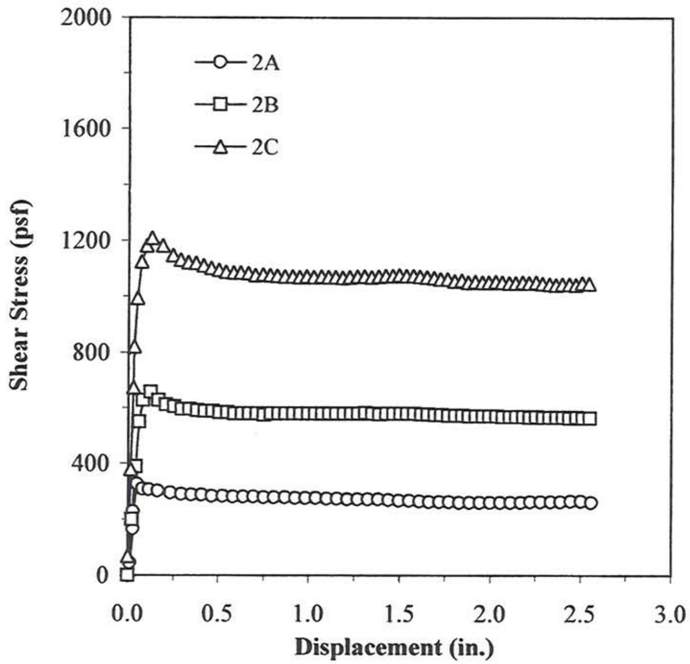
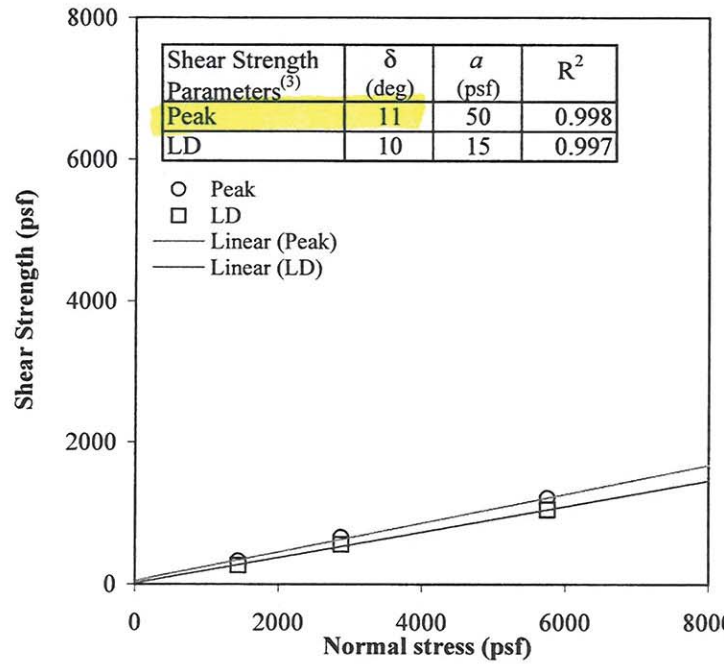
A Gundle/SLT Environmental, Inc. Company

GEOSYNTEC CONSULTANTS - INTERNATIONAL URANIUM CORP PROJECT
DIRECT SHEAR TESTING (ASTM D 5321)

Test Series Number 2: Woven side of Bentomat ST GCL (Lot # 200640LO/Roll #6397) in machine direction against black side of GSE 60-mil black/white smooth HDPE geomembrane (Roll # 105130507) in machine direction under soaked and consolidated conditions





Shear Strength Parameters[3]	δ (deg)	a (psf)	R^2
Peak	11	50	0.998
LD	10	15	0.997

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	GCL Soaking Stress (psf)	GCL Soaking Time (hour)	Consolidation[1] Stress (psf)	Consolidation[1] Time (hour)	Lower Soil γ_d (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_d (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_P (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
2A	12 x 12	1440	0.04	1440	24	1440	24	-	-	-	-	-	-	17.9	68.8	325	259	(2)
2B	12 x 12	2880	0.04	2880	24	2880	24	-	-	-	-	-	-	17.9	55.8	657	562	(2)
2C	12 x 12	5760	0.04	5760	24	5760	24	-	-	-	-	-	-	17.9	48.7	1211	1046	(2)

NOTES:

(1) The hydrated GCL specimen was placed on the geomembrane and consolidated together under each test normal stress for 24 hours prior to shearing. The test specimens were not submerged in water during consolidation.

(2) Sliding (i.e., shear failure) occurred at intended test interface in each test.

(3) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

SGI TESTING SERVICES, LLC

DATE OF TEST:	11/3 to 11/7/2006
FIGURE NO.	B-2
PROJECT NO.	SGI6014-03
DOCUMENT NO.	
FILE NO.	

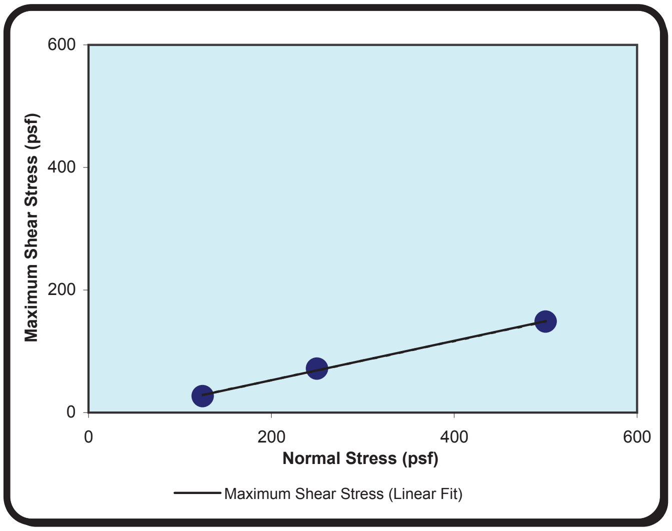
TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

INTERFACE FRICTION TEST REPORT

Client: **Agru**
Project: Anne Steacy
Test Date: 7/5-7/5/05

TRI Log#: E2201-75-03
Test Method: ASTM D 5321

Tested Interface: Agru 60 mil Studliner vs. Agru 60 mil Smooth Geomembrane



Upper Box: Agru 60 mil smooth Geomembrane

Lower Box: Agru 60 mil Studliner

Interface Conditioning: Interface soaked and loading applied for a minimum of 3 hours prior to shear

Box Dimension: 12"x12"x4"

Test Condition: Wet

Shearing Rate: 0.2 inches/minute

Trial Number	1	2	3
Bearing Slide Resistance (lbs)	9	10	13
Normal Stress (psf)	125	250	500
Maximum Shear Stress (psf)	36	82	161
Corrected Shear Stre	27	72	148
Secant Angle (degrees)	12.1	16.0	16.5

RESULTS: Maximum Friction Angle and Y-intercept

Regression Friction Angle (degrees): 16.2
Y-intercept or Regression Adhesion (psf): 0

Regression Line: Y= 0.290 * X + 0
Regression Coefficient (r squared): 0.986

Note: The regression line includes the origin.

John M. Allen, E.I.T., 07/11/2005
Quality Review/Date

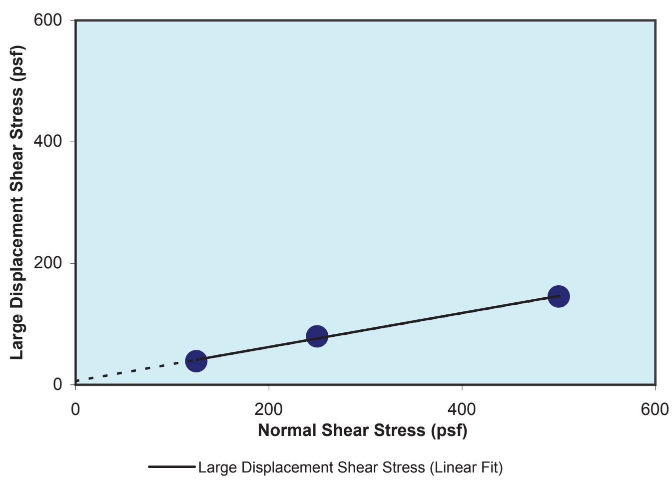
9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

INTERFACE FRICTION TEST REPORT

Client: **Agru**
Project: Anne Steacy
Test Date: 7/5-7/5/05

TRI Log#: E2201-75-03
Test Method: ASTM D 5321

Tested Interface: Agru 60 mil Studliner vs. Agru 60 mil Smooth Geomembrane



Upper Box: Agru 60 mil smooth Geomembrane

Lower Box: Agru 60 mil Studliner

Interface Conditioning: Interface soaked and loading applied for a minimum of 3 hours prior to shear

Box Dimension: 12"x12"x4"

Test Condition: Wet

Shearing Rate: 0.2 inches/minute

Trial Number	1	2	3
Bearing Slide Resistance (lbs)	9	10	13
Normal Stress (psf)	125	250	500
Large Displacment Shear Stress (psf)	48	90	158
Corrected Shear Stress (psf)	39	80	145
Secant Angle (degrees)	17.2	17.7	16.2

RESULTS: Large Displacement Friction Angle and Y-intercept at 3.5-in. of Displacement

Regression Friction Angle (degrees):		**15.7**		
Y-intercept or Regression Adhesion (psf):		**6**		
Regression Line:	Y=	0.281	* X +	6
Regression Coefficient (r squared):		0.997		

John M. Allen, E.I.T., 07/11/2005
Quality Review/Date

Large displacement shear stresses interperted at 2 inches of diplacement due to strain hardening effects.

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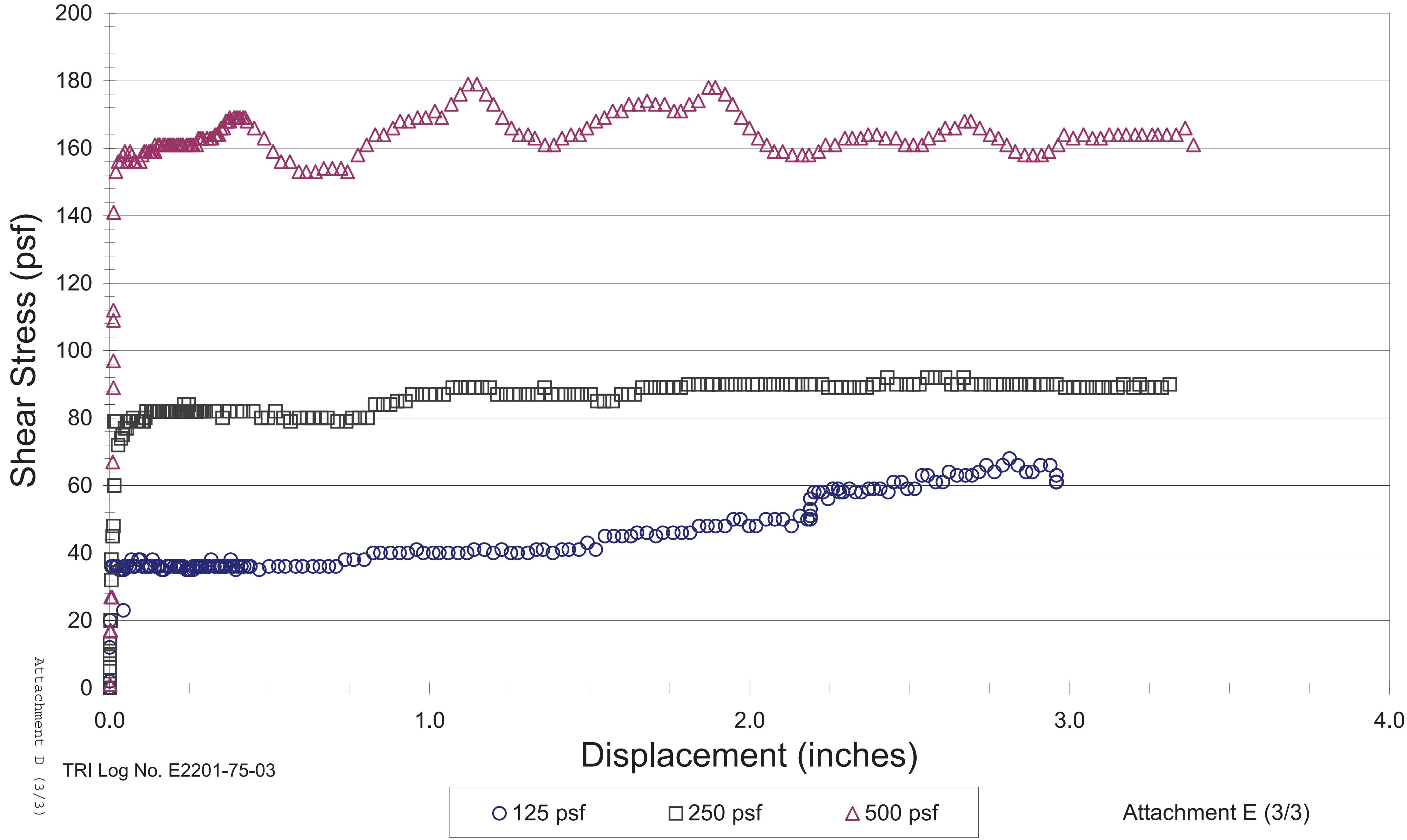
AGRU INTERFACE FRICTION TEST
Agru 60 mil Smooth Geomembrane vs. Agru 60 mil Studliner



TRI Log No. E2201-75-03

Attachment E (3/3)

Attachment D (3/3)

9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ FAX (512) 263-2558 □ 1-800-880-TEST

TABLE 5.3
TYPICAL PROPERTIES OF COMPACTED SOILS*

Group symbol	Soil type	Range of maximum dry unit weight, pcf	Range of optimum moisture, %	Typical value of compression: Percent of original height At 1.4 tsf (20 psi)	Typical value of compression: Percent of original height At 3.6 tsf (50 psi)	Typical strength characteristics: Cohesion (as compacted), psf	Typical strength characteristics: Cohesion (saturated), psf	Typical strength characteristics: Effective stress envelope φ, degrees	Typical strength characteristics: tan φ	Typical coefficient of permeability, ft/min	Range of CBR values	Range of subgrade modulus k, lb/in³
GW	Well-graded clean gravels, gravel-sand mixtures	125–135	11–8	0.3	0.6	0	0	>38	>0.79	5×10^{-2}	40–80	300–500
GP	Poorly graded clean gravels, gravel-sand mix	115–125	14–11	0.4	0.9	0	0	>37	>0.74	10^{-1}	30–60	250–400
GM	Silty gravels, poorly graded gravel-sand silt	120–135	12–8	0.5	1.1	...	...	>34	>0.67	$>10^{-6}$	20–60	100–400
GC	Clayey gravels, poorly graded gravel-sand-clay	115–130	14–9	0.7	1.6	...		>31	>0.60	$>10^{-7}$	20–40	100–300
SW	Well-graded clean sands, gravelly sands	110–130	16–9	0.6	1.2	0	0	38	0.79	$>10^{-3}$	20–40	200–300
SP	Poorly-graded clean sands, sand-gravel mix	100–120	21–12	0.8	1.4	0	0	37	0.74	$>10^{-3}$	10–40	200–300
SM	Silty sands, poorly graded sand-silt mix	110–125	16–11	0.8	1.6	1050	420	34	0.67	5×10^{-5} 2.54	10–40	100–300
SM-SC	Sand-silt clay mix with slightly plastic fines	110–130	15–11	0.8	1.4	1050	300	33	0.66	2×10^{-6} 1.07	...	
SC	Clayey sands, poorly graded sand-clay mix	105–125	19–11	1.1	2.2	1550	230	31	0.60	5×10^{-7} 2.54	5–20	100–300
ML	Inorganic silts and clayey silts	95–120	24–12	0.9	1.7	1400	190	32	0.62	10^{-5}	15 or less	100–200
ML-CL	Mixture of inorganic silt and clay	100–120	22–12	1.0	2.2	1350	460	32	0.62	5×10^{-7}	...	
CL	Inorganic clays of low to medium plasticity	95–120	24–12	1.3	2.5	1800	270	28	0.54	10^{-7}	15 or less	50–200
OL	Organic silts and silt-clays, low plasticity	80–100	33–21	...	...	...				...	5 or less	50–100
MH	Inorganic clayey silts, elastic silts	70–95	40–24	2.0	3.8	1500	420	25	0.47	5×10^{-7}	10 or less	50–100
CH	Inorganic clays of high plasticity	75–105	36–19	2.6	3.9	2150	230	19	0.35	10^{-7}	15 or less	50–150
OH	Organic clays and silty clays	65–100	45–21	...	...	...	...	...	...	...	5 or less	25–100

*[illegible] Manual DM 7 (1982).[5] All properties are for condition of "standard Proctor" maximum density, except [illegible] strength characteristics are for effective

GTC
11/23/05

1984

FI

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF** Project: **White Mesa Mill – Cells 5A and 5B** Project/ Proposal No.: Task No. **SC0634**

Title of Computations **EMERGENCY SPILLWAY CONCRETE PAVEMENT**

Computations by:	Signature		12/18/12 Date
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		12/20/12 Date
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations Checked by:	Signature		12/20/12 Date
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations backchecked by: (originator)	Signature		12/18/12 Date
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature		12/18/12 Date
	Printed Name	Gregory T. Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	WMM- Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	

EMERGENCY SPILLWAY CONCRETE PAVEMENT

OBJECTIVE

An emergency spillway will be constructed as part of Cell 5A and 5B construction at the White Mesa Mill, in Blanding, Utah for Energy Fuels (EF). The emergency spillways are 158 and 120 feet wide for Cells 5A and 5B, respectively, with approximately 19-foot wide access roads across the crest of the spillway. The emergency spillway is shown on Sheet 10 of the Construction Drawings prepared by Geosyntec Consultants. A pick-up truck design loading has been assumed for the pavement of the access road.

The design of the concrete slab will be performed in accordance with American Concrete Institute (ACI) Publications 318 and 360 standards (ACI 318 and ACI360). The objective of this design is to determine the dimensional, reinforcement, and concrete requirements necessary to withstand the applied loading.

SUMMARY OF DESIGN

Based on the assumptions and calculations presented herein, the slab on grade will be 6 inches thick and consist of concrete with compressive strength of 3,000 pounds per square inch (psi), and welded wire reinforcement (WWR) fabric sized as 6x6 – W1.4xW1.4.

ANALYSIS

Loading conditions

The loading conditions for the slab-on-grade for the emergency spillway is assumed to be a 12,000 lb loaded truck, which equates to an assumed 4,000 lb front axle loading and a maximum 8,000 lb rear axle loading. A wheel spacing of 60 inches was assumed.

To determine the required slab thickness, a Wire Reinforcement Institute (WRI) method, which simulates concentrated loads as the loading resulting from a single-axle, will be utilized. The method is presented in a report by ACI on the design of slabs on grade (ACI 360).

Written by:	**R. Flynn**	Date:	12/18/12	Reviewed by:	**G. Corcoran**	Date:	12/18/12
Client:	**EF**	Project:	**WMM- Cells 5A and 5B**	Project/ Proposal No.:	**SC0634**	Task No.:	

Slab on Grad Design Procedure

WRI presents a slab on grade thickness determination method based on the concentrated loads from the wheels of a forklift (ACI 360). The method accounts for the total axle load and each wheel individually. The method also takes into account the moments on the slab caused by the spacing of the wheels.

The determination of slab thickness can be made by following the example presented in Appendix A of the ACI 360. To utilize this method, some values and properties were required to be assumed. Modifications to the design may be required if the assumptions are determined to not be valid.

The design begins with the assumed values of:

- Concrete modulus (E_c) = 3,500 kips per square inch (ksi)
- Modified subgrade modulus (k_{12}) = 400 pounds per cubic inch (pci)
- Compressive strength of concrete (f_c') = 3,000 psi
- Modulus of rupture (MOR or f_r) = $7.5 \cdot \sqrt{f_c'} \approx 411 psi$
- Slab thickness = 6 inches

Note that 1 kip equals 1,000 lbs. The assumed modified subgrade modulus value is for a sandy soil (Attachment A). The compressive concrete strength, and therefore the modulus of rupture, can be specified when ordering concrete; this assumed value will not likely require modification. The value of 6 inches for the slab thickness is an arbitrary trial "guess", which will be validated or dispelled at the end of applying the method.

Figure A2.2.1 (Attachment B) is utilized to find the relative stiffness parameter (D/k) based on the above assumed values. The first trial results in a D/k value of 1.5 x 10^5 in^4.

Next, the contact area for each wheel must be converted to determine the diameter of a hypothetical circle that has the same area. A tire air pressure of 80 psi was assumed for a loaded truck. The following basic equations were used to determine the equivalent circle diameter:

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Client:	EF	Project:	WMM- Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	

Area of a circle:

$$A = \pi\left(\frac{D}{2}\right)^2$$

Where A is the area of the circle (based on tire pressure and tire load, Attachment E) and D is the diameter of the circle. Rearranging and solving for D:

$$D = 2\sqrt{\frac{A}{\pi}} = 2\sqrt{\frac{50\,in^2}{3.14}} = 8.0\ in$$

Therefore a circle with a 8.0-in. diameter has an area approximately equal to the contact area of one vehicle wheel (50-in^2).

Next, the distance between wheels on the axle must be incorporated into the design method. The length between the back two wheels on a pick-up truck is utilized to determine the equivalent forklift axle wheel spacing. This distance was assumed to be 60-in.

The equivalent wheel base, equivalent contact circle diameter, and the D/k value are then utilized to determine the basic bending moment in the slab (in-lb/in) that results per kip of wheel load applied. From Figure A2.2.2 (Attachment C), we see that the basic bending moment due to the two wheels is 200 plus 5 in-lb/in/kip, which results in a total moment of approximately 205 in-lb/in per kip stress. This value is multiplied by the "wheel" load to give the design moment. Based on a total vehicle operating weight of 10,000 lbs. The wheel load is:

$$\text{"}Wheel\,load\text{"} = \frac{Total\ axle\ weight}{\#\ of\ wheels} = \frac{8{,}000\,lbs}{2} = 4{,}000\frac{lbs}{wheel} = 4.0\frac{kip}{wheel}$$

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Client: EF	Project: WMM- Cells 5A and 5B		Project/ Proposal No.:	SC0634	Task No.:

Multiplying the basic moment by the "wheel load", the resulting design moment is:

$$Design\ moment = basic\ moment \times wheel\ load = \left(205\frac{\frac{in-lb}{in}}{kip}\right) \times (4.0\,kip) = 820\frac{in-lb}{in}$$

This design moment and the total allowable flexural stress are utilized to assess if the initial guess for slab thickness is valid. The total allowable flexural stress is the MOR (f_r) divided by a safety factor (SF). For concentrated loads, ACI 360 recommends a SF value between 1.7 and 2.0. For this design, the lower value of 1.7 will be utilized. The 1.7 SF value results in a total allowable tensile stress of:

$$\frac{MOR}{SF} = \frac{411\,psi}{1.7} = 242\,psi$$

Using this MOR/SF value and the design stress with Figure A2.2.3 (Attachment D), we check to see if our initial concrete thickness guess was accurate. With the values calculated above, we see that the resulting thickness is approximately 5 in. The calculations and resulting values are summarized in a spreadsheet, presented on Attachment E.

Temperature & Shrinkage Reinforcement Design

The subgrade drag equation (ACI 360) is used to determine the minimum area of steel reinforcement required to prevent temperature and shrinkage cracking:

$$A_{s,\min} = \frac{F \cdot L \cdot w}{2 \cdot f_s}$$

Where the variables are defined as follows:

$A_{s,min}$ = *minimum cross-sectional area of steel per foot width concrete*
F = *subgrade friction factor, for granular subbase = 1.5* *(Section 6.3))*

Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client: EF		Project:	WMM- Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	

L = *distance between joints in slab* = *15 ft*
w = *dead weight of slab, 12.5 lb per inch of 6-in. slab* = *75 lbs*
f_y = *yield strength of reinforcement steel, ASTM A610* = *60,000 psi*
f_s = *allowable tensile strength of reinforcement* ($.75f_y$) = *45,000 psi*

Substitution of variables in the preceding equation yields:

$$A_{s,\min} = \frac{(1.5)\cdot(15\text{ ft})\cdot(75\text{ lb})}{(2)\cdot(45{,}000\text{ psi})} = 0.019\text{ in}^2/\text{ft}$$

The result indicates that a minimum reinforcement area of 0.019-in^2 must be provided per each foot of slab length and width. This value is lower than the A_s value provided by the narrowest rebar (#3) at the maximum recommended spacing (18-in.), which provides an A_s value of 0.073-in (By ACI 318 standards, reinforcement spacing must not exceed 18-in. or the lesser of three times the slab thickness (also 18-in.). According to the WRI Manual of Standard Practice (WRI Manual), if welded reinforcement wire (WWR) were to be utilized, the product size denoted as 6x6 – W1.4xW1.4 would provide an A_s value of 0.028-in^2 (Attachment F). This value slightly exceeds the required $A_{s,min}$ value of 0.019-in^2, and requires considerably less steel than the minimum value provided if rebar were to be used. The WWR 6x6 – W1.4xW1.4 will be utilized.

The development length of the reinforcement steel must be checked to determine whether or not the steel has a chance to fully develop its tensile strength. According to Table 7 of the WRI Manual (Attachment G), the typical minimum development length for 6x6 – W1.4xW1.4 WWR is 8 inches.

REFERENCES

American Concrete Institute, *Design of Slabs on Grade (ACI 360R-92),* ACI: Farmington Hills, Michigan 1997.

Wire Reinforcement Institute, Incorporated, *Manual of Standard Practice: Structural Welded Wire Reinforcement,* WWR-500, 6th Edition, 2001

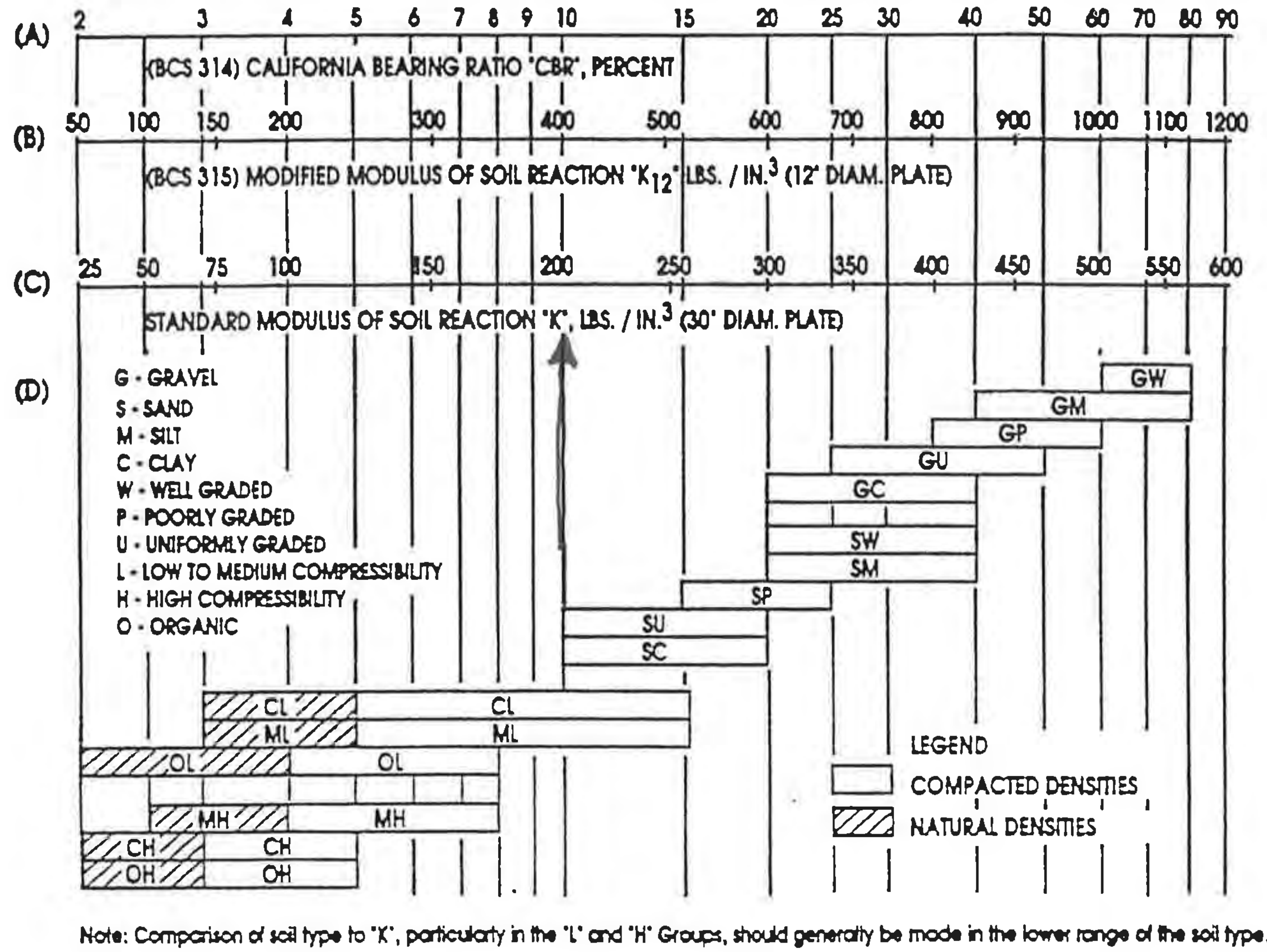


Fig. 3.3.5—Interrelationship of soil classifications and strengths (from Reference 23)

sand or gravel fill, or use the existing material in its in-situ condition.

Normally there is a wide range of soils across the site. The soil support system is rarely uniform. Therefore, some soil work is generally required to provide a more uniform surface to support the slab. The extent of this work, such as the degree of compaction or the addition of a sand-gravel base, is generally a problem of economics. Selection of soils in the wellgraded gravel (GW) and poorly graded gravel (GP) groups as a base material may appear costly. However, the selection of these materials has distinct advantages. Not only do they provide a superior modulus of subgrade reaction, but they also tend to speed construction during inclement weather.

3.4.2 *Economics and simplified design*—Certainly not all projects will require all of the data discussed above. On projects where the slab performance is not critical, engineering judgement should be exercised to reduce costs. A prime prerequisite for the proper design of a slab support system is soils identification. Without this knowledge, the modulus of subgrade reaction is unknown and potential volume change cannot be determined. With knowledge of soil classification, the engineer can select an appropriate k value and design for the specific soil conditions.

For small projects, it may be advantageous to assume a low k factor and add a selected thickness of crushed stone to enhance the safety factor rather than performing an expensive soil analysis. Use of the modified modulus of subgrade reaction test rather than the standard modulus test can also reduce costs. Risk of slab failure at an earlier age increases as the design is rationalized but there are occasions where the simplified design approach is justified. These decisions are a matter of engineering judgment and economics.

Compounding safety factors is a common error. Inclusion of safety factors in the modulus of subgrade reaction, the applied loads, the compressive strength of the concrete, the flexural strength of the concrete and the number of load repetitions will produce an expensive design. The safety factor is normally contained in the flexural strength of the concrete and is a function of the number of load repetitions (see Sec. 4.9).

3.5—Site preparation

3.5.1 *Introduction*—Prior to soil compaction, the top

ATTACHMENT A

CHAPTER A2—SLAB THICKNESS DESIGN BY WRI METHOD

A2.1—Introduction

The following two examples show the determination of thickness for a slab on grade intended to have mild steel reinforcement for shrinkage and temperature stresses. The amount of steel is commonly selected using the subgrade drag theory presented in Chapter 6 and discussed in Reference 53.

The design charts are for a single axle loading with two single wheels and for the controlling moment in an aisle with uniform loading on either side. The first situation is controlled by tension on the bottom of the slab and the second is controlled by tension on the top of the slab. Both procedures start with use of a relative stiffness term *D/k*, and require the initial assumption of the concrete modulus of elasticity *E* and slab thickness *H*, as well as selecting the allowable tensile unit stress and the appropriate subgrade modulus *k*.

A2.2—WRI thickness selection for single-axle wheel load

This procedure selects the concrete slab thickness for a single axle with wheels at each end of the axle, using Fig. A2.2.1, A2.2.2, and A2.2.3. The procedure starts with Fig. A2.2.1 where a concrete modulus of elasticity *E* and slab thickness *H*, and modulus of subgrade reaction *k* are assumed or known. For example, taking

E = 3000 ksi
Thickness = 8 in. (trial value)
Subgrade modulus k = 400 pci

Fig. A.2.2.1 gives the relative stiffness parameter $D/k = 3.4 \times 10^5$ in.^{4} The procedure then uses Fig. A2.2.2.
Wheel Contact Area = 28 sq in.

Diameter of equivalent circle = $\sqrt{[28 x 4]/\pi}$
= 6 in.

Wheel spacing = 45 in.

This gives the basic bending moment of 265 in.-lb/in. of width/kip of wheel load for the wheel load using the larger design chart in Fig. A2.2.2. The smaller chart in the figure gives the additional moment due to the other wheel as 16 in.-lb per in. of width per kip of wheel load.
Moment = 265 + 16 = 281 in.-lb/in./kip
(Note that in.-lb/in. = ft-lb/ft)

Axle Load = 14.6 kips
Wheel Load = 7.3 kips

Design Moment = 281 x 7.3 = 2051 ft-lb/ft

Then from Fig. A2.2.3:
Allowable tensile stress = 190 psi

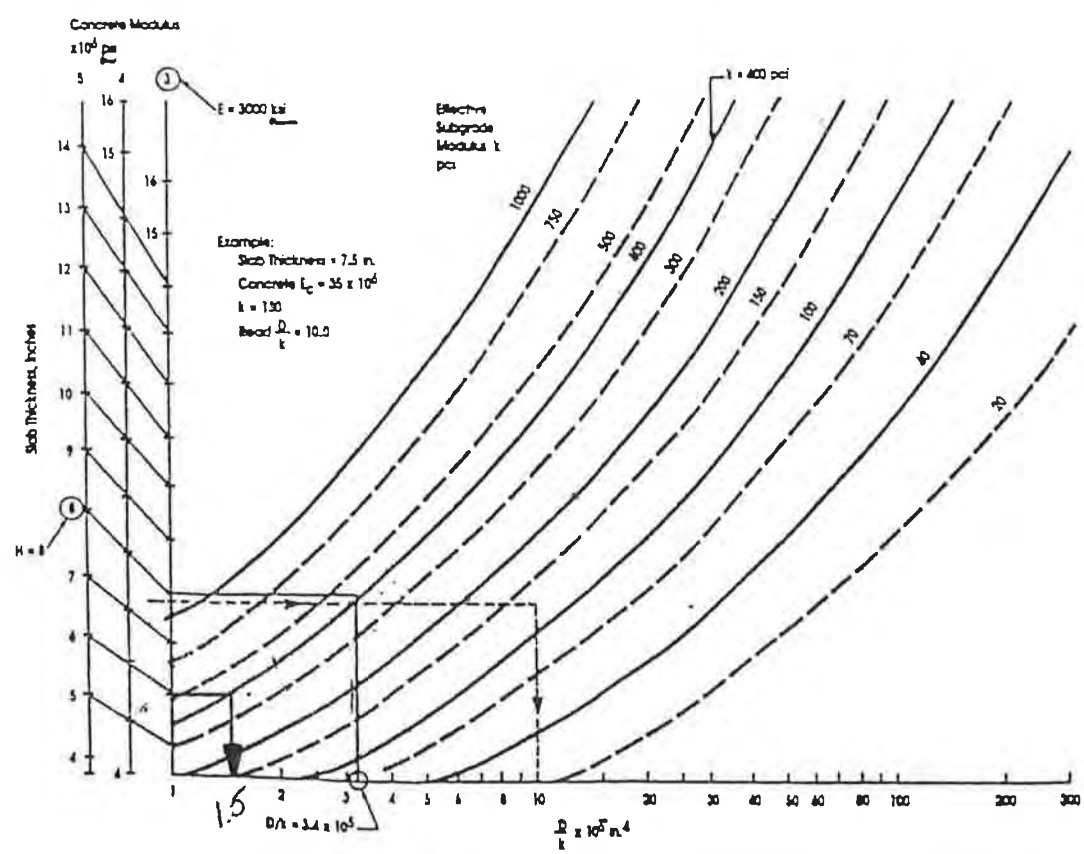


Fig. A2.2.1—Subgrade and slab stiffness relationship, used with WRI design procedure

ATTACHMENT B

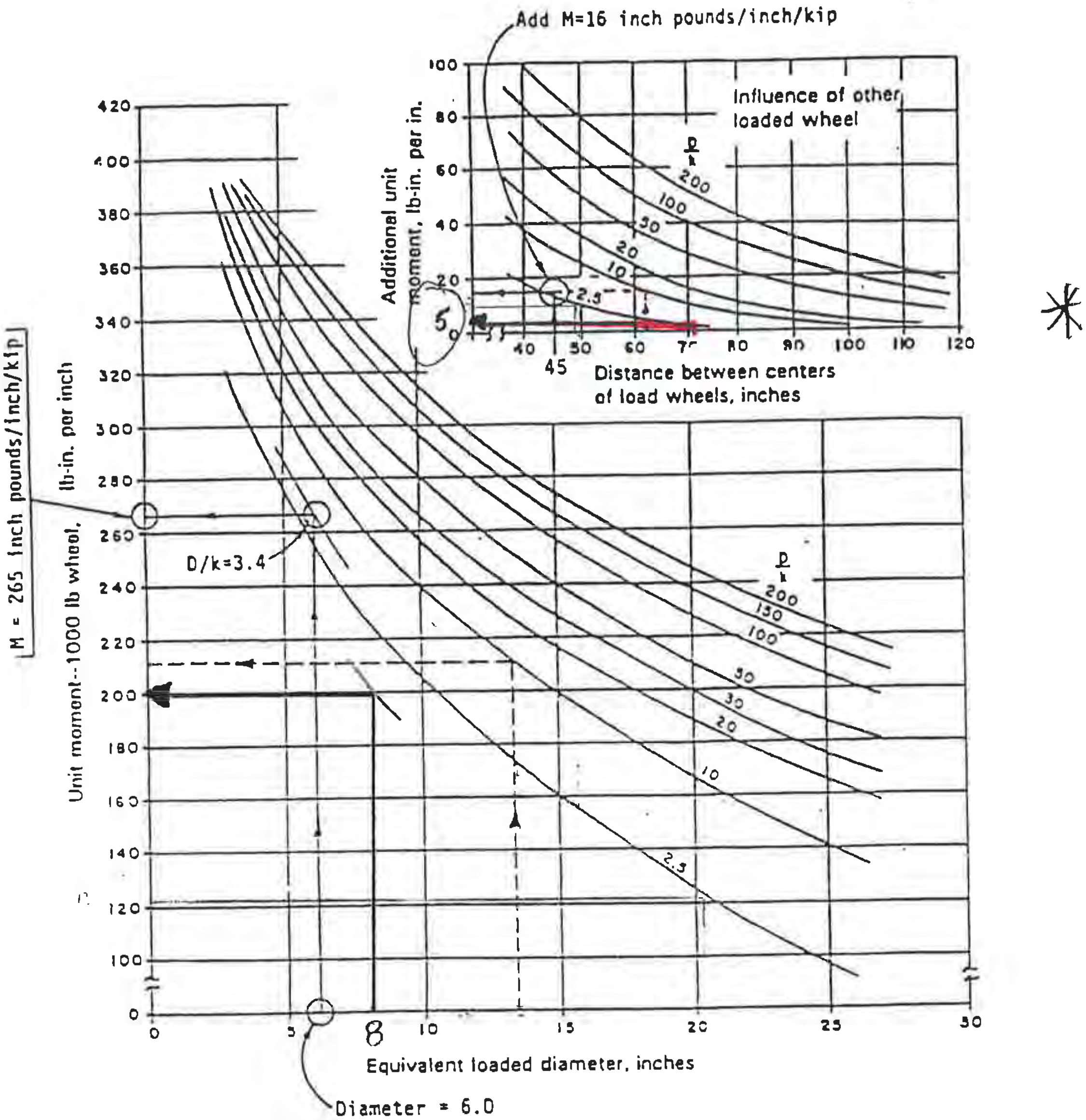


Fig. A2.2.2—Wheel loading design chart used with WRI procedure

Solution:
Slab thickness (H) = 7 7/8 in.

If the design thickness differs substantially from the assumed thickness, the procedure is repeated with a new assumption of thickness.

A2.3—WRI thickness selection for aisle moment due to uniform loading

The procedure for the check of tensile stress in the top of the concrete slab due to this loading uses Fig. A2.2.1 and A2.3. Note that Fig. A2.2.3 is a part of Fig. A2.3., separated here for clarity of procedure.

The procedure starts as before with determination of the term $D/k = 3.4 \times 10^5$ in.[4] It then goes to Fig. A2.3 as follows:

Aisle width = 10 ft = 120 in.
Uniform load = 2500 psf = 2.5 ksf
Allowable tension = MOR/SF = 190 psi

The solution is found by plotting up from the aisle width to D/k, then to the right-hand plot edge, then down through the uniform load value to the left-hand edge of the next plot, then horizontally to the allow-able stress and down to the design thickness.

Solution: Thickness = 8.0 in.

Again, if the design thickness differs substantially from the assumed value, the process should be repeated until reasonable agreement is obtained.

A2.4—Comments

These procedures assume the use of conventional steel reinforcement in the concrete slab. The applied moments from the loads are not used in selecting the steel reinforcement except in the case of a Type F structurally reinforced slab.

ATTACHMENT C

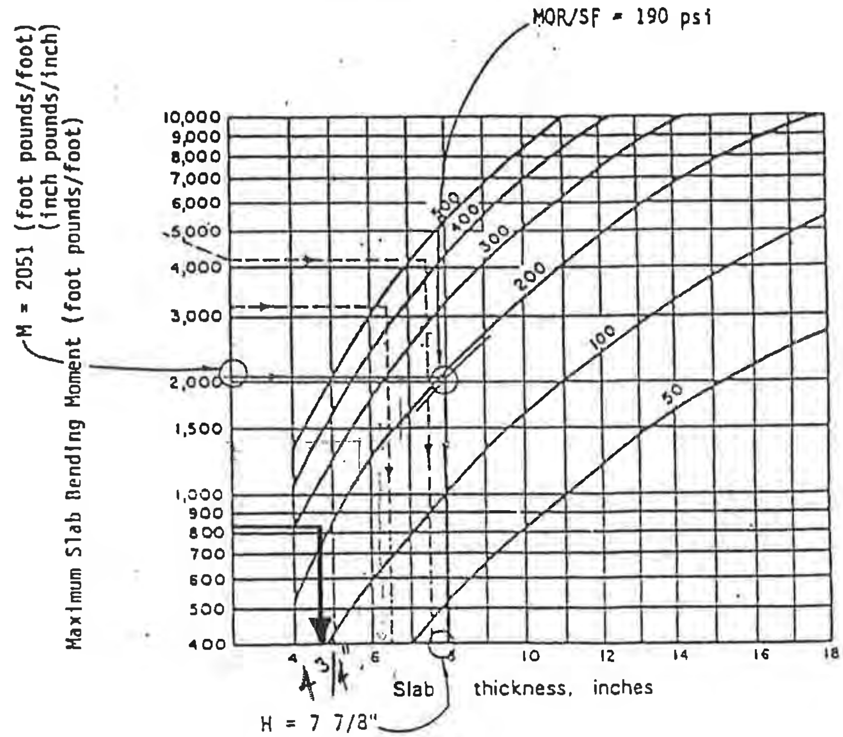


Fig. A2.2.3—Slab tensile stress charts used with WRI design procedure

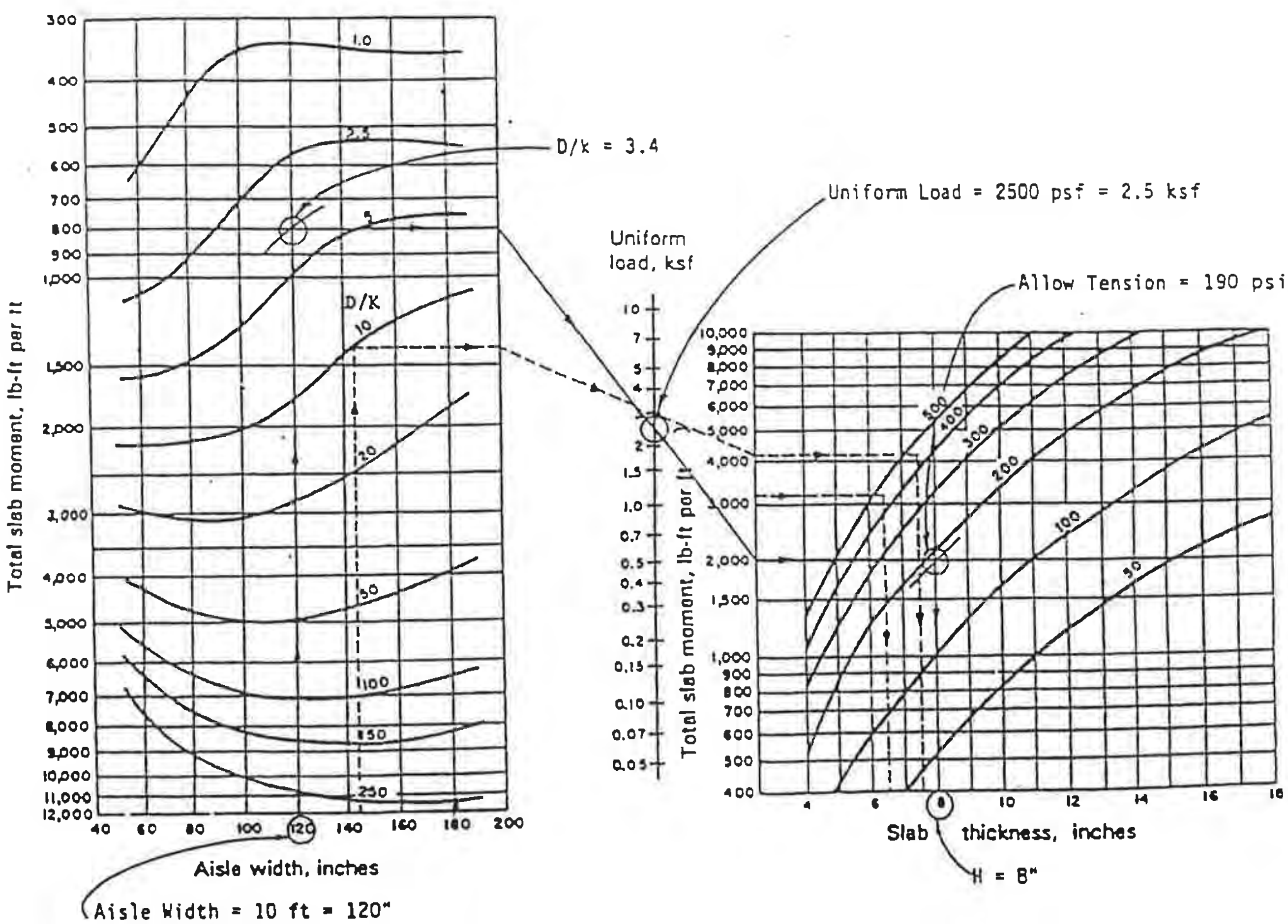


Fig. A2.3—Uniform load design and slab tensile stress charts used with WRI design procedure

ATTACHMENT D

Slab Design Thickness Determination

	Trial 1	Trial 2	Trial 3		
Wheel spacing =	**60**	**60**	**60**	**in**	*distance between wheels on same axle
Total working vehicle weight =	12,000	12,000	12,000	lb	Assume Pick-up Truck Loading
Rear Axle Load =	8,000	8,000	8,000	lb	Assume Pick-up Truck Loading
"Axle" load =	8.0	8.0	8.0	kip	rear axle
"Wheel" load =	4.0	4.0	4.0	kip	half of axle load
Wheel Tire Pressure =	80.0	80.0	80.0	psi	80 to 120 psi for pneumatic tires
Wheel Contact area =	50.0	50.0	50.0	sq in	
Wheel Equivalent Diameter =	8.0	8.0	8.0	in	
Concrete modulus (E) =	3,500	3,500	3,500	ksi	
Compressive strength of concrete ($f'c$) =	3,000	3,500	4,000	psi	
Subgrade Modulus (k) =	400	400	400	pci	Fig 3.3.5
Concrete Modulus of Rupture (MOR, f_r) =	411	444	474	psi	
Safety Factor (SF) =	1.7	1.7	1.7	---	
Allowable tensile stress (MOR/SF) =	242	261	279	psi	

WRI Method - Single Axle Wheel Load

	Units	Trial 1	Trial 2	Trial 3	
Trial Thickness =	in	6.0	6.0	6.0	
Stiffness parameter (D/k) =	x 10^{-5} in^4	1.5	1.5	1.5	(from Fig A2.2.1)
Basic bending moment per kip stress =	in-lb/in/kip	200	200	200	(from Fig A2.2.2)
Moment due to other wheel =	in-lb/in/kip	5	5	5	(from Fig A2.2.2)
Total moment per kip stress =	in-lb/in/kip	205	205	205	
Design moment =	in-lb/in	820	820	820	
SLAB THICKNESS =	**in**	**5.0**	**4.5**	**4.5**	(from Fig. A2.2.3)

**Highlighted values are calculated from other entered values.*

6-in. is an acceptable design slab thickness.

ATTACHMENT E

Slab Design Thickness Determination

	Trial 1	Trial 2	Trial 3		
Wheel spacing =	**72**	**72**	**72**	**in**	*distance between wheels on same axle
Total working vehicle weight =	12,000	12,000	12,000	lb	Assume Pick-up Truck Loading
Rear Axle Load =	8,000	8,000	8,000	lb	Assume Pick-up Truck Loading
"Axle" load =	8.0	8.0	8.0	kip	rear axle
"Wheel" load =	4.0	4.0	4.0	kip	half of axle load
Wheel Tire Pressure =	80.0	80.0	80.0	psi	80 to 120 psi for pneumatic tires
Wheel Contact area =	50.0	50.0	50.0	sq in	
Wheel Equivalent Diameter =	8.0	8.0	8.0	in	
Concrete modulus (E) =	3,500	3,500	3,500	ksi	
Compressive strength of concrete ($f'c$) =	3,000	3,500	4,000	psi	
Subgrade Modulus (k) =	400	400	400	pci	Fig 3.3.5
Concrete Modulus of Rupture (MOR, f_r) =	411	444	474	psi	
Safety Factor (SF) =	1.7	1.7	1.7	---	
Allowable tensile stress (MOR/SF) =	242	261	279	psi	

WRI Method - Single Axle Wheel Load

		Trial			
	Units	*1*	*2*	*3*	
Trial Thickness =	in	6.0	6.0	6.0	
Stiffness parameter (D/k) =	x 10^{-5} in^4	1.5	1.5	1.5	(from Fig A2.2.1)
Basic bending moment per kip stress =	in-lb/in/kip	200	200	200	(from Fig A2.2.2)
Moment due to other wheel =	in-lb/in/kip	5	5	5	(from Fig A2.2.2)
Total moment per kip stress =	in-lb/in/kip	205	205	205	
Design moment =	in-lb/in	820	820	820	
SLAB THICKNESS =	**in**	**5.0**	**4.5**	**4.5**	(from Fig. A2.2.3)

**Highlighted values are calculated from other entered values.*

6-in. is an acceptable design slab thickness.

ATTACHMENT E

Sectional Areas of Welded Wire Reinforcement

TABLE 5 Customary Units

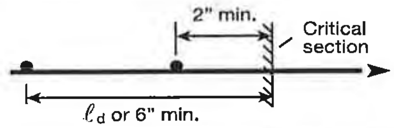
Wire Size Number		Nominal Diameter	Nominal Weight	As - Square Inch Per Linear Feet *Center to Center Spacing*								
Plain	*Deformed*	*Inches*	*Lbs./Lin. Ft.*	2"	3"	4"	6"	8"	10"	12"	16"	18"
W45	D45	0.757	1.530	2.70	1.80	1.35	.909	.68	.54	.45	.34	.30
W31	D31	0.628	1.054	1.86	1.24	.93	.62	.47	.37	.31	.23	.21
W20	D20	0.505	.680	1.20	.80	.60	.40	.30	.24	.20	.15	.13
W18	D18	0.479	.612	1.08	.72	.54	.36	.27	.216	.18	.14	.12
W16	D16	0.451	.544	.96	.64	.48	.32	.24	.192	.16	.12	.11
W14	D14	0.422	.476	.84	.56	.42	.28	.21	.168	.14	.11	.09
W12	D12	0.391	.408	.72	.48	.36	.24	.18	.144	.12	.09	.08
W11	D11	0.374	.374	.66	.44	.33	.22	.165	.132	.11	.08	.07
W10.5		0.366	.357	.63	.42	.315	.21	.157	.126	.105	.08	.07
W10	D10	0.357	.340	.60	.40	.30	.20	.15	.12	.10	.08	.07
W9.5		0.348	.323	.57	.38	.285	.19	.142	.114	.095	.07	.06
W9	D9	0.338	.306	.54	.36	.27	.18	.135	.108	.09	.07	.06
W8.5		0.329	.289	.51	.34	.255	.17	.127	.102	.085	.06	.06
W8	D8	0.319	.272	.48	.32	.24	.16	.12	.096	.08	.06	.05
W7.5		0.309	.255	.45	.30	.225	.15	.112	.09	.075	.056	.05
W7	D7	0.299	.238	.42	.28	.21	.14	.105	.084	.07	.053	.047
W6.5		0.288	.221	.39	.26	.195	.13	.097	.078	.065	.048	.043
W6	D6	0.276	.204	.36	.24	.18	.12	.09	.072	.06	.045	.04
W5.5		0.265	.187	.33	.22	.165	.11	.082	.066	.055	.041	.037
W5	D5	0.252	.170	.30	.20	.15	.10	.075	.06	.05	.038	.033
W4.5		0.239	.153	.27	.18	.135	.09	.067	.054	.045	.034	.03
W4	D4	0.226	.136	.24	.16	.12	.08	.06	.048	.04	.03	.027
W3.5		0.211	.119	.21	.14	.105	.07	.052	.042	.035	.026	.023
W3		0.195	.102	.18	.12	.09	.06	.045	.036	.03	.023	.02
W2.9		0.192	.098	.174	.116	.087	.058	.043	.035	.029	.022	.019
W2.5		0.178	.085	.15	.10	.075	.05	.037	.03	.025	.019	.017
W2.1		0.161	.070	.13	.084	.063	.042	.032	.025	.021	.016	.014
W2		0.160	.068	.12	.08	.06	.04	.03	.024	.02	.015	.013
W1.4		0.134	.049	.084	.056	.042	.028	.028	.017	.014	.011	.009

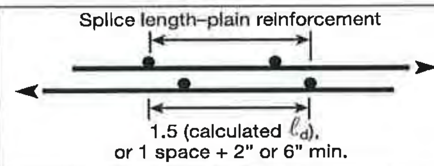
Note: For other available wire sizes other than those listed, contact your nearest WWR manufacturer.

ATTACHMENT F

TABLE 7 Customary Units (in.)
Welded Plain Wire Reinforcement

Typical Development and Splice Lengths, inches
f_y = 60,000 psi f'_c = 4,000 psi





WIRES TO BE DEVELOPED OR SPLICED		Development length when cross-wire spacing is:				Splice length when cross-wire spacing is:			
Wire Size	**Sw, spacing in.**	**4"**	**6"**	**8"**	**12"**	**4"**	**6"**	**8"**	**12"**
W1.4 to W5	4	6	8	10	14	6	8	10	14
	6	6	8	10	14	6	8	10	14
	12	6	8	10	14	6	8	10	14
W6	4	6	8	10	14	6	8	10	14
	6	6	8	10	14	6	8	10	14
	12	6	8	10	14	6	8	10	14
W7	4	6	8	10	14	7	8	10	14
	6	6	8	10	14	6	8	10	14
	12	6	8	10	14	6	8	10	14
W8	4	6	8	10	14	8	8	10	14
	6	6	8	10	14	6	8	10	14
	12	6	8	10	14	6	8	10	14
W9	4	6	8	10	14	9	10	10	14
	6	6	8	10	14	6	8	10	14
	12	6	8	10	14	6	8	10	14
W10	4	7	8	10	14	10	10	10	14
	6	6	8	10	14	7	8	10	14
	12	6	8	10	14	6	8	10	14
W12	4	8	8	10	14	12	12	12	14
	6	6	8	10	14	8	8	10	14
	12	6	8	10	14	6	8	10	14
W14	4	9	9	10	14	14	14	14	14
	6	6	8	10	14	9	9	10	14
	12	6	8	10	14	6	8	10	14
W16	4	11	11	11	14	16	16	16	16
	6	7	8	10	14	11	11	11	14
	12	6	8	10	14	6	8	10	14
W18	4	12	12	12	14	18	18	18	18
	6	8	8	10	14	12	12	12	14
	12	6	8	10	14	6	8	10	14
W20	4	13	13	13	14	20	20	20	20
	6	9	9	10	14	13	13	13	14
	12	6	8	10	14	8	8	10	14
W31	4	20	20	20	20	30	30	30	30
	6	14	14	14	14	20	20	20	20
	12	7	8	10	14	10	10	10	14
W45	4	29	29	29	29	44	44	44	44
	6	19	19	19	19	29	29	29	29
	12	10	10	10	10	15	15	15	15

ATTACHMENT G (1/1)

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF** Project: **White Mesa Mill – Cells 5A and 5B** Project/ Proposal No.: **SC0634** Task No. **02**

Title of Computations **GEOMEMBRANE TENSION DUE TO WIND UPLIFT**

Computations by:	Signature	[signature]	12/18/12 Date
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature	[signature]	12/20/12 Date
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations Checked by:	Signature	[signature]	12/20/12 Date
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations backchecked by: (originator)	Signature	[signature]	12/18/12 Date
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature	[signature]	12/18/12 Date
	Printed Name	Gregory Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	11/12/12	Reviewed by:	G. Corcoran	Date:	12/10/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

GEOMEMBRANE TENSION DUE TO WIND UPLIFT
WHITE MESA MILL
BLANDING, UTAH

OBJECTIVE

The project includes the installation of a triple liner system within Cells 5A and 5B at the White Mesa Mill in Blanding, Utah. Both Cells will have the same proposed liner system as shown in Attachment A. The objective of this calculation is to evaluate tension in the primary geomembrane on the exposed side slopes due to wind uplift. Two conditions are evaluated: the interim condition and the final condition. The interim condition corresponds to the construction period when the geomembranes may be secured within the anchor trench with a partial backfill until all layers are placed and secured in the final anchor trench.

The input variables, slope length, liner type, elevation, etc, which create the greatest tension in the geomembrane was evaluated in the design of both Cells 5A and 5B. The method outlined by Giroud, et al (1995) will be employed herein. Tension generated by wind uplift will be used to design the anchor trench capacity (see companion calculation package titled, *Evaluation of Liner System Anchor Trench Capacity*)

SITE CONDITIONS

The side slope liner system considered in the wind uplift calculation consists (from top to bottom) of:

- 60-mil (1.5 mm) HDPE geomembrane;
- 60-mil HDPE Drain Liner™ geomembrane;
- 60-mil HDPE Drain Liner™ geomembrane; and
- Prepared subgrade.

The capacity of the anchor trench is determined in a separate calculation package.

Written by:	R. Flynn	Date:	11/12/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

ANALYSIS

The analysis will follow the method outlined by Giroud, et al., in "Uplift of Geomembrane by Wind" (Attachment B). Giroud et al. offer the following equation for estimating the effective suction on a geomembrane (Attachment B):

$$S_e = 0.050\lambda V^2 e^{-[1.252\times10^{-4}]z} - 9.81\mu_{GM}$$ (Attachment B, 1/6)

where: S_e = effective suction (Pa)

λ = suction factor (dimensionless)

V = wind velocity (km/h)

z = altitude above sea level (m)

μ_{GM} = mass per unit area of geomembrane (kg/m^2)

Evaluate Variables

Interim Conditions		Final Conditions	
λ	Suction factor = 0.70 for the entire side slope being considered (Attachment B, page 2)	λ	Suction factor = 0.70 for the entire side slope being considered (Attachment B, page 2)
V	75% of Maximum Wind Speed = 25 x 0.75 mph = 30.2 km/h (IUC, 2003, see Attachment C) 1	V	maximum wind velocity = 25 mph = 40.2 km/h (IUC, 2003, see Attachment C)
z	altitude above sea level (m) A minimum elevation for the base side slopes is approximately 5,542 ft = 1689 meters (Cell 5B bottom elevation)	z	altitude above sea level (m) A minimum elevation for the base side slopes is approximately 5,542 ft = 1689 meters (Cell 5B bottom elevation)
μ_{GM}	mass per unit area of geomembrane (kg/m^2) μ_{GM} = 1.41 kg/m^2 (Attachment B, page 3/6)	μ_{GM}	mass per unit area of geomembrane (kg/m^2) μ_{GM} = 1.41 kg/m^2 (Attachment B, page 3/6)

Written by:	R. Flynn	Date:	11/12/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

Evaluate Suction

$S_e = 0.050(0.70)(30.2)^2 e^{-(1.252x10^{-4})1689} - 9.81(1.41)$	$S_e = 0.050(0.70)(40.2)^2 e^{-(1.252x10^{-4})1689} - 9.81(1.41)$
$S_e = 12.0\ Pa$	$S_e = 31.9\ Pa$

The maximum height of the exposed slope (2H:1V) is approximately 46 vertical feet, so the total length of exposed slope, L, is $L = \sqrt{46^2 + (2(46))^2} = 103\ \text{ft} = 31\ \text{m}$ (see Attachment A for the conceptual base grading plan). Therefore the resultant force of the applied effective suction becomes:

Interim Condition	Final Condition
$S_e L = 12.0 \frac{N}{m^2}(31\ m) \times \frac{1kN}{1000N} = 0.37 \frac{kN}{m}$	$S_e L = 31.9 \frac{N}{m^2}(31\ m) \times \frac{1kN}{1000N} = 0.99 \frac{kN}{m}$

EVALUATION OF TENSION IN GEOMEMBRANE

Geomembrane Properties

The geomembrane properties needed for the calculations herein are tensile stiffness and strain. These values are chosen from manufacturer data for 60-mil HDPE smooth geomembrane (Attachment D). The tensile strength and elongation at yield for a 60-mil, smooth HDPE geomembrane are 132 ppi (23.1 kN/m) and 13%, respectively (Attachment D).

The objective of this analysis is to evaluate wind induced tension in the geomembrane. Tension and strain in the geomembrane are linked by the following relationship, which is applicable to the initial portion of the tension-strain curve of the geomembrane which has been assumed to be linear:

Written by:	R. Flynn	Date:	11/12/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

$T = J\varepsilon$ (Attachment B, page 5)

where: T = Tension

J = Stiffness

ε = Strain

To evaluate tension, we need to first evaluate stiffness and strain.

Stiffness, J

The tensile stiffness is given by:

$J = Et_{GM}$

where: E = Elastic Modulus

= 450 MPa, this modulus value corresponds to wide-width tension values, according to Koerner (1998, Attachment E)

t_{GM} = Geomembrane Thickness

= 1.5×10^{-3} m (60 mil)

Therefore:

$J = (450\text{ MPa})(0.0015\text{ m}) = 675\text{ kN/m}$

Strain, ε

The strain on the geomembrane induced by wind uplift loading can be estimated using Table 4 (Attachment B, 6/6):

Written by:	R. Flynn	Date:	11/12/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

Interim Condition	Final Condition
$\frac{J}{S_e L} = \frac{675}{0.37} = 1824$, and from Table 4 (Attachment B, pg. 6), $\varepsilon = 0.24\%$	$\frac{J}{S_e L} = \frac{675}{0.99} = 682$, and from Table 4 (Attachment B, pg. 6), $\varepsilon = 0.46\%$

Therefore, the tension in the geomembrane is:

Interim Condition	Final Condition
$T = J\varepsilon = 675\frac{kN}{m}(0.0024) = 1.62\frac{kN}{m}$ $= 9.2\text{ ppi}$	$T = J\varepsilon = 675\frac{kN}{m}(0.0046) = 3.11\frac{kN}{m}$ $= 17.7\text{ ppi}$

CONCLUSIONS

Based on the calculation performed herein, the geomembrane is acceptable for a wind speed of 18.75 mph (75% of 25 mph) for the interim condition and 25 mph for the final condition, both with a slope length of approximately 103 ft (31 m). The tension in the geomembrane under the design conditions is 9.2 ppi (interim) and 17.7 ppi (final).

The capacity of the anchor trench is determined in a separate calculation package.

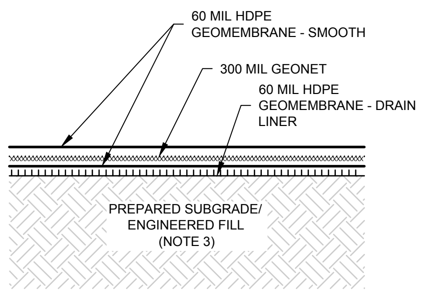
REFERENCES

Giroud, J.P., Pelte., Bathurst, R.J. 1995. *Uplift of Geomembranes by Wind*, Geosynthetic International, Vol. 2, No. 6, pg. 897-952. *(Attachment B)*

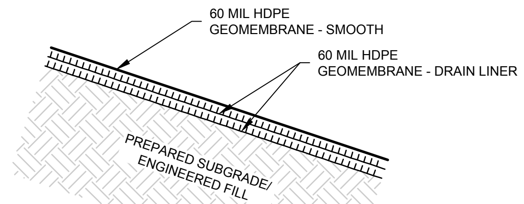
International Uranium (USA) Corporation (IUC). 2003. *Environmental Report*. June 20, 2003, page 3-3. *(Attachment C)*

Geosynthetic Research Institute. 2003. GRI Test Method GM13, Standard Specification for "Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes." Revision 5: May 15, 2003. *(Attachment D)*

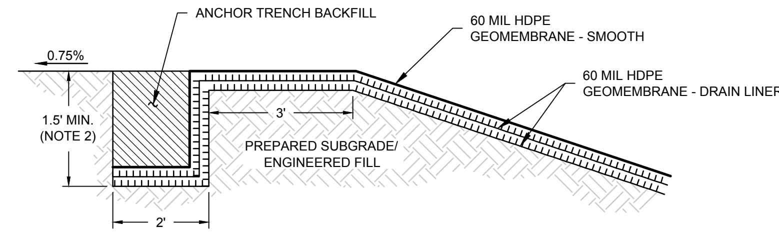
Koerner, R.M. 1998. *Designing with Geosynthetics*, 4th Edition. Prentice-Hall: Upper Saddle River, NJ. *(Attachment E)*



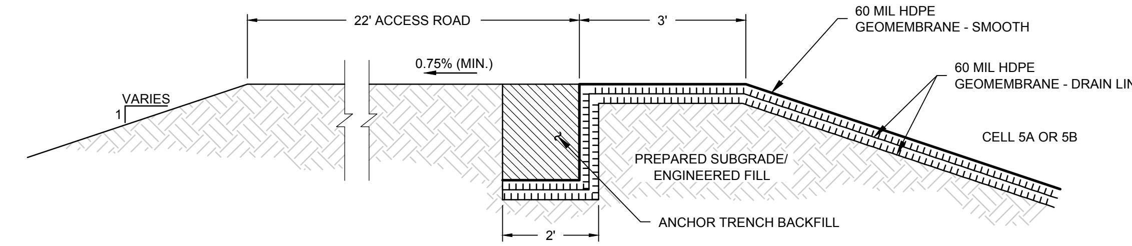
9 DETAIL
03A,03B,04A,04B BASE LINER SYSTEM
SCALE: 1" = 2'



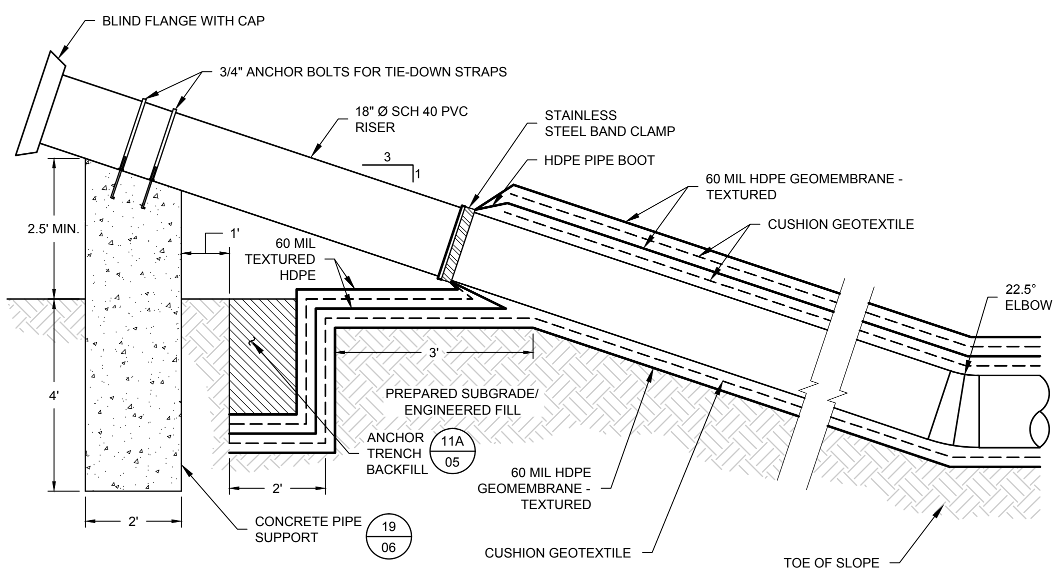
10 DETAIL
03A,03B,04A,04B SIDE SLOPE LINER SYSTEM
SCALE: 1" = 2'



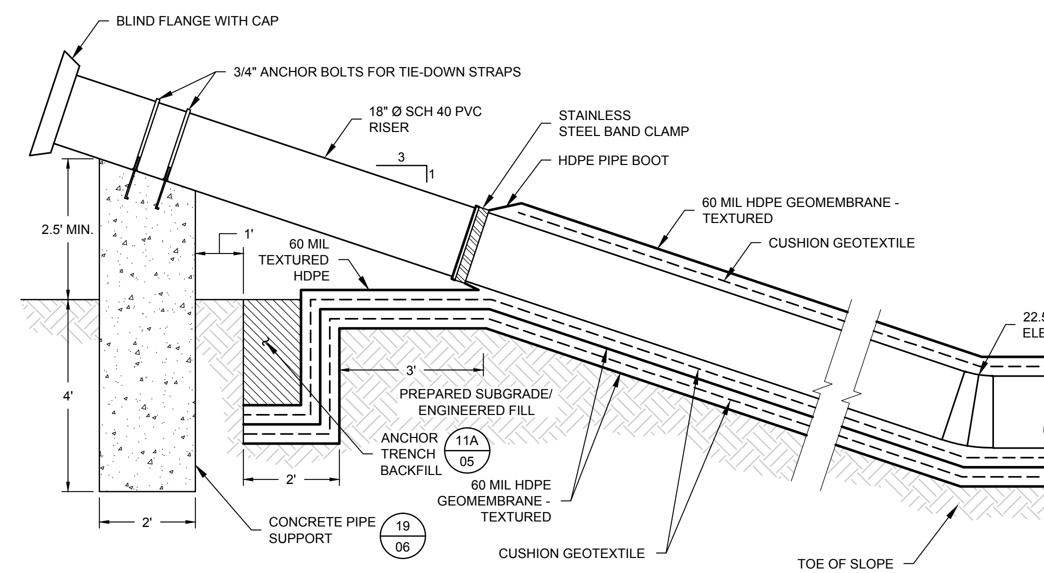
11A DETAIL
03A,03B,04A,04B,05,06,09 ANCHOR TRENCH
SCALE: 1" = 2'



11B DETAIL
03A,03B ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



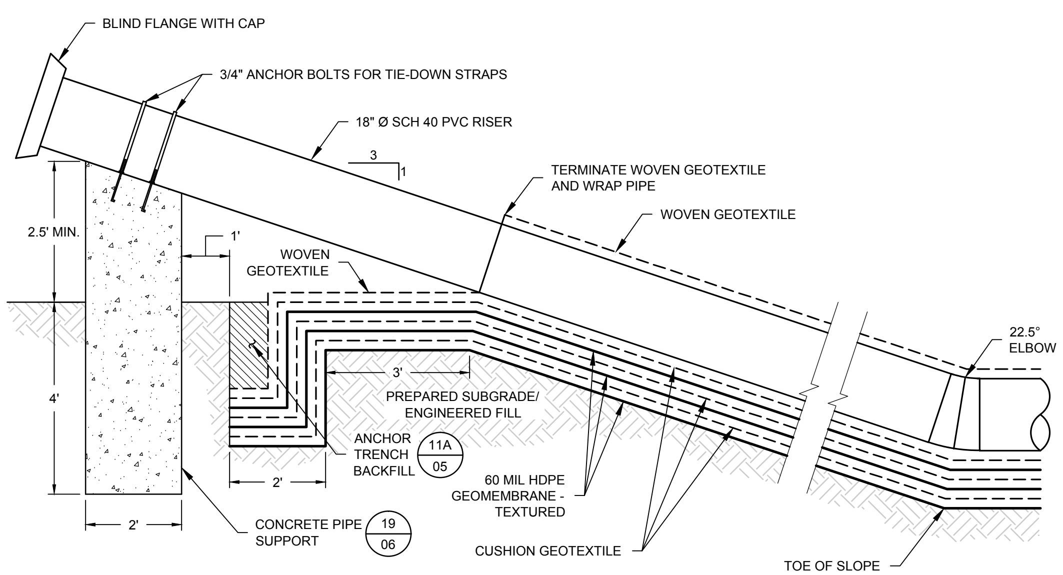
12 DETAIL
04A,04B SECONDARY LEAK DETECTION RISER PENETRATION
SCALE: 1" = 2'



13 DETAIL
04A,04B PRIMARY LEAK DETECTION SYSTEM RISER PENETRATION
SCALE: 1" = 2'

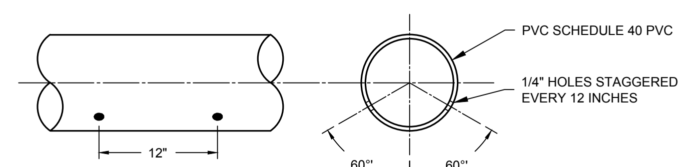
NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. ANCHOR TRENCHES MAY BE CONSTRUCTED WITH A MAXIMUM DEPTH OF 3.5 FEET WITH UP TO 1 FOOT OF BACKFILL BETWEEN EACH GEOMEMBRANE IN BOTTOM OF ANCHOR TRENCH.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.



14 DETAIL
04A,04B SLIMES DRAIN RISER PENETRATION
SCALE: 1" = 2'

Attachment A



15 DETAIL
07,08 PERFORATED PIPE
SCALE: 1" = 1'

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUTE 200
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS I

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	GTC	DATE:	JANUARY 2013
DRAWN BY:	MMC	PROJECT NO.:	SC0634
CHECKED BY:	RBF	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	05 OF 10	

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634-05-07.dwg Last Edited by: MikeC on 12/21/2012 9:51 AM

- At altitude z above sea level:

$$S_e = 0.6465 \lambda V^2 e^{-(1.252 \times 10^{-4})z} - 9.81 \mu_{GM} \tag{40}$$

with S_e(Pa), V(m/s), z(m), μ_{GM}(kg/m^2)

$$S_e = 0.050 \lambda V^2 e^{-(1.252 \times 10^{-4})z} - 9.81 \mu_{GM} \tag{41}$$

with S_e(Pa), V(km/h), z(m), μ_{GM}(kg/m^2)

3.3 Determination of Geomembrane Tension and Strain

According to Equation 36, the effective suction results from two components: a component due to the wind-generated suction, which is normal to the geomembrane; and a component due to the geomembrane mass per unit area, which is not normal to the geomembrane. The component due to the geomembrane mass per unit area is generally small compared to the component due to the wind-generated suction. Therefore, the effective suction is essentially normal to the geomembrane. Since the effective suction is taken as normal to the geomembrane and has been assumed to be uniformly distributed over the length L of geomembrane, and since the problem is considered to be two-dimensional (see Section 3.2.2), the cross section of the uplifted geomembrane has a circular shape (Figure 9). As a result, the resultant F of the applied effective suction is equal to the effective suction multiplied by the length of chord AB, i.e. L:

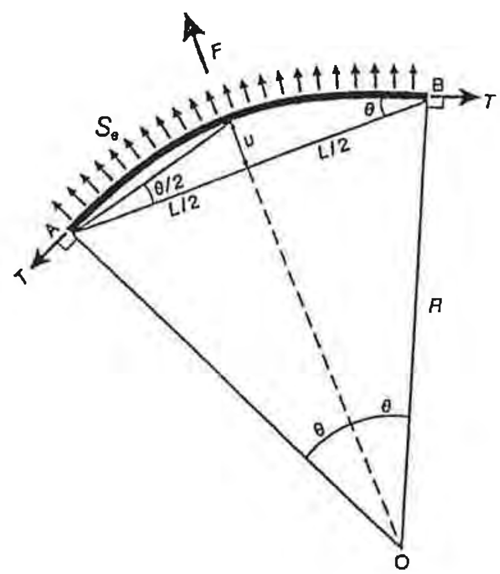


Figure 9. Schematic representation of uplifted geomembrane used for developing equations.

Attachment B 1/6

CTC 11/11/05

- A leeward slope experiences a suction over its entire length. The suction on the leeward slope ranges between 45% of the reference pressure variation at the toe of the slope and 75% at the top of the slope, with an average value of 60%, i.e. $0.45 \leq \lambda \leq 0.75$ with an average value of 0.6.
- Large portions of the reservoir bottom are subjected to a suction ranging between 20% and 40% of the reference pressure variation ($0.2 \leq \lambda \leq 0.4$).

The above conclusions result from modeling in a wind tunnel where the wind velocity is constant. In reality, there are gusts of wind that may cause suctions greater than those indicated above, in localized areas for short periods of time.

Considering the conclusions from wind tunnel tests presented above and the need for extra safety due to gusts of wind, the following values of the suction factor, λ, are recommended for design of any slope based on the critical leeward slope:

- $\lambda = 1.00$ if the crest only is considered;
- $\lambda = 0.70$ if an entire side slope is considered;
- $\lambda = 0.85$ for the top third, $\lambda = 0.70$ for the middle third, and $\lambda = 0.55$ for the bottom third for a slope decomposed in three thirds by intermediate benches or anchor trenches as shown in Figure 7c and 7d; and
- $\lambda = 0.40$ at the bottom.

These recommendations are summarized in Figure 5. According to Equation 13, the suction factor, λ, is to be multiplied by Δp_R to obtain the suction S. The reference pressure variation, Δp_R, can be calculated using Equations 7 to 11.

It should be emphasized that the recommendations made above and used in the remainder of this paper rely entirely on the results of small-scale wind tunnel tests reported by Dedrick (1973, 1974a, 1974b, 1975). Nevertheless, the tests can be deemed representative of most practical situations because they were carried out on a wide range of dike cross section geometries and alignments typically associated with reservoir structures. However, a review of data for other shapes including obstacles with sinusoidal or smooth curve geometry can result in suction factors as great as $\lambda = 1.30$. Therefore, for unusual geometries, the designer may elect to increase the values of the suction factor, λ, given in Figure 5 by up to 30%. Also, for unusual geometries or large projects for which wind-induced damage of exposed geomembranes may have large financial consequences, wind tunnel tests of reduced-scale models or numerical simulation may be warranted.

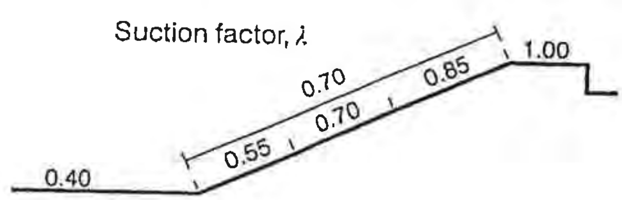


Figure 5. Recommended values of the suction factor for design of any slope based on the critical leeward slope.

Attachment B 2/6

GTC 11/11/05

Table 1. Typical density, thickness and mass per unit area for geomembranes, and relationship between mass per unit area and minimum uplift wind velocity.

Type of geomembrane	Geomembrane density ρ_{GM} (kg/m³)	Geomembrane thickness t_{GM} (mm)	Geomembrane mass per unit area μ_{GM} (4) (kg/m²)	Minimum uplift wind velocity V_{upmin} (5) (km/h)
PVC (1)	1250 (2)	0.5 1.0	0.63 1.25	11.1 15.7
* HDPE (1)	940	1.0 1.5 2.0 2.5	0.94 1.41 1.88 2.35	13.6 16.7 19.2 21.5
CSPE-R (1)	(3)	0.75 0.90 1.15	0.9 1.15 1.5	13.3 15.0 17.2
EIA-R (1)	(3)	0.75 1.0	1.0 1.3	14.0 16.0
Bituminous	(3)	3 5	3.5 6	26.2 34.3

Notes: (1) PVC = polyvinyl chloride; HDPE = high density polyethylene; CSPE-R = chlorosulfonated polyethylene-reinforced (commercially known as Hypalon); and EIA-R = ethylene interpolymer alloy-reinforced (commercially known as XR5). (2) PVC geomembranes have densities ranging typically from 1200 to 1300 kg/m³. An average value has been used in this table. (3) These geomembranes consist of several plies of different materials with different densities. (4) The relationship between density, thickness and mass per unit area is expressed by Equation 16. (5) Calculated using Equation 27 which is applicable to a geomembrane located at sea level and subjected to a suction equal to the reference pressure variation. Values tabulated in the last column can be found in Figure 6 on the curve for $z = 0$.

$$\mu_{GM} \geq \mu_{GMreq} = 0.0659\lambda V^2 e^{-(1.252 \times 10^{-4})z} \text{ with } \mu_{GMreq}(\text{kg/m}^2),\ V(\text{m/s}) \text{ and } z(\text{m}) \quad (20)$$

$$\mu_{GM} \geq \mu_{GMreq} = 0.005085\lambda V^2 e^{-(1.252 \times 10^{-4})z} \text{ with } \mu_{GMreq}(\text{kg/m}^2),\ V(\text{km/h}) \text{ and } z(\text{m}) \quad (21)$$

Figure 6 gives the relationship between the geomembrane mass per unit area, μ_{GM}, and the wind velocity, V, as a function of the altitude above sea level, z, for the case $\lambda = 1$, corresponding to the case where the geomembrane is subjected to a suction equal to the reference pressure variation ($S = \Delta p_R$). Figure 6 shows that typical polymeric geomembranes, with masses per unit area ranging between 0.5 and 2 kg/m², can resist uplift at sea level by winds with velocities ranging between 10 and 20 km/h, whereas bituminous geomembranes, with masses per unit area ranging between 3.5 and 6 kg/m², can resist uplift at sea level by winds with velocities ranging between 25 and 35 km/h.

Example 1. A 1.5 mm thick HDPE geomembrane is located at the bottom of a reservoir. The altitude of the reservoir is 450 m. Would this geomembrane be uplifted by a wind with a velocity of 30 km/h?

Attachment B 3/6

GTC 11/11/05

3.2.2 *Mechanical Behavior of the Geomembrane*

The problem is assumed to be two-dimensional. Therefore, the geomembrane is assumed to be characterized by its tension-strain curve measured in a tensile test that simulates plane-strain conditions. A wide-width tensile test provides a satisfactory approximation of this case. If only results of a uniaxial tensile test are available, the tensile characteristics under plane-strain conditions can be derived from the tensile characteristics under uniaxial conditions as indicated by Soderman and Giroud (1995).

Essential characteristics of geomembranes for use in design are the allowable tension, T_{all}, and strain, ε_{all}. Typical tension-strain curves are shown in Figure 8:

- If the geomembrane tension-strain curve has a peak (Curve 1), the allowable tension and strain correspond to the values of T and ε at the peak (as shown in Figure 8) or before the peak if a margin of safety is required.
- If the geomembrane tension-strain curve has a plateau (Curve 2), the allowable tension and strain correspond to the values of T and ε at the beginning of the plateau (as shown in Figure 8) or before if a margin of safety is required.
- If the geomembrane tension-strain curve has neither peak nor plateau (Curve 3), the allowable tension and strain correspond to the values of T and ε at the end of the curve, i.e. at break (as shown in Figure 8), or before if a margin of safety is required.

In all three cases, values of T_{all} and ε_{all} that are less than the values given above can be selected for any appropriate reasons (i.e. to meet regulatory requirements, to limit deformations, etc.).

* In some cases, the geomembrane tension-strain curve, or a portion of it, is assumed to be linear. Then, the following relationship exists:

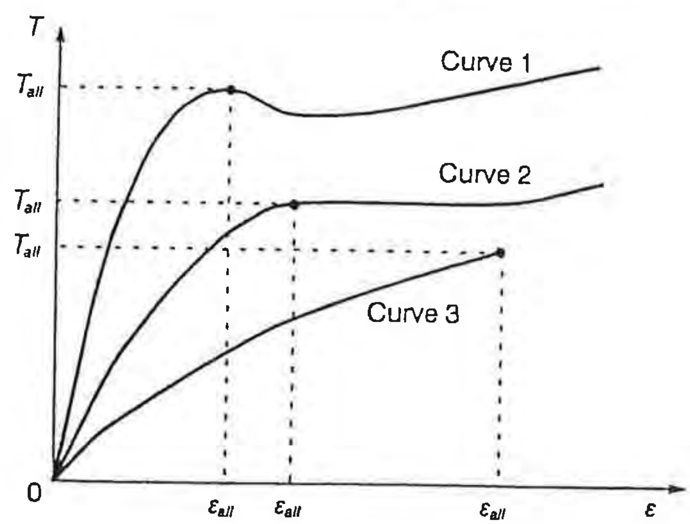


Figure 8. Typical tension-strain curves of geomembranes.

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* $$T = J\varepsilon \quad (34)$$

where: T = geomembrane tension; J = geomembrane tensile stiffness; and ε = geomembrane strain. The case of geomembranes with a linear tension-strain curve will be further discussed in Section 3.5.

It is important to note that geomembranes that are not reinforced with a fabric, for example PVC and PE geomembranes, have tensile characteristics that are highly dependent on temperature. Extensive data on the influence of temperature on the tensile characteristics of HDPE geomembranes are provided by Giroud (1994). The influence of temperature will be further discussed in Section 3.6.

3.2.3 *Suction Due to Wind*

In the subsequent analysis, the suction applied by the wind is assumed to be uniform over the entire length L. In reality, the suction due to the wind is not uniformly distributed as shown in Figure 4. Therefore, the design engineer using the method presented in this paper must exercise judgment in selecting the value of the length L and the value of the ratio λ defined by Equation 13.

In accordance with the discussions presented in Sections 2.3 and 2.4, the suction that effectively uplifts the geomembrane is:

$$S_e = S - \mu_{GM}\, g \quad (35)$$

where S_e is the "effective suction".

Combining Equations 2, 13 and 35 gives:

$$S_e = \lambda \varrho V^2/2 - \mu_{GM}\, g \quad (36)$$

Combining Equations 3 and 36 gives:

$$S_e = \lambda \varrho_o (V^2/2) e^{-\varrho_o g z / p_o} - \mu_{GM}\, g \quad (37)$$

Using the values of ϱ_o and p_o given in Section 2.1 and g = 9.81 m/s^2, Equation 37 gives:

- At sea level:

$$S_e = 0.6465 \lambda V^2 - 9.81 \mu_{GM} \quad (38)$$

with S_e(Pa), V(m/s), μ_{GM}(kg/m^2)

$$S_e = 0.050 \lambda V^2 - 9.81 \mu_{GM} \quad (39)$$

with S_e(Pa), V(km/h), μ_{GM}(kg/m^2)

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Table 4. Relationship between the strain of the geomembrane uplifted by the wind and the normalized tensile stiffness of the geomembrane for the case where the geomembrane has a linear tension-strain curve (Equation 57).

ε (%)	$\frac{J}{S_e L}$	ε (%)	$\frac{J}{S_e L}$	ε (%)	$\frac{J}{S_e L}$	ε (%)	$\frac{J}{S_e L}$
0	∞	3.6	31.347	7.2	11.607	10.8	6.607
0.1	6463.688	3.7	30.124	7.3	11.384	10.9	6.525
0.2	2288.342	3.8	28.981	7.4	11.168	11.0	6.443
0.3	1247.294	3.9	27.910	7.5	10.959	11.1	6.365
0.4	811.232	4.0	26.905	7.6	10.757	11.2	6.291
0.5	581.251	4.1	25.960	7.7	10.561	11.3	6.212
0.6	442.767	4.2	25.071	7.8	10.372	11.4	6.138
0.7	351.834	4.3	24.233	7.9	10.189	11.5	6.065
0.8	288.358	4.4	23.442	8.0	10.010	11.6	5.994
0.9	241.983	4.5	22.694	8.1	9.839	11.7	5.925
1.0	206.885	4.6	21.987	8.2	9.671	11.8	5.857
1.1	179.565	4.7	21.316	8.3	9.508	11.9	5.790
1.2	157.804	4.8	20.680	8.4	9.351	12.0	5.724
1.3	140.137	4.9	20.076	8.5	9.198	12.1	5.660
1.4	125.562	5.0	19.502	8.6	9.049	12.2	5.598
1.5	113.368	5.1	18.956	8.7	8.905	12.3	5.537
1.6	103.044	5.2	18.435	8.8	8.765	12.4	5.477
1.7	94.212	5.3	17.939	8.9	8.628	12.5	5.418
1.8	86.586	5.4	17.465	9.0	8.495	12.6	5.359
1.9	79.947	5.5	17.013	9.1	8.365	12.7	5.302
2.0	74.125	5.6	16.580	9.2	8.240	12.8	5.247
2.1	68.983	5.7	16.167	9.3	8.118	12.9	5.192
2.2	64.421	5.8	15.771	9.4	7.998	13.0	5.138
2.3	60.345	5.9	15.392	9.5	7.882	13.1	5.086
2.4	56.688	6.0	15.027	9.6	7.769	13.2	5.035
2.5	53.391	6.1	14.678	9.7	7.658	13.3	4.984
2.6	50.407	6.2	14.342	9.8	7.551	13.4	4.934
2.7	47.696	6.3	14.020	9.9	7.446	13.5	4.885
2.8	45.223	6.4	13.710	10.0	7.344	13.6	4.837
2.9	42.960	6.5	13.412	10.1	7.243	13.7	4.790
3.0	40.885	6.6	13.126	10.2	7.146	13.8	4.743
3.1	38.973	6.7	12.849	10.3	7.051	13.9	4.698
3.2	37.209	6.8	12.582	10.4	6.958	14.0	4.653
3.3	35.577	6.9	12.325	10.5	6.867	14.1	4.609
3.4	34.064	7.0	12.078	10.6	6.779	14.2	4.566
3.5	32.657	7.1	11.838	10.7	6.692	14.3	4.524

Attachment B 6/6

GTC
11/11/05

The weather in the Blanding area is typified by warm summers and cold winters. The mean annual temperature in Blanding is about 50°F (10°C). January is usually the coldest month and July is usually the warmest month.

Winds are usually light to moderate in the area during all seasons, although occasional stronger winds may occur in the late winter and spring. The predominant winds are from the north through north-east (approximately 30 percent of the time) and from the south through south-west (about 25 percent of the time). Winds are generally less than 15 mph, with wind speeds faster than 25 mph occurring less than one percent of the time. The National Weather Service Station in Blanding, Utah is located about 6.25 miles (10km) north of the Mill. Data from the station is considered representative of the local weather conditions (1978 ER, Section 2.7.2).

Further description of local and regional weather and climate data are given in the 1978 ER (Section 2.7) and in the FES (Section 2.1).

3.3.1.2 On Site

On-site meteorological monitoring at the Mill was initiated in early 1977 and continues today. The original purpose of the meteorological monitoring program was to document the regional atmospheric baseline and to provide data to assist in assessing the potential air quality and radiological impacts arising from the operation of the Mill.

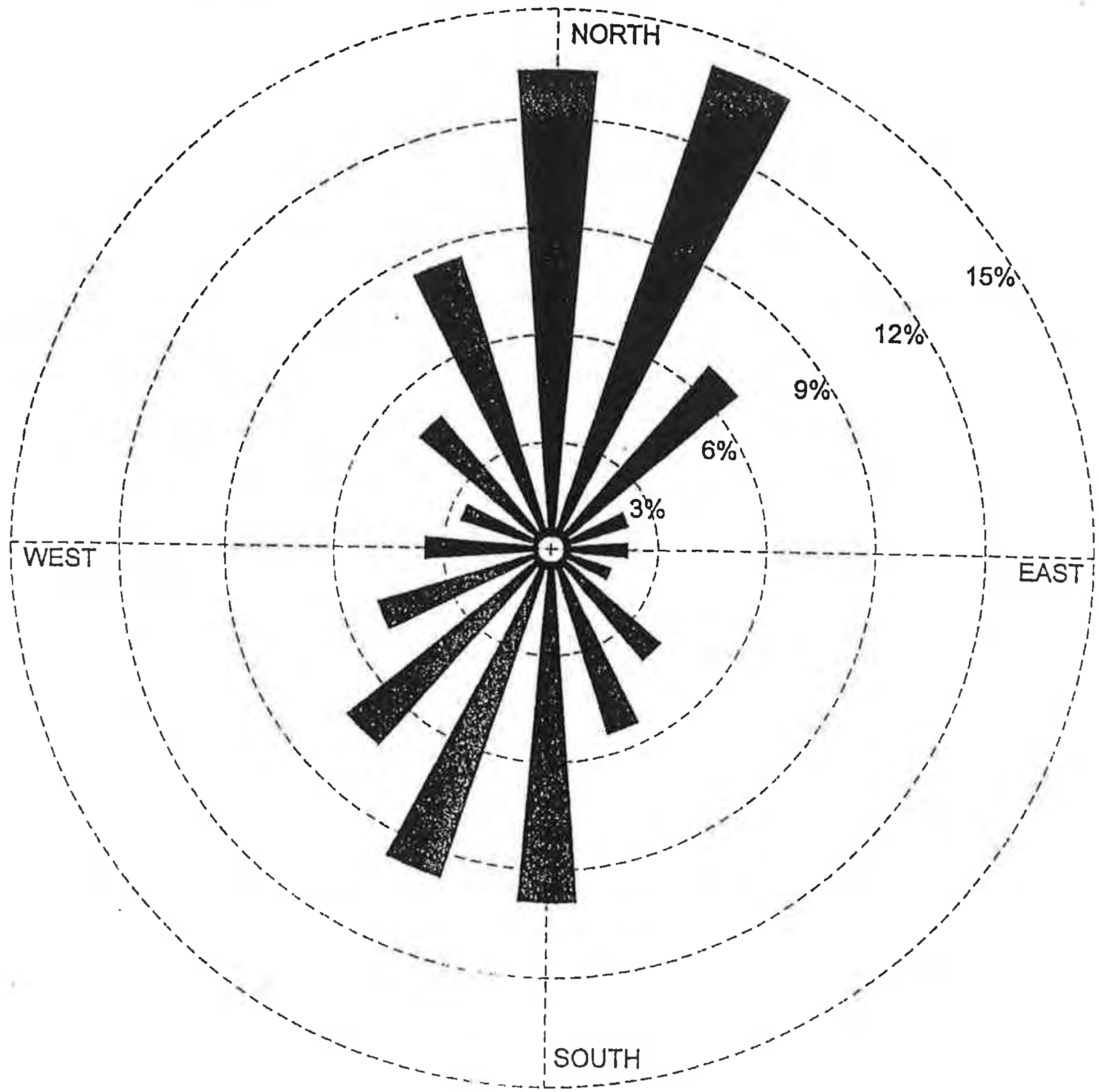
After the Mill construction was completed, the monitoring programs were modified to facilitate the assessment of Mill operations. The current meteorological monitoring program includes data collection for wind speed, wind direction, atmospheric stability according to the standard Pasquill scheme (via measurements of deviations in wind direction, referred to as sigma-theta), and precipitation as either rain or snow. The meteorological data are reported on a semi-annual basis. The details of these meteorological monitoring programs and the results are described in semi-annual reports prepared for IUSA and maintained at the Mill. Figure 3.3-1 shows windroses for the Mill site for January – December 2001.

3.3.2 Baseline Air Quality

3.3.2.1 FES Evaluation

At the time of the 1978 ER and FES, the Four Corners Air Quality Control Region which encompasses parts of Colorado, Arizona, New Mexico and Utah and within which the Mill site is located had a priority IA rating, signifying a violation of federal air standards, for particulate matter and sulfur dioxide due to emissions from fossil-fueled power plants located within the region (1978 ER, Sect. 2.7.4.2). This was an important consideration at the time since the original proposal was to use coal and oil as the source of process and building heat. Thus, much of the discussion of potential air quality effects of the Mill arose from discussions of the potential

Attachment C



January through December 2001

International Uranium (USA) Corporation

Project	WHITE MESA MILL	
REVISIONS	County:	State: UT
Date / By	Location:	
	Figure 3.3-1 Wind Speed Direction (blowing from) For All Hours	
Scale: AS SHOWN	Date: June 2003	figure 3.3-1.dwg
Author: HRR	Drafted By: BM	

High Density Polyethylene Drain Liner™

Product Data

Property	Test Method	Values			
Thickness (min. ave.), mil (mm)	ASTM D5994*	50 (1.25)	60 (1.5)	80 (2.0)	100 (2.5)
Thickness (lowest indiv.), mil (mm)	ASTM D5994*	50 (1.25)	54 (1.35)	72 (1.8)	90 (2.25)
*The thickness values may be changed due to project specifications (i.e., absolute minimum thickness)					
Drainage Stud Height (min. ave.), mil (mm)	ASTM D7466	130 (3.30)	130 (3.30)	130 (3.30)	130 (3.30)
Density, g/cc, minimum	ASTM D792, Method B	0.94	0.94	0.94	0.94
Tensile Properties (ave. both directions)	ASTM D6693, Type IV				
Strength @ Yield (min. ave.), lb/in width (N/mm)	2 in/minute	110 (19.3)	132 (23.1)	176 (30.8)	220 (38.5)
Elongation @ Yield (min. ave.), % (GL=1.3in)	5 specimens in each direction	13	13	13	13
Strength @ Break (min. ave.), lb/in width (N/mm)		110 (19.3)	132 (23.1)	176 (30.8)	220 (38.5)
Elongation @ Break (min. ave.), % (GL=2.0in)		300	300	300	300
Tear Resistance (min. ave.), lbs. (N)	ASTM D1004	38 (169)	40 (178)	53 (236)	64 (285)
Puncture Resistance (min. ave.), lbs. (N)	ASTM D4833	80 (355)	95 (422)	126 (560)	158 (703)
Carbon Black Content (range in %)	ASTM D4218	2 - 3	2 - 3	2 - 3	2 - 3
Carbon Black Dispersion (Category)	ASTM D5596	Only near spherical agglomerates for 10 views: 9 views in Cat. 1 or 2, and 1 view in Cat. 3			
Stress Crack Resistance (Single Point NCTL), hours	ASTM D5397, Appendix	300	300	300	300
Oxidative Induction Time, minutes	ASTM D3895, 200°C, 1 atm O_2	≥100	≥100	≥100	≥100
Melt Flow Index, g/10 minutes	ASTM D1238, 190°C, 2.16kg	≤1.0	≤1.0	≤1.0	≤1.0
Oven Aging with HP OIT, (% retained after 90 days)	ASTM D5721 ASTM D5885, 150°C, 500psi O_2	80	80	80	80
UV Resistance	GRI GM11	20hr. Cycle @ 75°C/4 hr. dark condensation @ 60°C			
with HP OIT, (% retained after 1600 hours)	ASTM D5885, 150°C, 500psi O_2	50	50	50	50

These product specifications meet or exceed GRI's GM13

Supply Information (Standard Roll Dimensions)

Thickness mil	Thickness mm	Width ft	Width m	Length ft	Length m	Area (approx.) ft²	Area (approx.) m²	Weight (average)* lbs	Weight (average)* kg
50	1.25	23	7	300	91.435	6,900	640.05	2,600	1,178.34
60	1.5	23	7	300	91.435	6,900	640.05	2,900	1,315.42
80	2.0	23	7	300	91.435	6,900	640.05	3,600	1,632.93
100	2.5	23	7	300	91.435	6,900	640.05	4,000	1,814.37

Notes:

All rolls are supplied with two slings. All rolls are wound on a 6 inch core. Special lengths are available on request. All roll lengths and widths have a tolerance of ±1%
**The weight values may change due to project specifications (i.e. absolute minimum thickness or special roll lengths) or shipping requirements (i.e. international containerized shipments).*

All information, recommendations and suggestions appearing in this literature concerning the use of our products are based upon tests and data believed to be reliable; however, it is the users responsibility to determine the suitability for their own use of the products described herein. Since the actual use by others is beyond our control, no guarantee or warranty of any kind, expressed or implied, is made by Agru/America as to the effects of such use or the results to be obtained, nor does Agru/America assume any liability in connection herewith. Any statement made herein may not be absolutely complete since additional information may be necessary or desirable when particular or exceptional conditions or circumstances exist or because of applicable laws or government regulations. Nothing herein is to be construed as permission or as a recommendation to infringe any patent.

500 Garrison Road, Georgetown, South Carolina 29440 843-546-0600 800-373-2478 Fax: 843-527-2738
email: salesmkg@agruamerica.com www.agruamerica.com

ATTACHMENT D

GTC 11/11/05

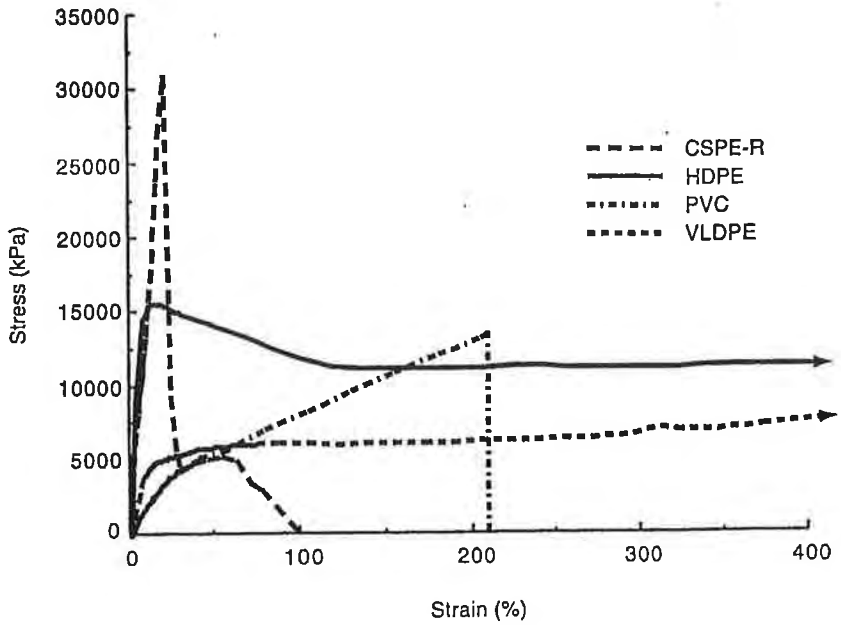


Figure 5.3 Tensile test results on 200 mm wide-width specimens of commonly used geomembranes using ASTM D-4885 test method.

formation beneath a geomembrane is such a case. This type of behavior could well be anticipated for a geomembrane used in a landfill cover placed over differentially subsiding solid-waste material. The situation can be modeled by placing the geomembrane in an empty container, as shown in Figure 5.4. An appropriate seal is made with the cover section and water is introduced above the geomembrane. Pressure is mobilized until the failure of the test specimen occurs. Beginning with Stefan [6], a number of variations of this test have been made. It is currently formalized as ASTM D5716.

TABLE 5.5b TENSILE BEHAVIOR PROPERTIES OF HDPE, VLDPE, PVC, AND CSPE-R

Test Property	Unit	Wide-Width Tension Tests (Figure 5.3)			
		HDPE	VLDPE	PVC	CSPE-R
Maximum stress and	(kPa)	15,900	7,600	13,800	31,000
corresponding strain	(%)	15	400+	210	23
Modulus	(MPa)	450	69	20	300
Ultimate stress and	(kPa)	11,000	7,600	13,800	2,800
corresponding strain	(%)	400+	400+	210	79

Nom. thicknesses are: HDPE 1.5 mm, VLDPE 1.0 mm, PVC 0.75 mm, CSPE-R 0.91 mm.
Abbreviations: + = did not fail

Attachment E

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF** Project: **White Mesa Mill – Cells 5A and 5B** Project/ Proposal No.: **SC0634** Task No. **02**

Title of Computations **PIPE STRENGTH CALCULATIONS**

Computations by:	Signature	[signature]	12/18/12
	Printed Name	Rebecca Flynn, P.E.	Date
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature	[signature]	12/20/12
	Printed Name	Keaton Botelho, P.E.	Date
	Title	Project Engineer	
Computations Checked by:	Signature	[signature]	12/20/12
	Printed Name	Keaton Botelho, P.E.	Date
	Title	Project Engineer	
Computations backchecked by: (originator)	Signature	[signature]	12/18/12
	Printed Name	Rebecca Flynn, P.E.	Date
	Title	Project Engineer	
Approved by: (pm or designate)	Signature	[signature]	12/13/12
	Printed Name	Gregory Corcoran, P.E.	Date
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:		Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	WMM – Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

PIPE STRENGTH CALCULATIONS
WHITE MESA MILL
BLANDING, UTAH

OBJECTIVE

The project involves placement of a triple liner system for the bases of Cells 5A and 5B at the White Mesa Mill in Blanding, Utah. The proposed liner system is shown in Attachment A. A 4-in diameter schedule 40 Poly Vinyl Chloride (PVC) pipe will be buried under a maximum of 43 ft of tailing deposits plus 9 feet of cover soil for a total of 52 feet of overburden. This calculation will evaluate if the pipe will remain structurally intact with the maximum load placed above the buried pipe.

SUMMARY OF ANALYSIS

The maximum possible load on the buried pipe is evaluated to be 45.1 pounds per square inch (psi). Assuming a maximum allowable ring deflection of 7.5 percent, a schedule 40 PVC pipe diameter of 4-in will remain structurally intact.

SITE CONDITIONS

The construction components pertinent to this analysis are, from top to bottom:

- Maximum of 43 ft of silt-like deposits with assumed maximum wet unit weight of 125 pounds per cubic foot (pcf) and 9 feet of cover soil with a maximum unit weight of 125 pcf;
- 60-mil smooth HDPE Geomembrane;
- 4-in diameter schedule 40 PVC pipe, embedded in coarse aggregate for the primary leak detection system (LDS);
- 300-mil geonet;
- 60-mil smooth HDPE Geomembrane;
- 4-in diameter schedule 40 PVC pipe, embedded in coarse aggregate for the secondary leak detection system (LDS); and
- 60-mil Drain Liner® HDPE Geomembrane.

A cross-section of the site conditions is presented as Attachment A.

ANALYSIS

In the analysis herein, the allowable ring deflection and the factor of safety values against pipe wall crushing and buckling will be evaluated.

Ring Deflection

Ring deflection is the change in the vertical diameter of the pipe as the pipe/bedding aggregate system deforms under the external vertical pressure. Ring deflection can be evaluated using Spangler's Modified Iowa Formula, as follows:

$$\frac{\Delta}{D} = \frac{D_L KP + KW'}{\left[\frac{2E}{3(DR-1)^3}\right] + 0.061E'}$$

(Attachment. B, 6/8)

where:

Δ	Pipe deflection or change in diameter, in.
D	Pipe diameter, in.
P	Prism soil load, psi
K	Bedding constant
W′	Live load, psi
DR	Standard dimension ratio (SDR)
E	Modulus of elasticity of pipe, psi
E′	Modulus of soil reaction, psi
D_L	Deflection lag factor

Evaluate Variables

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Δ/D The allowable ring deflection for PVC pipe is 7.5 percent based on a factor of safety of 4 (Attachment C, 2/2)

P Prism soil load = 125 pcf × 52 ft = 6,500 psf = 45.1 psi

Effect of Perforations

The effects of the perforations in the pipe should be checked to ensure they will not significantly reduce the pipe strength. The frequency of perforations in the pipe will be 2 perforations per every 12 lineal inches of the pipe (Attachment A). The perforations are anticipated to be 0.25 inches in diameter. According to EPA, Manual SW-8, "Lining of Waste Impoundment and Disposal Facilities," the cumulative length of perforations (lp) in the pipe should be determined per foot of pipe (Attachment G). This value is determined by:

$$l_p = \left(\frac{length}{perforation}\right)\cdot(perforations) = \left(\frac{0.25\ in}{perforation}\right)\cdot(2\,perforations) = 0.50\ in$$

The total vertical stress (prism soil load) to be utilized for pipe design calculations should be adjusted according to the following equation:

$$P_T = \left(\frac{12in}{12in - l_p}\right)\cdot(P) = \left(\frac{12in}{12in - 0.50\ in}\right)\cdot(45.1psi) = 47.1psi = 6{,}777\ psf$$

K Bedding constant = 0.1 (typical value, Attachment B, 5/8)

W′ Live load = 0 (no live loads are expected for the site)

DR Standard dimension ratio = $\frac{D_o}{t}$ (Attachment B, 3/8)

where:

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D_o Outside diameter of pipe = 4.500 in. (Attachment D, 2/2)

t Minimum pipe wall thickness = 0.237 in. (Attachment D, 2/2)

$$\text{so, DR} = \frac{4.500}{0.237} = 19.0$$

E Modulus of elasticity of pipe = 400,000 psi

(for Class 12454-B rigid PVC pipe; Attachment E, 2/2)

E′ Modulus of soil reaction = 3,000 psi

(for crushed rock, Attachment B, 5/8)

D_L = 1.0 (Attachment B, 5/8)

Solve for the deflection provides:

$$\frac{\Delta}{D} = \frac{D_L KP + KW'}{\left[\frac{2E}{3(DR-1)^3}\right] + 0.061E'}$$

$$= \frac{1.0(0.1)(47.1) + 0.1(0)}{\left[\frac{2(400{,}000)}{3(19.0-1)^3}\right] + 0.061(3{,}000)} = 2.1\%$$

Since the calculated ring deflection (2.1%) is lower than the maximum allowable ring deflection (7.5%), the schedule 40 PVC pipe with 4-in will be suitable for the anticipated loading conditions.

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Wall Crushing

Wall crushing can occur when the stress in the pipe wall, due to external vertical pressure, exceeds the compressive strength of the pipe material. Wall crushing can be calculated using the following equation:

$$T = \frac{P_y D_o}{2}$$ (Attachment B, 8/8)

where:

T Wall thrust, lbs/in.

P_y Vertical pressure, psi

D_o Outside diameter of pipe = 4.500 in (Attachment D, 2/2)

and;

$$\sigma_c = \frac{T}{A}$$ (Attachment B, 8/8)

where:

σ_c Compressive stress = 9,600 psi (Attachment F, 1/1)

A Cross sectional area of the pipe wall per unit length

$$= \frac{\pi}{4}\left(4.500^2 - (4.500 - 2(0.237))^2\right) = 3.174\,\text{in}^2/12\,\text{in} = 0.265\,\text{in}^2/\text{in}$$

Combining Equations and solving for P_y provides:

$$P_y = \frac{2\sigma_c A}{D_o}$$

Substituting the variables into the above equation provides:

$$P_y = \frac{2(9{,}600)(0.265)}{4.500} = 1{,}129 \text{ psi}$$

Comparing the above estimated value to the maximum loading allowed under ring deflection criteria (47.1 psi) provides:

FS_{WC} = 1,129/47.1

= 23.9

This value is greater than the acceptable factor of safety of 2.

Wall Buckling

Wall buckling, a longitudinal wrinkling in the pipe wall, can occur when the external vertical pressure exceeds the critical buckling pressure of the pipe/bedding aggregate system. Wall buckling can be calculated using the following equation:

$$P_{cr} = \frac{2E}{(DR-1)^3}$$ (Attachment B, 7/8)

where:

P_{cr} Buckling pressure, psi

E Modulus of elasticity = 400,000 psi (Attachment E, 2/2)

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DR Standard dimension ratio $= \frac{D_o}{t} = \frac{4.500}{0.237} = 19.0$

Therefore,

$$P_{cr} = \frac{2(400{,}000)}{(19.0-1)^3} = 137\text{ psi}$$

Comparing the above estimated value to the maximum loading allowed under ring deflection criteria (47.1 psi) provides:

FS_{WC} = 137/47.1

= 2.9

This value is greater than the acceptable factor of safety of 2.

SUMMARY AND CONCLUSIONS

Using the Modified Iowa Formula as outlined in the Uni-Bell Plastic Pipe Association Handbook on PVC Pipe, the maximum load on the buried pipe assumed to be 45.1 psi will only cause a ring deflection of 2.0 percent, which is below the acceptable ring deflection of 7.5 percent. Acceptable factor of safety values against wall crushing and wall buckling were also evaluated using methods outlined in Uni-Bell Plastic Pipe Association Handbook on PVC Pipe. Therefore, schedule 40 PVC pipe with 4-in diameter is suitable for this application.

REFERENCES

ASTM D 1784 (1993), "Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds" ASTM Annual Method of Standards - Plastics

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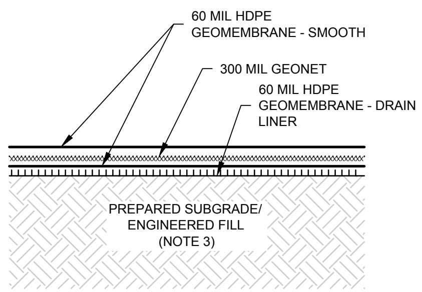
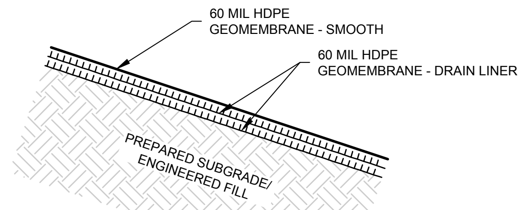
ASTM D 1785 (1996), "Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120" ASTM Annual Method of Standards - Plastics

ASTM D 3034 (1997), "Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings" ASTM Annual Method of Standards - Plastics

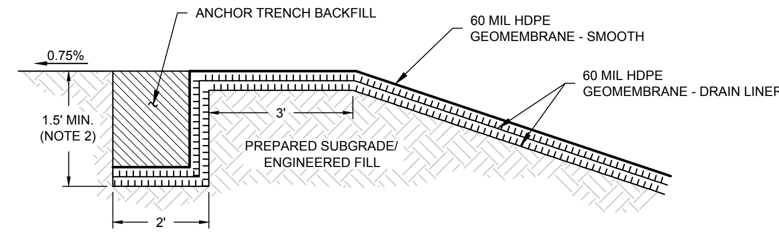
The Uni-Bell Plastic Pipe Association, "Handbook of PVC Pipe, Design and Construction," Dallas, Texas, 214-243-3902



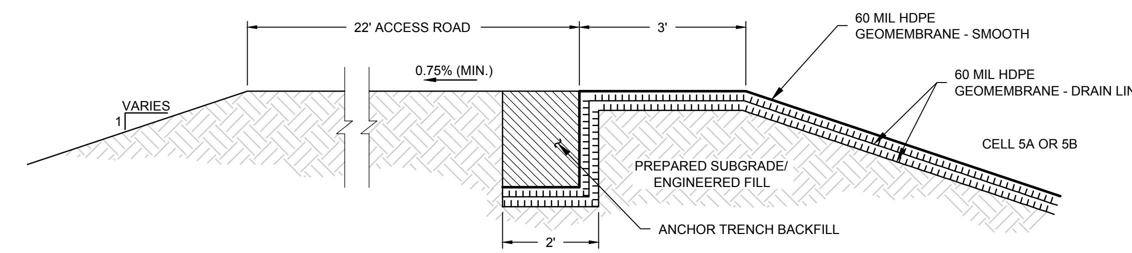
9 DETAIL 03A,03B,04A,04B
BASE LINER SYSTEM
SCALE: 1" = 2'



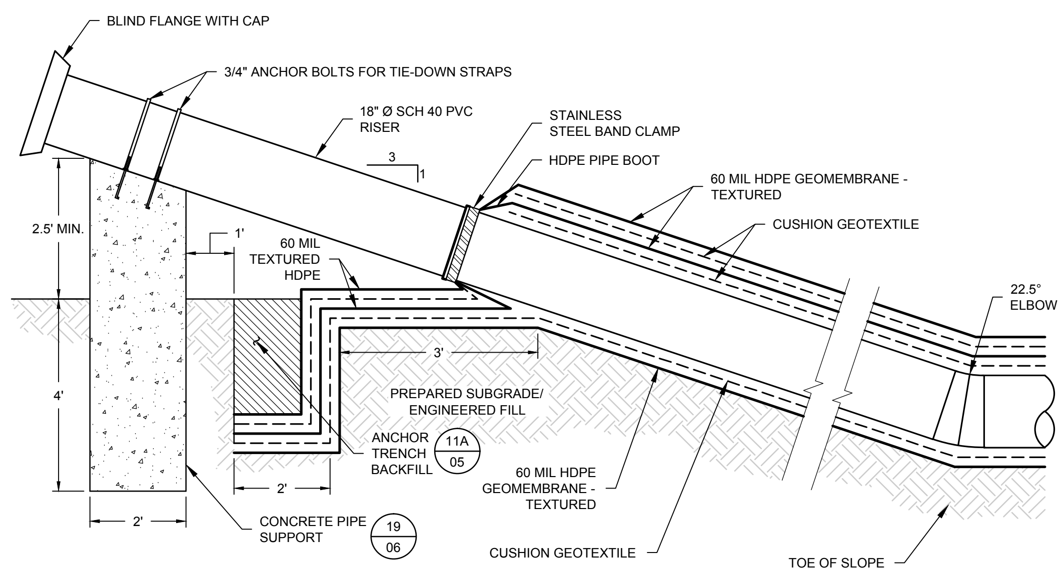
10 DETAIL 03A,03B,04A,04B
SIDE SLOPE LINER SYSTEM
SCALE: 1" = 2'



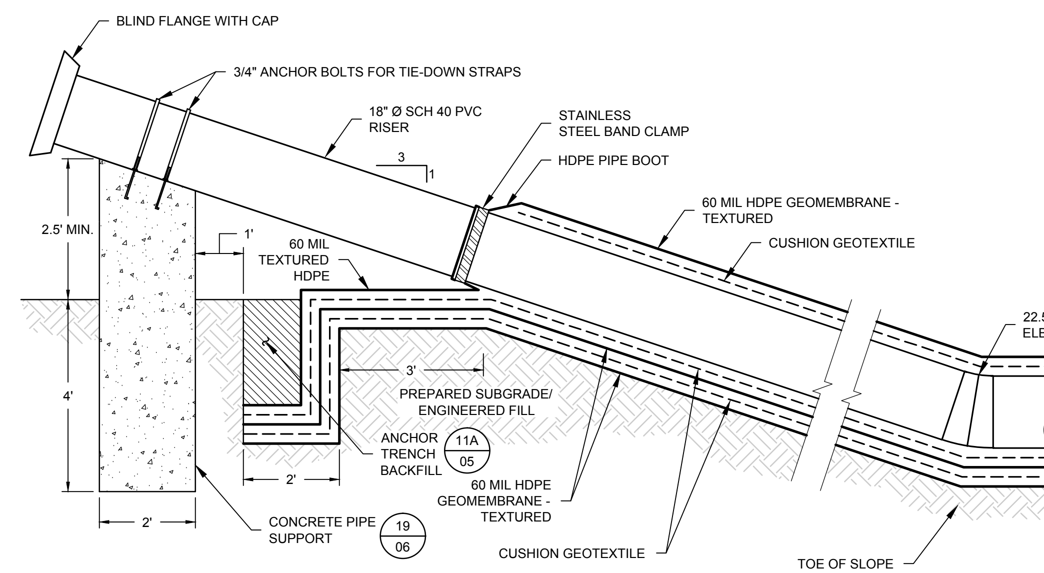
11A DETAIL 03A,03B,04A,04B,05,06,09
ANCHOR TRENCH
SCALE: 1" = 2'



11B DETAIL 03A,03B
ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



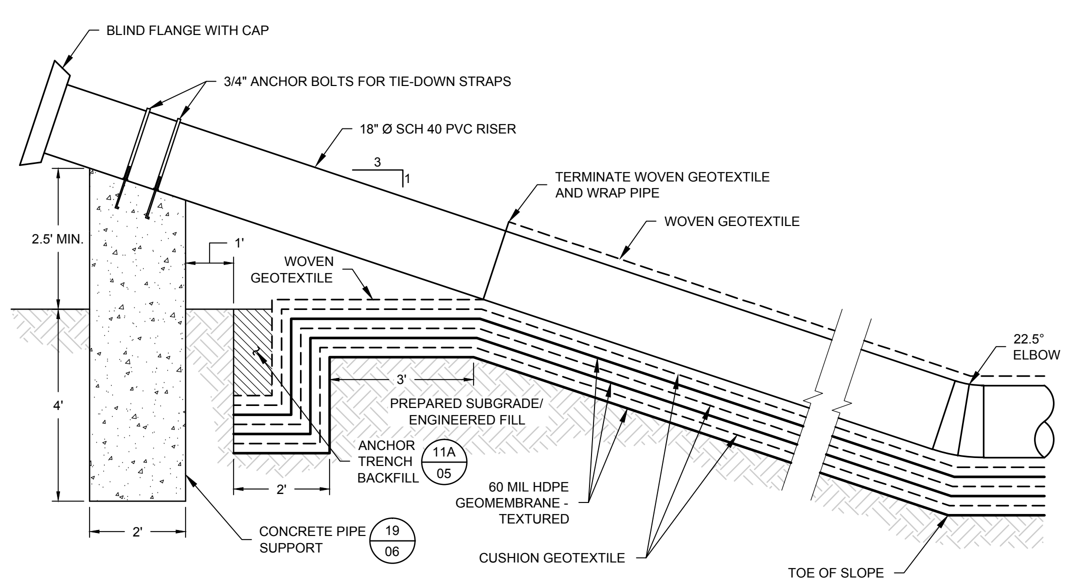
12 DETAIL 04A,04B
SECONDARY LEAK DETECTION RISER PENETRATION
SCALE: 1" = 2'



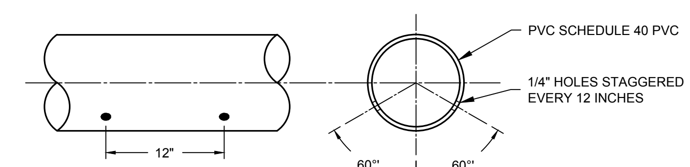
13 DETAIL 04A,04B
PRIMARY LEAK DETECTION SYSTEM RISER PENETRATION
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. ANCHOR TRENCHES MAY BE CONSTRUCTED WITH A MAXIMUM DEPTH OF 3.5 FEET WITH UP TO 1 FOOT OF BACKFILL BETWEEN EACH GEOMEMBRANE IN BOTTOM OF ANCHOR TRENCH.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.



14 DETAIL 04A,04B
SLIMES DRAIN RISER PENETRATION
SCALE: 1" = 2'



15 DETAIL 07,08
PERFORATED PIPE
SCALE: 1" = 1'

Attachment A

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS I

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	GTC	DATE:	JANUARY 2013
DRAWN BY:	MMC	PROJECT NO.:	SC0634
CHECKED BY:	RBF	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	05 OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634-05-07.dwg Last Edited by: MikeC on 12/21/2012 9:51 AM

The Uni-Bell PVC Pipe Association

Handbook of PVC Pipe

Design and Construction

Uni-Bell PVC Pipe Association

2655 Villa Creek Drive, Suite 155

Dallas, Texas 75234

$40.00

ATTACHMENT B, 1/8

TABLE 6.3 - Continued

Height of Cover (ft)	Soil Unit Weight (lb/ft³) 100	110	120	125	130
36	25.00	27.50	30.00	31.25	32.50
37	25.69	28.26	30.83	32.12	33.40
38	26.39	29.03	31.67	32.99	34.31
39	27.08	29.79	32.50	33.85	35.21
40	27.78	30.56	33.33	34.72	36.11
41	28.47	31.32	34.17	35.59	37.01
42	29.17	32.08	35.00	36.46	37.92
43	29.86	32.85	35.83	37.33	38.82
44	30.56	33.61	36.67	38.19	39.72
45	31.25	34.38	37.50	39.06	40.63
46	31.94	35.14	38.33	39.93	41.53
47	32.64	35.90	39.17	40.80	42.43
48	33.33	36.67	40.00	41.67	43.33
49	34.03	37.43	40.83	42.53	44.24
50	34.72	38.19	41.67	43.40	45.14

Tables 6.1, 6.2 and 6.3 assume a typical range for H and w. The table limits do not imply application limits.

Live Loads: Underground PVC pipe may also be subjected to live loads from different sources such as highways and railways. Live loads have little effect on pipe performance except at shallow burial depths.

Several methods exist for calculating these live loads. The design approach presented here is taken from the American Water Works Association standard for fiberglass pipe (AWWA C950).

Based on the Boussinesq formula for a point load at the surface of a semi-infinite elastic soil:

$$W_L = \frac{C_L P(1 + I_f)}{12} \quad *$$

Where: W_L = live-load on pipe, in pounds per inch
C_L = live-load coefficient, per foot of effective length
P = wheel load, in pounds
I_f = impact factor, dimensionless ($I_f = 0.766 - 0.133H$; $0 \le I_f \le 0.50$) * $1+I_f$ = 1.5 max.

Note: ...ndard AASHTO H20 ...

2/8

Tables 6.4 and 6.5 give the live load coefficient C_L for a single wheel load and for two passing trucks, respectively. The design appr taken in these tables conservatively represents a wheel load as a point l Analytical expressions for C_L are given below the tables in terms of the diameter or radius and the height of cover.

TABLE 6.4
LIVE-LOAD COEFFICIENTS FOR SINGLE-WHEEL LOA

Pipe Diameter in.	Height of Cover Over Pipe H -- ft: 2	4	6	8	10	12	14	16	
	Live-Load Coefficient C_L								
8	0.056	0.020	0.010	0.006	0.004	0.003	0.002	0.001	0.
10	0.069	0.025	0.012	0.007	0.004	0.003	0.002	0.002	0.
12	0.081	0.029	0.014	0.008	0.005	0.004	0.003	0.002	0.
14	0.091	0.034	0.016	0.009	0.006	0.004	0.003	0.002	0.
16	0.103	0.038	0.018	0.010	0.007	0.005	0.004	0.003	0.
18	0.115	0.042	0.020	0.012	0.008	0.005	0.004	0.003	0.
20	0.124	0.046	0.022	0.013	0.008	0.006	0.004	0.003	0.
24	0.141	0.055	0.026	0.015	0.010	0.007	0.005	0.004	0.
30	0.167	0.066	0.032	0.019	0.012	0.007	0.006	0.005	0.
36	0.183	0.076	0.038	0.022	0.015	0.010	0.008	0.006	0.
42	0.196	0.085	0.044	0.026	0.017	0.012	0.009	0.007	0.
48	0.205	0.094	0.049	0.029	0.019	0.014	0.010	0.008	0.

NOTE 1: An effective length of 3.0 ft of pipe is assumed.
NOTE 2:

$$C_L = \frac{1}{3} - \frac{2}{3\pi}\text{ARCSIN}\left[H\sqrt{\frac{R^2 + H^2 + 1.5^2}{(R^2 + H^2)(H^2 + 1.5^2)}}\right] + \frac{RH\left[\left(\frac{1}{R^2 + H^2} + \frac{1}{H^2 + 1.5^2}\right)\right]}{\pi\sqrt{R^2 + H^2 + 1.5^2}}$$

WHERE: H = earth cover, in feet; R = pipe radius, in feet; ARCSIN must be in radians.

As mentioned previously, the influence of live loads on the performa of PVC pipe is only significant in shallow depths, usually 4 feet (1.2 and less for highway loads. This is graphically demonstrated by the gr in Figure 6.7. Both show the total load calculated on a pipe exposed to loads and earth loads for highway and for railway traffic xible pipe may be defined as a conduit that will deflect at least two without any sign of structural distress such as injurious cracking. nduit to behave as a flexible pipe when buried, it is required that the nore yielding than the embedment soil surrounding it.

xible pipe derives its soil load carrying capacity from its flexibility. oil load, the pipe tends to deflect, thereby developing passive soil at the sides of the pipe. At the same time, the ring deflection re- e pipe of the major portion of the vertical soil load which is then y the surrounding soil through the mechanism of an arching action pipe. (See Chapter VI.)

effective strength of the pipe-soil system is remarkably high. For , tests at Utah State University indicate that a rigid pipe with a three- ring strength of 3300 lb/ft (48.15 kN/m) buried in Class C bedding with a soil load of 5000 lb/ft (72.95 kN/m). However, under the soil conditions and loading, PVC sewer pipe with a minimum pipe of 46 psi deflects only 5 percent. This deflection is far below that ould cause damage to the PVC pipe wall. Thus, in this example, the e has failed but the flexible pipe has performed successfully.

ourse, in flat plate or three-edge loading, the rigid pipe will support ore than the flexible pipe. This anomaly tends to mislead many e flexible pipe users because they relate low flat plate supporting for flexible pipe to the in-soil load capacity. Flat plate or three-edge is an appropriate measure of load bearing strength for rigid pipes or flexible pipes.

Stiffness: The inherent strength of flexible pipe is called pipe which is measured, according to ASTM D 2412 Standard Test for External Loading Properties of Plastic Pipe by Parallel-Plate , at an arbitrary datum of 5 percent deflection. Pipe stiffness is de-

EQUATION 7.1

$$PS = F/\Delta Y = \frac{EI}{0.149r^3} = \frac{6.71EI}{r^3}$$

l wall pipes Equation 7.1 can be rewritten as:

$$PS = F/\Delta Y = \frac{6.71Et^3}{12r^3} = 0.559E\left[\frac{t}{r}\right]^3$$

Where:
- PS = Pipe Stiffness, lbf/in/in. or psi
- F = Force, lbs./Lin.
- ΔY = Vertical deflection, in.
- E = Modulus of elasticity, psi
- I = Moment of inertia of the wall cross-section per unit length of pipe, in^4/Lin. = in^3
- r = Mean radius of pipe, in.
- t = wall thickness, in.

For solid wall PVC pipe with outside diameter controlled dimensions (rather than I.D.) Equation 7.2 can be further simplified:

EQUATION 7.3

$$PS = 4.47 \frac{E}{(DR - 1)^3}$$

Where: $DR = \frac{D_o}{t}$

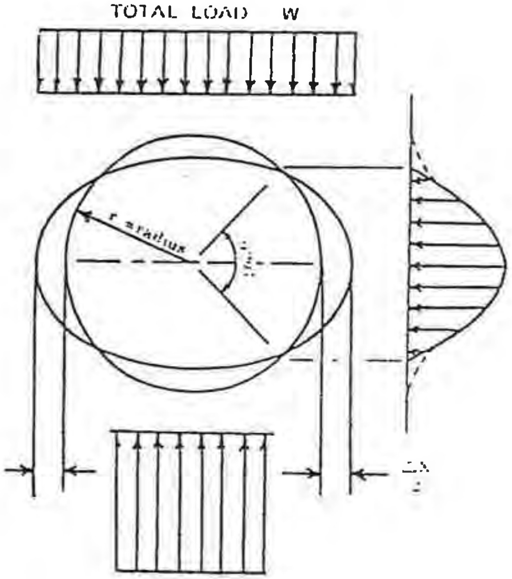
The resulting PS values for various dimension ratios and E values of PVC pipe are as shown in Table 7.1.

In addition to altering the "I" value by changing the DR, alternative shapes can be employed. It is this option of more efficient shapes that has resulted in a variety of profile wall gravity PVC pipe products for sanitary and drain applications. Users are afforded the economy of a higher stiffness than a DR product of the same raw material quantity and strength.

Equation 7.1 shows that the pipe stiffness increases as the moment of inertia of the wall cross section increases. For a solid wall pipe the moment of inertia is equal to $\frac{t^3}{12}$ in^4/Lin., with the center of gravity being at the mid-point of the pipe wall.

ATTACHMENT B, 3/8

SIS OF SPANGLER'S DERIVATION OF THE IOWA 'RMULA FOR DEFLECTION OF BURIED PIPES



(EQUATION 7.6)

$$\Delta X = \frac{D_L K W_c r^3}{EI + 0.061 e r^4}$$

THE IOWA FORMULA

e = $2h/\Delta X$
2r = D = Mean Pipe diameter
K = Bedding constant
D_L = Deflection lag factor
EI = Stiffness factor (related to pipe stiffness)

EQUATION 7.9

$$\Delta X = D_L \frac{K W_c r^3}{EI + 0.061 e r^4}$$

e: D_L = Deflection lag factor
K = Bedding constant
W_c = Marston's load per unit length of pipe, lb/Lin.
r = Mean radius of the pipe, in.
E = Modulus of elasticity of the pipe material, psi
I = Moment of inertia of the pipe wall per unit length, $in^4/Lin = in^3$
e = Modulus of passive resistance of the side fill, $lb/in^2/in.$
ΔX = Horizontal deflection or change in diameter, in.

n 7.9 can be used to predict deflections of buried pipe if the three onstants **K**, **D_L** and e are known. The bedding constant, K, accommodates the response of the buried flexible pipe to the opposite and equal reaction to the load force derived from the bedding under the pipe. The bedding constant varies with the width and angle of the bedding achieved in the installation. The bedding angle is shown in Figure 7.4. Table 7.2 contains a list of bedding factors, **K**, dependent upon the bedding angle. These were determined theoretically by Spangler and published in 1941. As a general rule, a value of **K** = 0.1 is assumed.

ATTACHMENT B. 4/8

FIGURE 7.4
BEDDING ANGLE

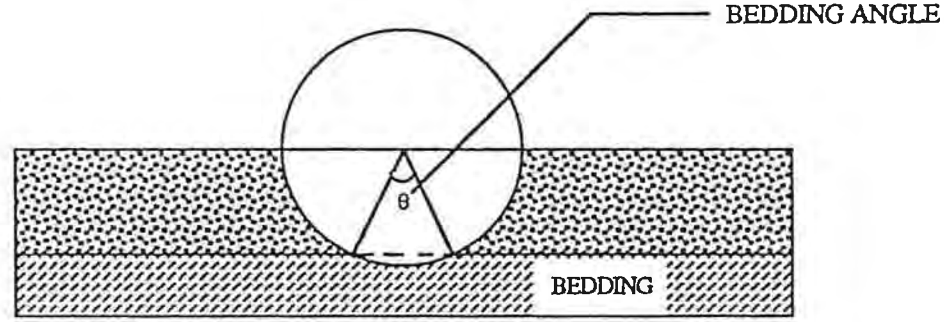


TABLE 7.2
VALUES OF BEDDING CONSTANT, K

BEDDING ANGLE (DEGREES)	K
0	0.110
30	0.108
45	0.105
60	0.102
90	0.096
120	0.090
180	0.083

In 1955, Reynold K. Watkins, a graduate student of Spangler, was investigating the modulus of passive resistance through model studies and examined the Iowa Formula dimensionally. The analysis determined that **e** could not possibly be a true property of the soil in that its dimensions are not those of a true modulus. As a result of Watkins' effort, another soil parameter was defined. This was the modulus of soil reaction, E' = er.

EQUATION 7.10

$$\Delta X = D_L \frac{KW_c r^3}{EI + 0.061E'r^3}$$

other observations from Watkins' work are of particular note. little point in evaluating E' by a model test and then using the to predict ring deflection; the model gives ring deflection directly. ection may not be the only performance limit.

research efforts have attempted to measure E' without success. useful method has involved the measure of deflections for a pipe hich other conditions were known followed by back-calculation the Modified Iowa Formula to determine the correct value of E'. ires assumptions regarding the load, bedding factor and deflection to be used and has led to a variation in reported values of E'. attempt to acquire information on values of E' was conducted by C. Howard of the United States Bureau of Reclamation. Howard both laboratory and field data from many sources. Using inforom over 100 laboratory and field tests, he compiled a table of averlues for various soil types and densities (see Table 7.3). He was o this by assuming values of E', K and W_c and then using the Iowa Formula to calculate a theoretical value of deflection. This l deflection was then compared with actual measurements. By asie E' values of Table 7.3, a bedding constant K = 0.1 and deflecactor D_L = 1.0, Howard was able to correlate the theoretical and results to within ± 2 percent deflection when he used the prism

This means that if theoretical deflections using Table 7.3 were ately 5 percent, measured deflection would range between 3 and 7 Although the vast majority of data from this study was taken from teel and reinforced plastic mortar pipe with diameters greater than , it does provide some useful information to guide designers of all ipe including PVC pipe since it helps to give an understanding of ied Iowa Deflection Formula.

AVERAGE VALUES OF MODULUS OF SOIL REACTION, E' (For Initial Flexible Pipe Deflection)

Soil type-pipe bedding material (Unified Classification System[a]) (1)	E' for Degree of Compaction of Bedding, in pounds per square inch: Dumped (2)	Slight, <85% Proctor, <40% relative density (3)	Moderate, 85%-95% Proctor, 40%-70% relative density (4)	High, >95% Proctor, >70% relative density (5)
Fine-grained Soils (LL > 50)[b] Soils with medium to high plasticity CH, MH, CH-MH	No data available; consult a competent soils engineer; Otherwise use E' = 0			
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with less than 25% coarse-grained particles	50	200	400	1,000
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with more than 25% coarse-grained particles; Coarse-grained Soils with Fines GM, GC, SM, SC[c] contains more than 12% fines	100	400	1,000	2,000
Coarse-grained Soils with Little or no Fines GW, GP, SW, SP[c] contains less than 12% fines	200	1,000	2,000	3,000
Crushed Rock	1,000	3,000	3,000	3,000
Accuracy in Terms of Percentage Deflection[d]	±2	±2	±1	±0.5

[a]ASTM Designation D 2487, USBR Designation E-3.
[b]LL = Liquid limit.
[c]Or any borderline soil beginning with one of these symbols (i.e. GM-GC, GC-SC).
[d]For ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Note: Values applicable only for fills less than 50 ft (15 m). Table does not include any safety factor. For use in predicting initial deflections only, appropriate Deflection Lag Factor must be applied for long-term deflections. If bedding falls on the borderline between two compaction categories, select lower E' value or average the two values. Percentage Proctor based on laboratory maximum dry density from test standards using about 12,500 ft-lb/cu ft (598,000 J/m³) (ASTM D 698, AASHTO T-99, USBR Designation E-11). 1 psi = 6.9 kPa.

SOURCE: "Soil Reaction for Buried Flexible Pipe" by Amster K. Howard, U.S. Bureau of Reclamation, Denver, Colorado. Reprinted with permission from American Society of Civil Engineers.

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TABLE 7.4

CALCULATED DEFLECTIONS OF BURIED AWWA C900 PVC PIPE
Deflection (Percent) for Highway H20 and Railway E80 Loads

of Cover →	2'		4'		6'		8'		10'		12'		14'		16'		18'		20'	
Load →	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80
E' Value	DR 14																			
50	0.58	2.26	0.49	1.75	0.51	1.66	0.59	1.43	0.67	1.28	0.80	1.25	0.94	1.27	1.07	1.35	1.21	1.49	1.34	1.51
200	0.54	2.10	0.45	1.63	0.48	1.55	0.55	1.34	0.62	1.19	0.75	1.16	0.87	1.19	1.00	1.26	1.12	1.33	1.25	1.40
400	0.50	1.93	0.42	1.49	0.44	1.42	0.50	1.22	0.57	1.09	0.69	1.07	0.80	1.09	0.91	1.15	1.03	1.22	1.14	1.29
1000	0.40	1.54	0.34	1.19	0.35	1.13	0.40	0.98	0.46	0.87	0.55	0.85	0.64	0.87	0.73	0.92	0.82	0.97	0.91	1.03
2000	0.30	1.15	0.25	0.89	0.26	0.85	0.30	0.73	0.34	0.66	0.41	0.64	0.48	0.65	0.55	0.69	0.62	0.73	0.68	0.77
E' Value	DR 18																			
50	1.26	4.89	1.07	3.79	1.11	3.60	1.28	3.10	1.45	2.79	2.09	2.71	2.04	2.76	2.33	2.93	2.62	3.10	2.91	3.27
200	1.09	4.22	0.92	3.28	0.97	3.11	1.12	0.69	1.25	2.40	1.51	2.34	1.76	2.38	2.01	2.53	2.26	2.67	2.51	2.82
400	0.92	3.58	0.78	2.77	0.82	2.63	0.93	2.27	1.06	2.03	1.28	1.98	1.48	2.01	1.69	2.14	1.91	2.26	2.12	2.38
1000	0.63	2.44	0.53	1.89	0.56	1.79	0.63	1.55	0.72	1.38	0.87	1.35	1.01	1.37	1.16	1.46	1.30	1.54	1.45	1.63
2000	0.41	1.59	0.35	1.23	0.36	1.17	0.42	1.01	0.47	0.91	0.57	0.88	0.66	0.90	0.76	0.95	0.85	1.01	0.95	1.06
E' Value	DR 25																			
50	3.24	12.56	2.73	9.73	2.86	9.23	3.29	7.96	3.73	7.15	4.48	6.97	5.22	7.09	5.97	7.52	6.71	7.96	7.46	8.39
200	2.30	8.91	1.94	6.96	2.05	6.60	2.34	5.71	2.66	5.10	3.21	4.97	3.71	5.03	4.23	5.34	4.76	5.65	5.29	5.95
400	1.65	6.47	1.41	4.97	1.47	4.75	1.68	4.10	1.91	3.66	2.30	3.57	2.67	3.63	3.05	3.85	3.43	4.07	3.82	4.29
1000	0.90	3.51	0.76	2.71	0.80	2.58	0.91	2.23	1.04	1.99	1.25	1.94	1.45	1.97	1.66	2.09	1.87	2.21	2.08	2.34
2000	0.51	1.99	0.43	1.54	0.45	1.46	0.52	1.26	0.59	1.13	0.71	1.10	0.83	1.12	0.94	1.19	1.06	1.26	1.18	1.33

(EQUATION 7.12)

Deflection Calculated by:

$$\frac{\Delta Y}{D} = \frac{D_L KP + KW'}{[2E/(3(DR - 1)^3)] + 0.061E'}$$

Where:
- P = Prism Load, psi
- K = Bedding constant, 0.1
- W' = Live load, psi
- DR = Dimension ratio
- E = 400,000 psi
- E' = Modulus of soil reaction, psi
- D_L = Deflection lag factor, 1.0

NOTE: Calculation based on soil weight (w) = 120 lb/ft³

Deflection Lag and Creep: The length of time that a buried flex pipe will continue to deflect after the maximum imposed load is realize limited and is a function of soil density in the pipe zone. As soil densit the sides of the pipe increases, the time during which the pipe will conti to deflect decreases, and the total deflection in response to load decrease:

In fact, after the trench load reaches a maximum, the pipe-soil sys continues to deflect only as long as the soil around the pipe is in the proc of consolidation. Once the embedment soil has reached the density requ to support the load, the pipe will not continue to deflect.

The full load on any buried pipe is not reached immediately after ins lation unless the final backfill is compacted to a high density. For a p with good flexibility, the long-term load will not exceed the prism lc The increase in load with time is the largest contribution to increasing flection. Therefore, for design, the prism load should be used, thus ef tively compensating for the increased trench consolidation load with t and resulting increased deflection. When deflection calculations are ba on prism loads, the deflection lag factor, D_L, should be 1.0.

Creep is normally associated with the pipe material and is defined continuing deformation with time when the material is subjected to a c stant load. Most plastics exhibit creep. As temperature increases, the cr rate under a given load increases. Also, as stress increases, the creep for a given temperature increases. As PVC creeps, it also relaxes with ti Stress relaxation is defined as the decrease in stress, with time, in a mate held in constant deformation.

Figure 7.5 shows stress relaxation curves for PVC pipe samples hel a constant deflection condition. It is evident that PVC pipe does re stresses with time. The highest stress in a buried PVC non-pressure pip encountered at the equilibrium deflection condition. The behavior dem strated in Figure 7.5 results in a decrease in the actual stress in the pip that deflection.

Figure 7.6 shows long-term data for PVC pipe buried in a soil b Long-term deflection tests were run at Utah State University by imposi given soil load which was held constant throughout the duration of the t PVC pipe material creep properties have little influence on deflection but soil properties such as density exert great influence.

ui up tu 10 kip axle. Under light to medium aircraft loads of up to 00 pounds gross weight, a minimum burial depth of 2 feet is recommed.

is recommended that special attention be given to the selection, placeınd compaction of backfill material with shallow burial flexible pipe, s PVC pipe underneath rigid pavement to prevent injurious cracking road surface.

reverse curvature performance limit for flexible steel pipe was estabshortly after publication of the Iowa Formula. It was determined that ;ated steel pipe would begin to reverse curvature at a deflection of 20 percent. Design at that time called for a limit of 5 percent deflecıus providing a structural safety factor of 4.0. From this early design eration, an arbitrary design value of 5.0 percent deflection was se-

ried PVC sewer pipe (ASTM D 3034, DR 35), when deflecting in re- to external loading, may develop recognizable reversal of curvature flection of 30 percent. This level of deflection has been commonly ated as a conservative performance limit for PVC sewer pipe. Reat Utah State University has demonstrated that the load carrying caof PVC sewer pipe continues to increase even when deflections insubstantially beyond the point of reversal of curvature. With considof this performance characteristic of PVC sewer pipe, engineers lly consider the 7.5 percent deflection limit recommended by ASTM (Appendixes) to provide a very conservative factor of safety against :al failure.

ıgitudinal bending of a pipeline is usually indicative of less than sat:y installation conditions. Unlike "rigid pipes," PVC pipe will not n flexure but will bend. Usually such bending does not significantly a pipeline's performance. Only short radius bends can be considered ıance limiting for PVC pipe. (See Chapter VIII - Special Design ıtions - Longitudinal Bending.)

: *buckling* phenomenon may govern design of flexible pipes under ons of internal vacuum, sub-aqueous installations or loose soil :f the external load exceeds the compressive strength of the pipe ma-For a circular ring subjected to a uniform external pressure or internal ı, the critical buckling pressure (P_{cr}) is defined by Timoshenko as:

*

$$P_{cr} = \frac{3EI}{r^3} = 0.447 \ PS$$

Where:
- r = Mean pipe radius, in.
- I = Pipe wall moment of inertia (in^4/in)
- PS = Pipe stiffness
- E = Modulus of elasticity, psi

With the moment of inertia (I) defined as $t^3/12$ for solid wall pipes, Equation 7.13 becomes:

EQUATION 7.14

$$P_{cr} = \frac{2E}{\left[\frac{D_o - t}{t}\right]^3} = \frac{2E}{(DR - 1)^3}$$

Where:
- E = Modulus of elasticity, psi
- DR = Dimension ratio
- D_o = Outside pipe diameter, in.
- t = Pipe wall thickness, in.

For long tubes such as pipelines under combined stress, E is replaced by $E/(1 - v^2)$ and the critical buckling pressure is:

EQUATION 7.15

$$P_{cr} = \frac{3EI}{(1 - v^2)r^3} = \frac{0.447 \ PS}{(1 - v^2)}$$

or for solid wall pipes

EQUATION 7.16

$$P_{cr} = \frac{2E}{(1 - v^2)(DR - 1)^3} = \frac{2E}{(1 - v^2)}\left[\frac{t}{D_o - t}\right]^3$$

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·d in this installation.

$$= \frac{2E}{(1-v^2)(DR-1)^3} = \frac{2(400,000)}{[1 - (0.38)^2]\ (18-1)^3} = 190.3 \text{ psi}$$

:

DR 35 PVC sewer pipe with a 400,000 psi modulus of elasticity ıfined in a saturated soil providing E' = 800 psi, what height (H) of ırated soil which weighs 120 lbs/ft^3 (w) would cause buckling? eight will be limited so deflection does not exceed 7.5 percent.

$$P_{cr} = \frac{2(400,000)}{[1 - (0.38)^2]\ (35 - 1)^3} = 23.8 \text{ psi}$$

$$P_b = 1.15 \sqrt{23.8\ (800)} = 158.7 \text{ psi} = 22,850 \text{ psf}$$

$$H = P/w = 22,850/120 = 190 \text{ feet}$$

deflection to 7.5 percent:

$$\Delta = \frac{KP_e}{.149\ PS + .061E'} \times 100$$

$$P_e = \frac{\Delta(.149\ PS + .061E')}{K}$$

$$= \frac{0.075\ [.149(46) + .061(800)]}{0.11}$$

$$P_e = 37.9 \text{ psi} = 5,464 \text{ psf}$$

$$H \text{ (to limit deflection)} = 5,464/120 = 45.5 \text{ ft.}$$

:imum cover is limited by the allowable deflection not by buckling. 'efore, the safety factor for the critical failure mode by buckling of 'VC pipe is ample.

:arch has established that flexible steel pipe walls can buckle at de- : considerably less than 20 percent if the load is large and the soil ling the pipe is extremely compacted. Based on these observations, the design of buried flexible pipes. This theory assumed that the backfill was highly compacted, that deflection would be negligible and that the performance limit was *wall crushing*. The design concept is expressed by:

EQUATION 7.21

$$T = P_y \times \frac{D_o}{2}$$

Where: P_y = Vertical soil pressure, psi
D_o = Outside diameter, in.
T = Wall Thrust, pounds/in.

EQUATION 7.22

$$\sigma_c = \frac{T}{A}$$

Where: σ_c = Compressive stress, psi
A = Area of the pipe wall, in.^{2}/in.

Example: A profile wall PVC pipe (D_o = 19.15 in., A = 2.503 in.^{2}/ft.) is concrete cradled. At what vertical soil pressure or depth of cover could one expect failure by ring compression? (w = 120 lbs./ft.^{3})

$$\sigma_c = \frac{T}{A} \qquad P_y = wH$$

Conservatively assume σ_c = hydrostatic design basis or hoop tensile = 4000 psi.

$$P_y = \frac{\sigma_c 2A}{D_o} = \frac{4000(2)(2.503/12)}{19.15}$$

$$P_y = 87.1 \text{ psi} = wH$$

$$H = \frac{P_y}{w} = \frac{87.1 \text{ psi}}{120 \text{ lbs/ft.}^3} \times 144 \text{ in}^2/\text{ft}^2$$

ATTACHMENT B 8/8

Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings[1]

This standard is issued under the fixed designation D 3034; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers requirements and test methods for materials, dimensions, workmanship, flattening resistance, impact resistance, pipe stiffness, extrusion quality, joining systems and a form of marking for type PSM poly(vinyl chloride) (PVC) sewer pipe and fittings.

1.2 Pipe and fittings produced to this specification should be installed in accordance with Practice D 2321.

1.3 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following precautionary caveat pertains only to the test methods portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D1600 Terminology for Abbreviated Terms Relating to Plastics[2,3]

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[3]

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D2152 Test Method for Degree of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion[3]

D2321 Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications[3]

D2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading[3]

D2444 Test Method for Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)[3]

D2564 Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems[3]

D2749 Symbols for Dimensions of Plastic Pipe Fittings[3]

D2855 Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings[3]

D3212 Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals[3]

F412 Terminology Relating to Plastic Piping Systems[3]

2.2 *Federal Standard:*[4]

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *Military Standard:*[4]

MIL-STD-129 Marking for Shipment and Storage

3. Terminology

3.1 *Definitions*— Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise specified. The abbreviation of poly(vinyl chloride) plastics is PVC.

3.1.1 The term PSM is not an abbreviation but rather an arbitrary designation for a product having certain dimensions.

4. Significance and Use

4.1 The requirements of this specification are intended to provide pipe and fittings suitable for non-pressure drainage of sewage and surface water.

NOTE 1—Industrial waste disposal lines should be installed only with the specific approval of the cognizant code authority since chemicals not commonly found in drains and sewers and temperatures in excess of 60°C (140°F) may be encountered.

5. Materials

5.1 *Basic Materials*—The pipe shall be made of PVC plastic having a cell classification of 12454-B or 12454-C or 12364-C or 13364-B (with minimum tensile modulus of

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[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.62 on Sewer.

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

ATTACHMENT C, 1/2

TABLE X1.1 Base Inside Diameters and 7½ % Deflection Mandrel Dimension

Nominal Size, in.	SDR-41 Average Inside Diameter	SDR-41 Base Inside Diameter[A]	SDR-41 7½ % Deflection Mandrel	SDR-35 Average Inside Diameter	SDR-35 Base Inside Diameter[A]	SDR-35 7½ % Deflection Mandrel	SDR-26 Average Inside Diameter	SDR-26 Base Inside Diameter[A]	SDR-26 7½ % Deflection Mandrel	SDR 23.5 Average Inside Diameter	SDR 23.5 Base Inside Diameter[A]	SDR 23.5 7½ % Deflection Mandrel
						in.						
6	5.951	5.800	5.37	5.893	5.742	5.31	5.764	5.612	5.19	5.713	5.562	5.14
8	7.966	7.740	7.16	7.891	7.665	7.09	7.715	7.488	6.93	...	...	...
9	8.952	8.691	8.04	...	...	...	...	...	...	...	...	...
10	9.958	9.657	8.93	9.864	9.563	8.84	9.644	9.342	8.64	...	...	...
12	11.854	11.478	10.62	11.737	11.361	10.51	11.480	11.102	10.27	...	...	...
15	14.505	14.029	12.98	14.374	13.898	12.86	14.053	13.575	12.56	...	...	...
						mm						
6	151.16	147.32	136.3	149.68	145.85	134.9	146.41	142.54	131.8	145.11	141.27	130.6
8	202.34	196.60	181.8	200.43	194.69	180.1	195.96	190.20	175.9	...	...	...
9	227.38	220.75	204.2	...	...	...	...	...	...	...	...	...
10	252.93	245.29	226.9	250.54	242.90	224.7	244.96	237.29	219.5	...	...	...
12	301.09	291.54	269.7	298.12	288.57	266.9	291.59	281.99	260.9	...	...	...
15	368.43	356.34	329.6	365.10	353.01	326.5	356.95	344.80	318.9	...	...	...

[A] Base inside diameter is a minimum pipe inside diameter derived by subtracting a statistical tolerance package from the pipe's average inside diameter. The tolerance package is defined as the square root of the sum of squared standard manufacturing tolerances.

$$\text{Average inside diameter} = \text{average outside diameter} - 2(1.06)t$$

$$\text{Tolerance package} = \sqrt{A^2 + 2B^2 + C^2}$$

where:

t = minimum wall thickness (Table 1),
A = outside diameter tolerance (Table 1),
B = excess wall thickness tolerance = $0.06t$, and
C = out-of-roundness tolerance.

The values for C were derived statistically from field measurement data and are given as follows for various sizes of pipe:

Nominal Size, in.	Value for C, in.	Value for C, mm
6	0.150	3.81
8	0.225	5.72
9	0.260	6.60
10	0.300	7.62
12	0.375	9.52
15	0.475	12.06

X2. RECOMMENDED LIMIT FOR INSTALLED DEFLECTION[5]

X2.1 Design engineers, public agencies, and others who have the responsibility to establish specifications for maximum allowable limits for deflection of installed PVC sewer pipe have requested direction relative to such a limit.

X2.2 PVC sewer piping made to this specification and installed in accordance with Practice D 2321 can be expected to perform satisfactorily provided that the internal diameter of the barrel is not reduced by more than 7½ % of its base inside diameter when measured not less than 30 days following completion of installation.

[5] Supporting data can be obtained from ASTM Headquarters. Request RR:F17-1009.

ATTACHMENT C, 2/2

Designation: D 1785 – 96b

An American National Standard

Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120[1]

This standard is issued under the fixed designation D 1785; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers poly(vinyl chloride) (PVC) pipe made in Schedule 40, 80, and 120 sizes and pressure-rated for water (see Appendix). Included are criteria for classifying PVC plastic pipe materials and PVC plastic pipe, a system of nomenclature for PVC plastic pipe, and requirements and test methods for materials, workmanship, dimensions, sustained pressure, burst pressure, flattening, and extrusion quality. Methods of marking are also given.

1.2 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The following safety hazards caveat pertains only to the test methods portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific precautionary statement is given in Note 7.

NOTE 1—CPVC plastic pipes, Schedules 40 and 80, which were formerly included in this specification, are now covered by Specification F 441.

NOTE 2—The sustained and burst pressure test requirements, and the pressure ratings in the Appendix, are calculated from stress values obtained from tests made on pipe 4 in. (100 mm) and smaller. However, tests conducted on pipe as large as 24-in. (600-mm) diameter have shown these stress values to be valid for larger diameter PVC pipe.

NOTE 3—PVC pipe made to this specification is often belled for use as line pipe. For details of the solvent cement bell, see Specification D 2672 and for details of belled elastomeric joints, see Specifications D 3139 and D 3212.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[3]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[2]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2152 Test Method for Degree of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion[3]

D 2672 Specification for Joints for IPS PVC Pipe Using Solvent Cement[3]

D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials[3]

D 3139 Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals[3]

D 3212 Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 441 Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80[3]

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[4]

2.4 *NSF Standards:*

Standard No. 14 for Plastic Piping Components and Related Materials[5]

Standard No. 61 for Drinking Water System Components—Health Effects[5]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise specified. The abbreviation for poly(vinyl chloride) plastic is PVC.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *hydrostatic design stress*—the estimated maximum

[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.25 on Vinyl Based Pipe.

Current edition approved Dec. 10, 1996. Published November 1997. Originally published as D 1785 – 60. Last previous edition D 1785 – 96a[ε1].

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[5] Available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106.

ATTACHMENT D 1/2

TABLE 1 Outside Diameters and Tolerances for PVC Plastic Pipe Schedules 40, 80, and 120, in. (mm)

Nominal Pipe Size	Outside Diameter	Tolerances		
			Maximum Out-of-Roundness (maximum minus minimum diameter)	
		Average	Schedule 40 sizes 3½ in. and over; Schedule 80 sizes 8 in. and over	Schedule 40 sizes 3 in. and less; Schedule 80 sizes 6 in. and less; Schedule 120 sizes all
⅛	0.405 (10.29)	±0.004 (±0.10)	...	0.016 (0.41)
¼	0.540 (13.72)	±0.004 (±0.10)	...	0.016 (0.41)
⅜	0.675 (17.14)	±0.004 (±0.10)	...	0.016 (0.41)
½	0.840 (21.34)	±0.004 (±0.10)	...	0.016 (0.41)
¾	1.050 (26.67)	±0.004 (±0.10)	...	0.020 (0.51)
1	1.315 (33.40)	±0.005 (±0.13)	...	0.020 (0.51)
1¼	1.660 (42.16)	±0.005 (±0.13)	...	0.024 (0.61)
1½	1.900 (48.26)	±0.006 (±0.15)	...	0.024 (0.61)
2	2.375 (60.32)	±0.006 (±0.15)	...	0.024 (0.61)
2½	2.875 (73.02)	±0.007 (±0.18)	...	0.030 (0.76)
3	3.500 (88.90)	±0.008 (±0.20)	...	0.030 (0.76)
3½	4.000 (101.60)	±0.008 (±0.20)	0.100 (2.54)	0.030 (0.76)
4	4.500 (114.30)	±0.009 (±0.23)	0.100 (2.54)	0.030 (0.76)
5	5.563 (141.30)	±0.010 (±0.25)	0.100 (2.54)	0.060 (1.52)
6	6.625 (168.28)	±0.011 (±0.28)	0.100 (2.54)	0.070 (1.78)
8	8.625 (219.08)	±0.015 (±0.38)	0.150 (3.81)	0.090 (2.29)
10	10.750 (273.05)	±0.015 (±0.38)	0.150 (3.81)	0.100 (2.54)
12	12.750 (323.85)	±0.015 (±0.38)	0.150 (3.81)	0.120 (3.05)
14	14.000 (355.60	±0.015 (±0.38)	0.200 (5.08)	...
16	16.000 (406.40)	±0.019 (±0.48)	0.320 (8.13)	...
18	18.000 (457.20)	±0.019 (±0.48)	0.360 (9.14)	...
20	20.000 (508.00)	±0.023 (±0.58)	0.400 (10.2)	...
24	24.000 (609.60)	±0.031 (±0.79)	0.480 (12.2)	...

TABLE 2 Wall Thicknesses and Tolerances for PVC Plastic Pipe, Schedules 40, 80, and 120,[A,B] in. (mm)

Nominal Pipe Size	Wall Thickness[A]					
	Schedule 40		Schedule 80		Schedule 120	
	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
⅛	0.068 (1.73)	+0.020 (+0.51)	0.095 (2.41)	+0.020 (+0.51)	...	...
¼	0.088 (2.24)	+0.020 (+0.51)	0.119 (3.02)	+0.020 (+0.51)	...	...
⅜	0.091 (2.31)	+0.020 (+0.51)	0.126 (3.20)	+0.020 (+0.51)	...	...
½	0.109 (2.77)	+0.020 (+0.51)	0.147 (3.73)	+0.020 (+0.51)	0.170 (4.32)	+0.020 (+0.51)
¾	0.113 (2.87)	+0.020 (+0.51)	0.154 (3.91)	+0.020 (+0.51)	0.170 (4.32)	+0.020 (+0.51)
1	0.133 (3.38)	+0.020 (+0.51)	0.179 (4.55)	+0.021 (+0.53)	0.200 (5.08)	+0.024 (+0.61)
1¼	0.140 (3.56)	+0.020 (+0.51)	0.191 (4.85)	+0.023 (+0.58)	0.215 (5.46)	+0.026 (+0.66)
1½	0.145 (3.68)	+0.020 (+0.51)	0.200 (5.08)	+0.024 (+0.61)	0.225 (5.72)	+0.027 (+0.68)
2	0.154 (3.91)	+0.020 (+0.51)	0.218 (5.54)	+0.026 (+0.66)	0.250 (6.35)	+0.030 (+0.76)
2½	0.203 (5.16)	+0.024 (+0.61)	0.276 (7.01)	+0.033 (+0.84)	0.300 (7.62)	+0.036 (+0.91)
3	0.216 (5.49)	+0.026 (+0.66)	0.300 (7.62)	+0.036 (+0.91)	0.350 (8.89)	+0.042 (+1.07)
3½	0.226 (5.74)	+0.027 (+0.68)	0.318 (8.08)	+0.038 (+0.96)	0.350 (8.89)	+0.042 (+1.07)
4	0.237 (6.02)	+0.028 (+0.71)	0.337 (8.56)	+0.040 (+1.02)	0.437 (11.10)	+0.052 (+1.32)
5	0.258 (6.55)	+0.031 (+0.79)	0.375 (9.52)	+0.045 (+1.14)	0.500 (12.70)	+0.060 (+1.52)
6	0.280 (7.11)	+0.034 (+0.86)	0.432 (10.97)	+0.052 (+1.32)	0.562 (14.27)	+0.067 (+1.70)
8	0.322 (8.18)	+0.039 (+0.99)	0.500 (12.70)	+0.060 (+1.52)	0.718 (18.24)	+0.086 (+2.18)
10	0.365 (9.27)	+0.044 (+1.12)	0.593 (15.06)	+0.071 (+1.80)	0.843 (21.41)	+0.101 (+2.56)
12	0.406 (10.31)	+0.049 (+1.24)	0.687 (17.45)	+0.082 (+2.08)	1.000 (25.40)	+0.120 (+3.05)
14	0.437 (11.10)	+0.053 (+1.35)	0.750 (19.05)	+0.090 (+2.29)	...	...
16	0.500 (12.70)	+0.060 (+1.52)	0.843 (21.41)	+0.101 (+2.57)	...	...
18	0.562 (14.27)	+0.067 (+1.70)	0.937 (23.80)	+0.112 (+2.84)	...	...
20	0.593 (15.06)	+0.071 (+1.80)	1.031 (26.19)	+0.124 (+3.15)	...	...
24	0.687 (17.45)	+0.082 (+2.08)	1.218 (30.94)	+0.146 (+3.71)	...	...

[A] The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.

[B] These dimensions conform to nominal IPS dimensions, with the exception that Schedule 120 wall thickness for pipe sizes ½ to 3½ in. (12.5 to 87.5 mm), inclusive, are special PVC plastic pipe sizes.

ATTACHMENT D, 2/2

following

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Designation: D 1784 – 92

An American National Stan

Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[1]

This standard is issued under the fixed designation D 1784; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers rigid PVC and CPVC compounds intended for general purpose use in extruded or molded form, including piping applications involving special chemical and acid resistance or heat resistance, composed of poly(vinyl chloride), chlorinated poly(vinyl chloride), or vinyl chloride copolymers containing at least 80 % vinyl chloride, and the necessary compounding ingredients. The compounding ingredients may consist of lubricants, stabilizers, non-poly(vinyl chloride) resin modifiers, pigments and inorganic fillers.

NOTE 1—Selection of specific compounds for particular end uses or applications requires consideration of other characteristics such as thermal properties, optical properties, weather resistance, etc. Specific requirements and test methods for these properties shall be by mutual agreement between the purchaser and the seller.

1.2 Rigid PVC compounds intended for pipe, fittings and other piping appurtenances are covered in Specifications D 3915 and D 4396.

1.3 Rigid PVC compounds intended for building product applications are covered in Specification D 4216.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following safety hazards caveat pertains only to the test methods portion, Section 11, of this specification: *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 2—This specification is similar in content (but not technically equivalent) to ISO 1163-1:1985 and ISO 1163-2:1980.[2]

2. Referenced Documents

2.1 *ASTM Standards:*

D 256 Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials[3]

D 471 Test Method for Rubber Property—Effect Liquids[4]

D 543 Test Method for Resistance of Plastics to Chemic Reagents[3]

D 618 Practice for Conditioning Plastics and Electric Insulating Materials for Testing[3]

D 635 Test Method for Rate of Burning and/or Extent an Time of Burning of Self-Supporting Plastics in a Ho zontal Position[3]

D 638 Test Method for Tensile Properties of Plastics[3]

D 648 Test Method for Deflection Temperature of Plasti Under Flexural Load[3]

D 790 Test Methods for Flexural Properties of Unrei forced and Reinforced Plastics and Electrical Insulatir Materials[3]

D 883 Terminology Relating to Plastics[3]

D 1600 Terminology for Abbreviated Terms Relating t Plastics[3]

D 1898 Practice for Sampling of Plastics[5]

D 1921 Test Methods for Particle Size (Sieve Analysis) (Plastic Materials[5]

D 3892 Practice for Packaging/Packing of Plastics[5]

D 3915 Specification for Poly(Vinyl Chloride) (PVC) an Related Plastic Pipe and Fitting Compounds for Pre sure Applications[7]

D 4216 Specification for Rigid Poly(Vinyl Chloride) (PVC and Related Plastic Building Products Compounds[7]

D 4396 Specification for Rigid Poly(Vinyl Chloride) (PVC and Related Plastic Compounds for Non-Pressure Pip ing Products[7]

D 5260 Classification for Chemical Resistance of Poly (Vinyl Chloride) (PVC) Homopolymer and Copolyme Compounds and Chlorinated Poly(Vinyl Chloride (CPVC) Compounds[6]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Defi nitions D 883 and abbreviations with Terminology D 160(unless otherwise indicated.

4. Classification

4.1 Means for selecting and identifying rigid PVC com

[1] This specification is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials.

Current edition approved Oct 15, 1992. Published December 1992. Originally published as D 1784 – 60 T. Last previous edition D 1784 – 90.

[2] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 09.01.

[5] *Annual Book of ASTM Standards*, Vol 08.02.

[6] *Annual Book of ASTM Standards*, Vol 08.03.

[7] *Annual Book of ASTM Standards*, Vol 08.04.

ATTACHMENT E. 1/?

TABLE 1 Class Requirements for Rigid Poly(Vinyl Chloride) Compounds

NOTE—The minimum property value will determine the cell number although the maximum expected value may fall within a higher cell

Designation Order No.	Property and Unit	Cell Limits 0	1	2	3	4	5	6	7	8
1	Base resin	unspecified	poly(vinyl chloride) homopolymer	chlorinated poly(vinyl chloride)	vinyl copolymer					
2	Impact strength (Izod) min: J/m of notch	unspecified	<34.7	34.7	80.1	266.9	533.8	800.7		
	ft·lb/in. of notch		<0.65	0.65	1.5	5.0	10.0	15.0		
3	Tensile strength, min: MPa	unspecified	<34.5	34.5	41.4	48.3	55.2			
	psi		<5 000	5 000	6 000	7 000	8 000			
4	Modulus of elasticity in tension, min: MPa	unspecified	<1930	1930	2206	2482	2758	3034		
	psi		<280 000	280 000	320 000	360 000	400 000	440 000		
5	Deflection temperature under load, min, 1.82 MPa (264 psi): °C	unspecified	<55	55	60	70	80	90	100	110
	°F		<131	131	140	158	176	194	212	230
	Flammability	A	A	A	A	A	A	A	A	A

A All compounds covered by this specification when tested in accordance with Method D 635 shall yield the following results: average extent of burning of <25 mm; average time of burning of <10 s.

pounds are provided in Tables 1 and 2. The properties enumerated in Table 1 and the tests defined are expected to provide identification of the compounds selected. They are not necessarily suitable for direct application in design because of differences in shape of part, size, loading, environmental conditions, etc.

4.2 Classes are designated by the cell number for each property in the order in which they are listed in Table 1 including a suffix letter specifying the requirements for chemical resistance, as shown in Table 2.

NOTE 3—The chemical resistance requirements in Table 2 are included to provide identification of the compounds selected. They are not necessarily suitable for rating of application chemical resistance.

NOTE 4—The manner in which selected materials are identified by this classification system is illustrated by a Class 12454-B rigid PVC compound having the following requirements (see Tables 1 and 2):

Class	1	2	4	5	4	B
Identification:						
Poly(vinyl chloride) homopolymer	1					
Property and Minimum Value:						
Impact strength (Izod) (34.7 J/m (0.65 ft·lbf/in.))		2				
Tensile stength (48.3 MPa (7000 psi))			4			
Modulus of elasticity in tension (2758 MPa (400 000 psi))				5		
Deflection temperature under load (70°C (158°F))					4	
Chemical resistance (meets the requirements of Suffix B in Table 2)						B

NOTE 5—The cell-type format provides the means for identification and close characterization and specification of material properties, alone or in combination, for a broad range of materials. This type format, however, is subject to possible misapplication since unobtainable property combinations can be selected if the user is not familiar with commercially available materials. The manufacturer should be consulted.

4.3 Type and grade number designations have been widely used to define the minimum physical properties and chemical resistance requirements of certain commercial classes of rigid PVC compounds. Table X1.1 in the Appendix lists these type and grade numbers and the corresponding class numbers selected from Table 1 and 2. The classes for previous types and grades of poly(vinyl chloride vinyl acetate) compounds are listed in Table X2.1 in the Appendix.

4.4 Product application chemical resistance when specified shall be classified according to the Classification Section of Classification D 5260.

5. Ordering Information

5.1 The purchase order, or inquiry for these materials, shall state the specification number and identify the class selected, for example, D 1784, Class 12454-B.

5.2 Further definition, as may be required for the fol-

TABLE 2 Suffix Designation for Chemical Resistance

Solution	A	B	C	D
H_2SO_4 (93 %)—14 days immersion at 55 ± 2°C:				
Change in weight:				
Increase, max, %	1.0A	5.0A	25.0	NAB
Decrease, max, %	0.1A	0.1A	0.1	NA
Change in flexural yield strength:				
Increase, max, %	5.0A	5.0A	5.0	NA
Decrease, max, %	5.0A	25.0A	50.0	NA
H_2SO_4 (80 %—30 days immersion at 60 ± 2°C:				
Change in weight:				
Increase, max, %	NA	NA	5.0	15.0
Decrease, max, %	NA	NA	5.0	0.1
Change in flexural yield strength:				
Increase, max, %	NA	NA	15.0	25.0
Decrease, max, %	NA	NA	15.0	25.0
ASTM Oil No. 3—30 days immersion at 23°C:				
Change in weight:				
Increase, max, %	0.5	1.0	1.0	10.0
Decrease, max, %	0.5	1.0	1.0	0.1

A Specimens washed in running water and dried by an air blast or other mechanical means shall show no sweating within 2 h after removal from the acid bath.

B NA = not applicable.

ATTACHMENT E, 2/2

Physical Properties of Harvel Rigid PVC & CPVC Pipe

Properties	ASTM Test Method	PVC 1120 (Normal Impact)	PVC 2110 (Hi Impact)	Harvel CPVC 4120
Mechanical				
Specific Gravity, g/cm³	D792	1.40 ± .02	1.37 ± .02	1.55 ± .02
Tensile Strength at 73° F psi	D638	7,450	6,400	8,000
Modulus Elasticity In Tension, psi at 73° F	D638	420,000	385,000	360,000
Compressive Strength, psi at 73° F	D695	9,600	8,600	9,000
Flexural Strength at 73° F psi	D790	14,450	11,850	15,100
Izod Impact, ft. lb./in. notch at 73° F	D256	.75	10.9	1.5
Hardness Durometer D	D2240	82 ± 3	78 ± 3	–
Hardness Rockwell R	D785	110 - 120	–	119
Thermal				
Coefficient of Thermal Conductivity $\frac{(Cal.)(cm)}{(cm^2)(sec.)(°C)} \times 10^{-4}$	C177	3.5	4.5	0.96
Coefficient of Linear Expansion x 10^{-5} cm/cm °C	D696	5.2	9.9	6.2
x 10^{-5} in/in °F		2.9	5.5	3.4
Heat Distortion Temperature, °F at 264 psi	D648	170	145	217
Specific Heat, Cal./°C/gm	D2766	0.25	0.25	–
Upper Service Temp. Limit °F		140	140	200
Flammability				
Average Time of Burning (sec.)	D635	<5	<5	<5
Average Extent of Burning (mm)		<10	<15	<10
Flame Spread Index	E162	<10	–	<10
Flame Spread	E84	10-25	–	4-18
Flash Ignition		730°F	–	900°F
Smoke Developed*		600-1000	–	9-169
Flammability (.062")	UL-94	V-O	–	V-O, 5VB, 5VA
Softening Starts, approx. °F		250	–	295
Material Become Viscous, °F		350	–	395
Material Carbonizes, °F		425	–	450
Limiting Oxygen Index (LOI)				60
Electrical				
Dielectric Strength, volts/mil	D149	1,413	1,085	1,250
Dielectric Constant	D150			
60 cps at 30°C		3.70	3.90	–
1000 cps at 30°C		3.62	3.31	–
Power Factor %	D150			
60 cps at 30°C		1.25	2.85	–
1000 cps at 30°C		2.82	3.97	–
Volume Resistivity at 95°C, ohms/cm/10^{12}		1.2	2.4	–
Harvel Rigid Pipe is non-electrolytic.				
Other Properties				
Water Absorption, % Increase– 24hrs. at 25°C	D570	0.05	0.10	0.03
Light Transmission	E308	Opaque	Opaque	–
Light Stability		Excellent	Excellent	–
Effect of Sunlight		Slight Darkening	Slight Darkening	–
Color (Standard)		Dark Grey	Light Grey	Medium Grey
Material Cell Classification				
ASTM D1784		12454-B	16334-D	23447-B
ASTM D3915		12452-4	14341-1	23444-4

ASTM D1784 and D3915 refer to similar compounds. The major difference is that the alphabetical sixth place designation refers to corrosion resistance under ASTM D1784, and the sixth place designation under D3915 refers to the hydrostatic design stress. In addition, D3915 also places upper limits for values in the second through the fifth place designations.

*Tests performed on pipe sizes 3/4" - 4" with a single pipe exposed each test. Some of the CPVC pipes were water filled and these resulted in the lower smoke development values.

NOTE: Harvel CPVC pipe is extruded from Corzan™ CPVC compounds manufactured by BF Goodrich Specialty Polymers and Chemicals Division.

HARVEL PLASTICS MANUFACTURER DOCUMENTATION

ATTACHMENT F, 1/1

be small compared to the pressure due to the fill, the vertical pressure on the top of the pipe can be assumed to be equal to the unit weight of the refuse fill multiplied by the distance from top of fill to top of pipe, thus:

$$\sigma_v = (\omega_f)(H_f).$$

V.2.2.3 Perforated Pipe

Perforations will reduce the effective length of pipe available to carry loads and resist deflection. The effect of perforations can be taken into account by using an increased load per nominal unit length of the pipe. If l_p equals the cumulative length in inches of perforations per foot of pipe, the increased vertical stress to be used equals:

$$(\sigma_v)\text{design} = \frac{12}{12-l_p} \times (\sigma_v)\text{actual}$$

REFERENCE: EPA, MANUAL SW-8 "LINING OF WASTE IMPOUNDMENT AND DISPOSAL FACILITIES". SEPTEMBER 1980

Attachment G 1/1

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **Energy Fuels**	Project: **White Mesa Mill – Cells 5A and 5B**	Project/ Proposal No.:	**SC0634**
		Task No.	**02**

Title of Computations **PUNCTURE EVALUATION**

Computations by:	Signature	[signature]	12/18/12 Date
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature	[signature]	12/20/12 Date
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations Checked by:	Signature	[signature]	12/20/12 Date
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations backchecked by: (originator)	Signature	[signature]	12/18/12 Date
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature	[signature]	12/18/12 Date
	Printed Name	Gregory Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Geosyntec consultants

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/10/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

PUNCTURE EVALUATION
WHITE MESA MILL
BLANDING, UTAH

OBJECTIVE

The project involves placement of a triple liner system for the base of Cells 5A and 5B at the White Mesa Mill in Blanding, Utah. The proposed liner system is shown in Attachment A. The objective of this calculation is to evaluate the maximum particle sizes of soil/aggregate materials adjacent to the geomembrane that will not puncture or damage the geomembrane.

SUMMARY OF ANALYSIS

The analyses suggest that the following maximum particle sizes and geotextile mass per unit areas will be required:

Component of Liner	Maximum Particle Size (in)	Maximum Protrusion Height (in)	*Cushion Material*
Slimes drain system over geomembrane	1	N/A	16 oz/yd^2
Leak detection system (LDS) over geomembrane	1	N/A	16 oz/yd^2
Geomembrane over prepared subgrade	N/A	0.7	N/A

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

SITE CONDITIONS

The proposed triple liner system will be comprised of the following components on the side slopes, from top to bottom:

- primary 60-mil smooth HDPE geomembrane;
- secondary 60-mil HDPE Drain Liner® geomembrane;
- tertiary 60-mil HDPE Drain Liner® geomembrane; and
- prepared subgrade.

On the cell bottom the proposed triple liner system with be comprised of the following components, from top to bottom:

- primary 60-mil smooth HDPE geomembrane;
- 300-mil geonet
- secondary 60-mil smooth HDPE geomembrane;
- tertiary 60-mil HDPE Drain Liner® geomembrane; and
- prepared subgrade.

The slimes drain header pipe will be placed on top of the primary geomembrane with cushion geotextile and drainage aggregate placed above (Attachment A). Two Leak Detection Systems (LDS) will be installed (1) between the primary geomembrane and the secondary geomembrane and (2) between the secondary geomembrane and tertiary geomembrane (Attachment A). The LDS will consist of a PVC pipe surrounded by aggregate and wrapped in a 16 oz/yd^2 geotextile. The tertiary geomembrane will be installed over prepared subgrade.

The tailings deposits are anticipated to be similar to silt with an average maximum wet unit weight of 125 pounds per cubic foot (pcf) (See slope stability calculation for this value). For conservatism, we have assumed that a maximum of 43 ft of tailing deposits plus 9 feet of cover soil may be present. Therefore, the design overburden pressure is 52 ft × 125 pcf = 6,500 pounds per square foot (psf) or 311 kilopascals (kPa).

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

APPROACH

LDS Trenches

The geomembranes will be under- and/or over-lain by a nonwoven cushion geotextile to protect against puncture from the underlying and/or overlying LDS gravel. The approach by Koerner (1997) was used to evaluate the required properties of the cushion geotextile. According to this approach, the important parameters that affect the puncture protection of geomembranes are: overlying pressure, mass per area of the geotextile, and the particle size and shape of the material overlying the geotextile. For the analysis herein, the overlying pressure and the mass per unit area of the geotextile are given and the maximum particle size is evaluated for the geotextile.

Subgrade and Geomembrane

The tertiary geomembrane will be installed directly on the prepared subgrade. Evaluation of the maximum allowable particle size for the soil materials located directly against these geomembranes is calculated using the methods presented in Giroud et al. (1995). According to the analysis by Giroud et al. (1995), a relationship can be made between the failure strength of a geomembrane in a laboratory probe test and the failure pressure of a geomembrane in the field when loaded by a water pressure. Attachment C presents portions of the Giroud et al. (1995) paper for use herein.

ANALYSES

LDS Trenches and Slimes Drain Header Pipe

Narejo et al. (1996, Attachment B) present the following equation for evaluating geotextile puncture protection of 60 mil (1.5 mm) HDPE geomembrane:

$$H^2 = \frac{450 M_A}{P_{allow}} \qquad \text{(Attachment B)}$$

where:

H = cone height (mm), which corresponds to predicted effective protrusion height, which equals one-half maximum stone size.

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M_A = mass per unit area geotextile (g/m^2)

= 16 oz/yd^2 = 542 g/m^2 (slimes drain and LDS)

P_{allow} = maximum long term allowable pressure

where: $P_{allow} = P'_{allow}(MF_S \times MF_{PC} \times MF_A)(FS_{CR} \times FS_{CBD})$ (Attachment B)

where: MF_S, MF_{PC}, MF_A = modification factors (discussed below)

FS_{CR}, FS_{CBD} = partial factor of safety values (discussed below)

P'_{allow} = allowable pressure on geomembrane

$= (FS)(P_{actual\,field\,pressure})$ (Attachment B)

where: FS = global factor of safety, 3.0 (Attachment B)

$P_{actual\ field\ pressure}$ = 311 kPa

P'_{allow} = (311)(3) = 933 kPa

MF_S = shape factor: (Attachment B)

1.0 (assume angular particles)

MF_{PC} = protrusion configuration: (Attachment B)

1.0 (assume isolated protrusions)

MF_A = soil arching: (Attachment B)

1.0 (assume none)

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FS_{CR} = partial factor of safety for creep: (Attachment B)
for H>12 mm, $FS_{CR} = 1.3$

FS_{CBD} = partial factor of safety for chemical and biological degradation: (Attachment B)
1.5 (based on aggressive environment for polypropylene geotextiles in LDS and slimes drain)

Solving for P_{allow} provides:

$$P_{allow} = (933)\,(1.0 \times 1.0 \times 1.0)\,(1.3 \times 1.5)$$

$$P_{allow} = 1{,}820 \text{ kPa}$$

Solving for H, the predicted effective protrusion height, provides:

$$H^2 = \frac{450M_A}{P_{allow}}$$

$$H_{cushion} = \left(\frac{450(542)}{1820}\right)^{1/2} = 11.6 \text{ mm} = 0.5 \text{ in}$$

The predicted effective protrusion height equals one half the maximum stone size. Therefore, the maximum stone size for the gravel to be placed around the slimes drain and in the LDS is 2 × 0.5 inches, or 1.0 inches. We recommend the maximum particle size for construction be 1 inch for the slimes drain and LDS.

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Subgrade and Geomembrane

Giroud's equation (Giroud et al. 1995) is used to calculate the maximum subgrade protrusion height. The relationship is as follows (Attachment C)

$$\frac{\lambda \times d_{s,round} \times P_p}{t_{GMs}} = \frac{F_p \times Z_{\varepsilon Peak}}{d_p \times t_{GMp}}$$

where: λ = term that characterizes the stone arrangement
= 0.87 for densely packed stones (Attachment C)

$d_{s,\ round}$ = the stone size **[to be solved]**

P_p = field pressure, kPa
= 311 kPa

$Z_{\varepsilon Peak}$ = 0.749, function of ε defined by
$\varepsilon = \frac{\sin^{-1} Z_\varepsilon}{Z_\varepsilon} - 1$; ε=strain at yield, 13% (Attachment D)

$t_{GM,s}$ = t_{GMp} = thickness of the geomembrane in the application and the probe test, respectively
= 1.5 mm (60 mil)

F_p = 95 lb = 422 N, puncture resistance as reported for 60-mil HDPE geomembrane (Attachment D)

F_p' = $\frac{F_p}{\sum FS}$ where $\sum FS = FS_{cr} \times FS_{id} \times FS_{cd} \times FS_{bd}$
Factor of Safety for Creep, FS_{cr} = 1.5
Factor of Safety for Installation Damage, FS_{id} = 2.0
Factor of Safety for Chemical Degradation, FS_{cd} = 2.0
Factor of Safety for Biological Degradation, FS_{bd} = 1.0

F_p' = $\frac{422\ N}{1.5 \times 2 \times 2 \times 1}$ = 70 N

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/10/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

d_p = diameter of probe
= 8 mm used in laboratory puncture test according to ASTM D 4833

Therefore, solving Giroud's equation from above:

$$d_{s,round} = \frac{F_p \times Z_{\varepsilon Peak} \times t_{GMS}}{d_p \times \lambda \times P_p}$$

$$d_{s,round} = \frac{70\ N \times 0.749 \times 1.5mm}{8mm \times 0.87 \times 311kPa}$$

$d_{s,round}$ = 36 mm = 1.40 in.

Therefore, the maximum particle size of the subgrade should be 1.4 in. A maximum protrusion size of 0.7 in. will be specified for the subgrade.

NOTE TO TECHNICAL SPECIFICATIONS

For practical construction and CQA purposes, the calculated maximum particle sizes and protrusion heights of the soil components of the liner are rounded down to a convenient magnitude. The subgrade will be rolled and compacted; therefore, the maximum protrusion height (instead of maximum particle size) is required for the technical specifications. The specifications should reflect the following information:

Soil Component of Liner	Maximum Protrusion Height (in.)	Maximum Particle Size (in.)
Drainage aggregate	N/A	1
Prepared subgrade	0.7	N/A

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/8/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

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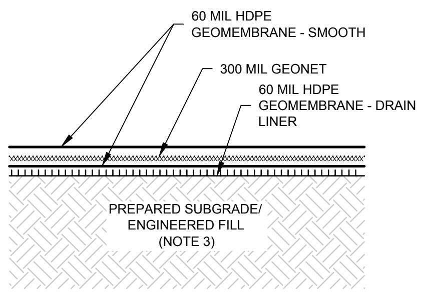
Agru Product Data: High Density Polyethylene Drain Liner

Giroud, J.P., Badu-Tweneboah, K., and Soderman, K.L. (1995) "Theoretical Analysis of Geomembrane Puncture," Geosynthetics International, Vol. 2, No. 6, pp.1019-1048

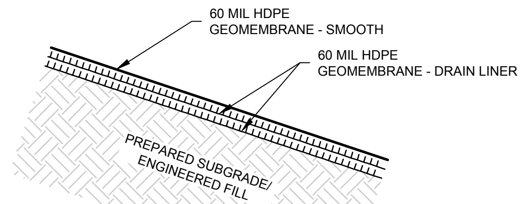
Koerner, R.M., Wilson-Fahmy, R.F. and Narejo, D. (1996) "Puncture Protection of Geomembranes Part III: Examples", Geosynthetics International, Vol. 3, No. 5, pp. 655-675.

Narejo, D., Koerner, R.M. and Wilson-Fahmy, R.F. (1996) "Puncture Protection of Geomembranes Part II: Experimental", Geosynthetics International, Vol. 3, No. 5, pp. 629-653.

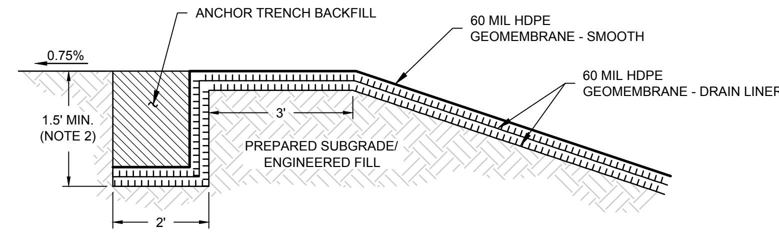
Wilson-Fahmy, R.F., Narejo, D., and Koerner, R.M. (1996) "Puncture Protection of Geomembranes Part I, Theory", Geosynthetics International, Vol. 3, No. 5, pp. 605-628.



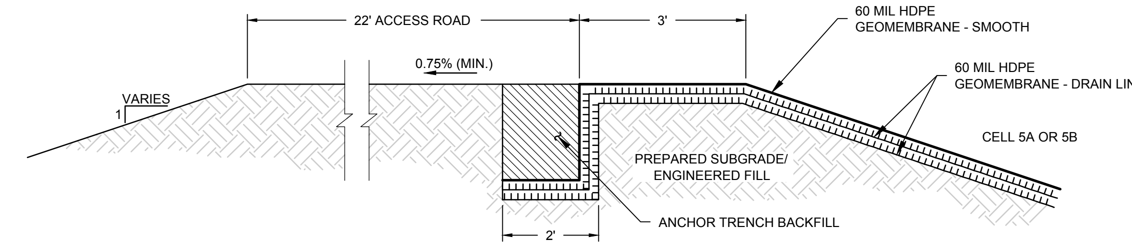
9 DETAIL 03A,03B,04A,04B
BASE LINER SYSTEM
SCALE: 1" = 2'



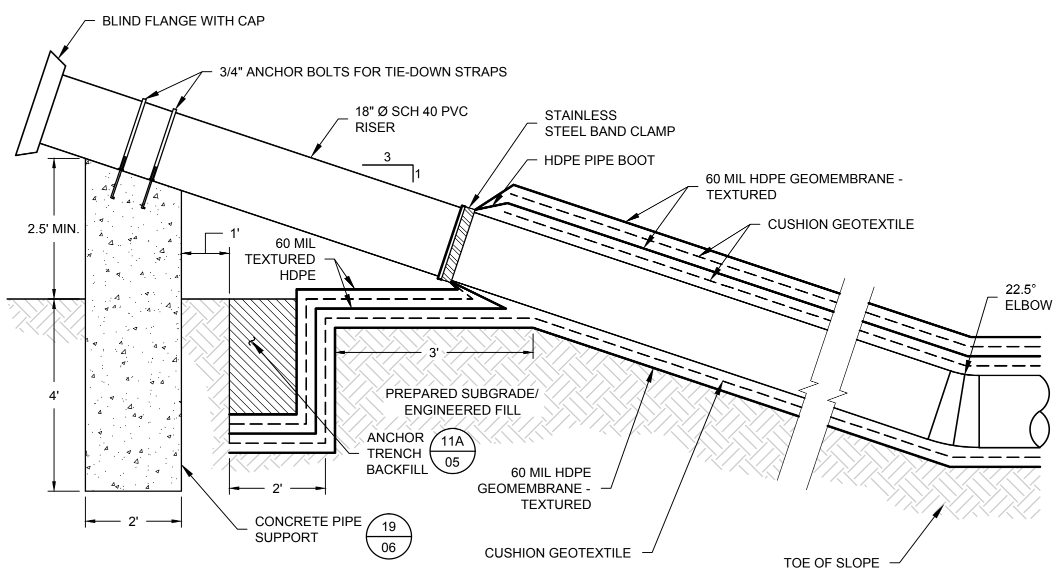
10 DETAIL 03A,03B,04A,04B
SIDE SLOPE LINER SYSTEM
SCALE: 1" = 2'



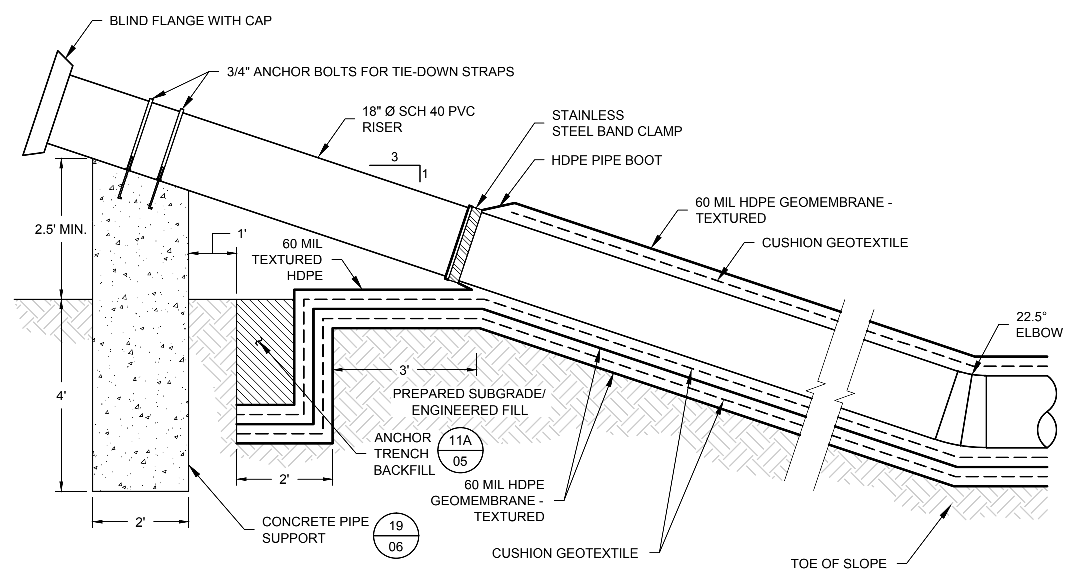
11A DETAIL 03A,03B,04A,04B,05,06,09
ANCHOR TRENCH
SCALE: 1" = 2'



11B DETAIL 03A,03B
ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



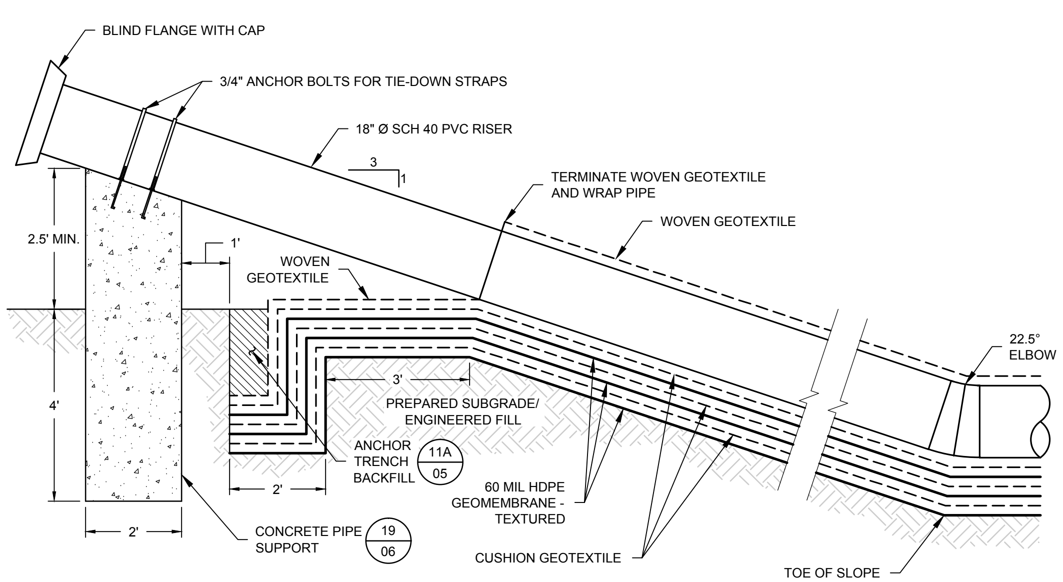
12 DETAIL 04A,04B
SECONDARY LEAK DETECTION RISER PENETRATION
SCALE: 1" = 2'



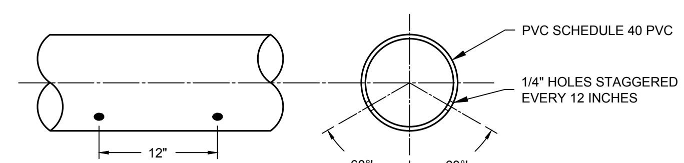
13 DETAIL 04A,04B
PRIMARY LEAK DETECTION SYSTEM RISER PENETRATION
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. ANCHOR TRENCHES MAY BE CONSTRUCTED WITH A MAXIMUM DEPTH OF 3.5 FEET WITH UP TO 1 FOOT OF BACKFILL BETWEEN EACH GEOMEMBRANE IN BOTTOM OF ANCHOR TRENCH.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.



14 DETAIL 04A,04B
SLIMES DRAIN RISER PENETRATION
SCALE: 1" = 2'



15 DETAIL 07,08
PERFORATED PIPE
SCALE: 1" = 1'

Attachment A (1/2)

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUTE 200
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS I

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

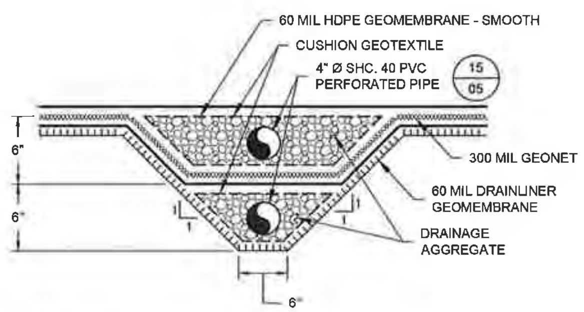
DATE

DESIGN BY:	GTC	DATE:	JANUARY 2013
DRAWN BY:	MMC	PROJECT NO.:	SC0634
CHECKED BY:	RBF	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	05 OF 10	

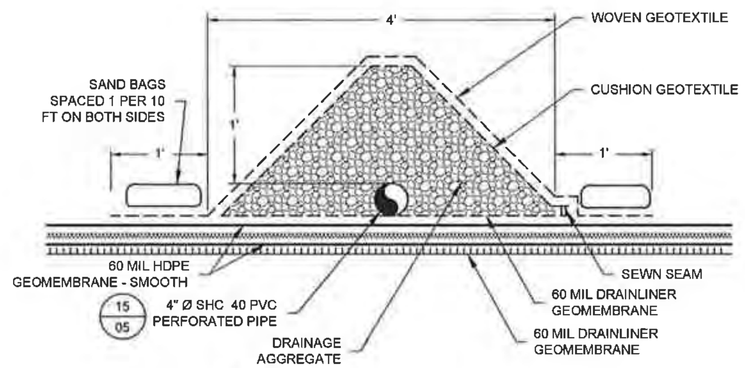
PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

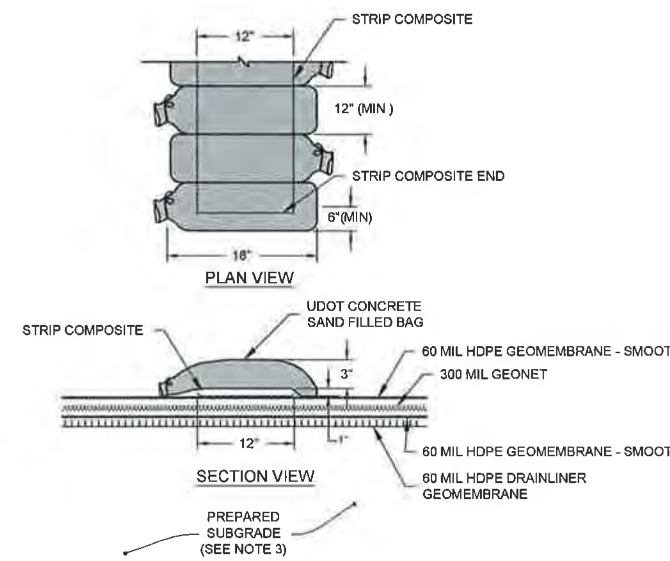
P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634-05-07.dwg Last Edited by: MikeC on 12/21/2012 9:51 AM



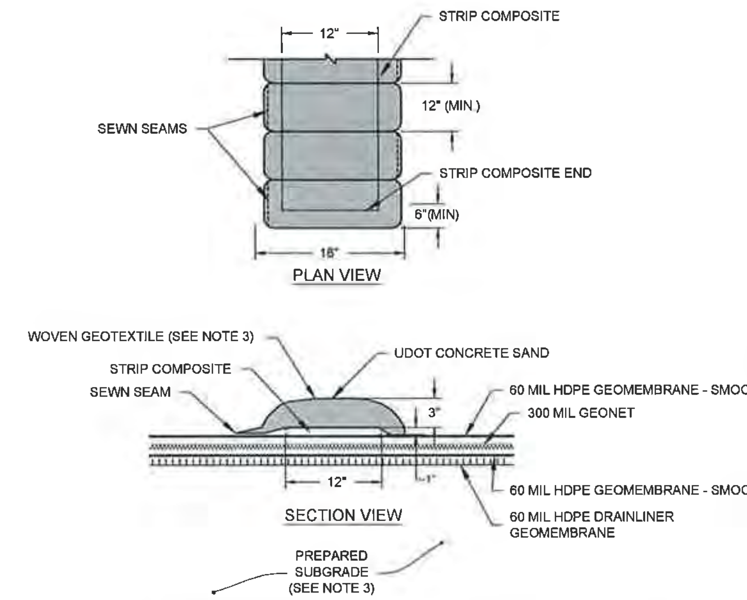
16 DETAIL
04A,04B LEAK DETECTION SYSTEM TRENCHES
SCALE: 1" = 1'



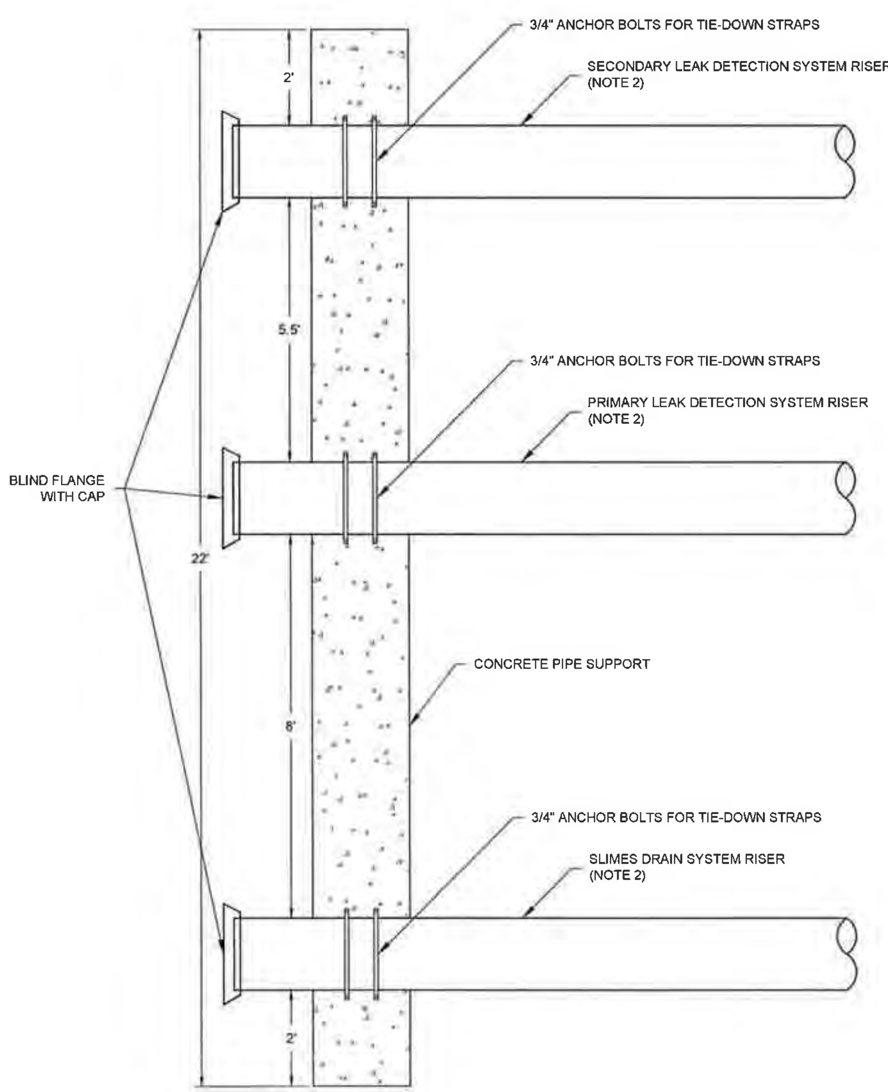
17 DETAIL
04A,04B SLIMES DRAIN HEADER
SCALE: 1" = 1'



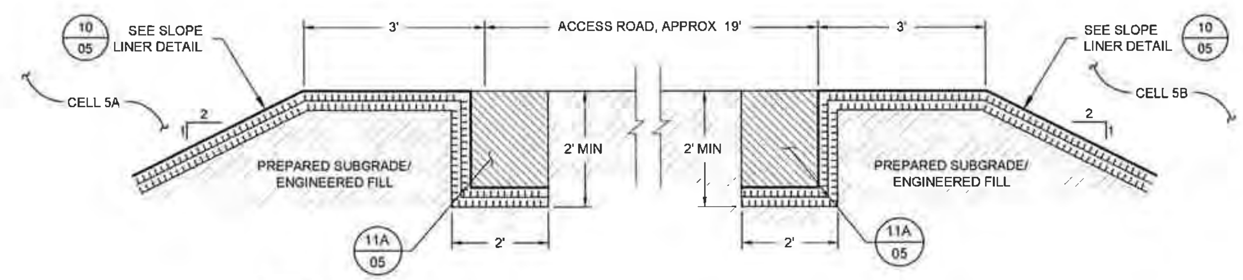
18A DETAIL
04A,04B SLIMES DRAIN LATERAL - OPTION 1
SCALE: 1" = 1'



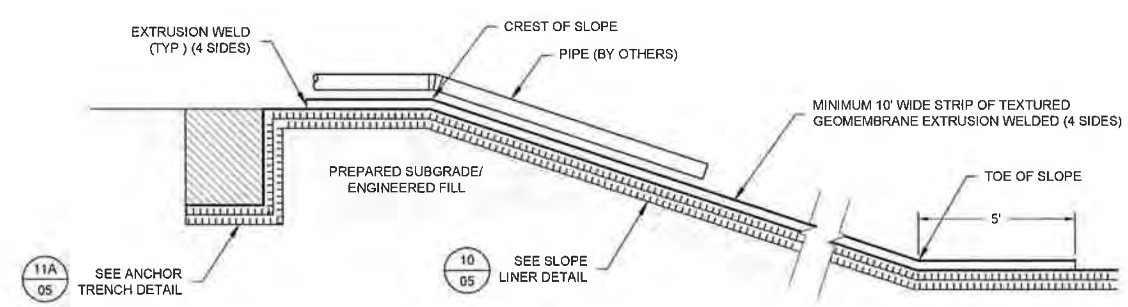
18B DETAIL
04A,04B SLIMES DRAIN LATERAL - OPTION 2
SCALE: 1" = 1'



19 DETAIL
03A,03B,04A,04B CONCRETE PIPE SUPPORT
SCALE: 1" = 2'



20 DETAIL
03A,03B,04A,04B CELL 5A - CELL 5B ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



21 DETAIL
03A,03B,04A,04B SPLASH PAD DETAIL
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY
2. EXPOSED PVC PIPE SHALL BE PAINTED TO MINIMIZE DAMAGE DUE TO UV
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATION

Attachment A (2/2)

PERMIT LEVEL DESIGN
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REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
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SAN DIEGO, CA 92127
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Energy Fuels Resources (USA) Inc

TITLE: LINER SYSTEM DETAILS II

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL, BLANDING, UTAH

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SIGNATURE

DATE

DESIGN BY	GTC	DATE	JANUARY 2013
DRAWN BY	MMC	PROJECT NO.	SC0834
CHECKED BY	RBF	FILE	SC0634-05-07
REVIEWED BY	GTC	DRAWING NO.	
APPROVED BY	GTC	06 OF 12	

(1in) (2in) (3in) (4in) SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634-05-07.dwg Last Edited by: MikeC on 12/13/2012 11:32 AM

SIMPLIFIED DESIGN CHARTS FOR GEOMEMBRANE CUSHIONS

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DERON N. AUSTIN, P.E. – SYNTHETIC INDUSTRIES, INC. (USA)

ABSTRACT

Recent and ongoing research indicates that use of a properly selected nonwoven, needle-punched geotextile cushion adjacent to (above and/or below) a geomembrane can effectively protect it from construction and operational damage. The current practice selects an appropriate geotextile cushion using the Geosynthetic Research Institute (GRI) method (Koerner, et. al. 1996). This method was used to develop simplified design charts allowing quick, conservative selection of an appropriate geotextile cushion. Charts are provided for typical applications including solid waste landfills and liquid impoundments with varying load, subgrade and cover/subgrade soil conditions. In addition, a brief discussion of the design procedure is provided with completed numerical examples.

INTRODUCTION

Most solid and hazardous waste landfills, lagoons and reservoirs built today incorporate geomembranes to contain liquids. Although these low permeability liners have demonstrated excellent performance, they are susceptible to damage when drainage stone or alternate drainage media (such as shredded tires, crushed glass, etc.) are placed over them (Figure 1). In addition, geomembranes are prone to damage from isolated protrusions present in the subgrade onto which they are deployed.

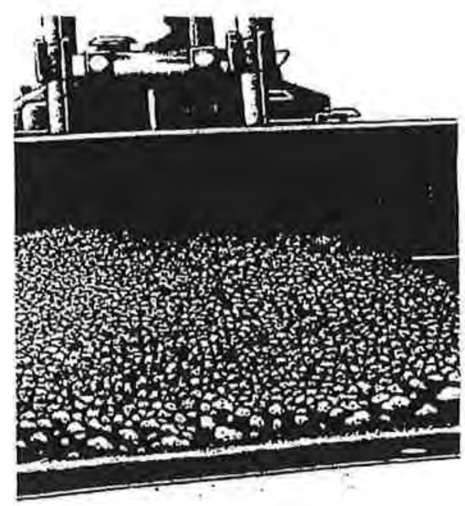

Figure 1. Stone Placement over a Geomembrane

Figure 2 illustrates the typical components of modern landfill liner system and Figure 3 represents a typical liquid impoundment liner system. Of these components, the geomembrane is the most prone to

Attachment B – 1/16

damage. Protecting the geomembrane from tearing or puncturing during construction and operation is critical. Recent and ongoing research indicates that deployment of a properly selected nonwoven, needle-punched geotextile cushion adjacent to (above and/or below) a geomembrane provides effective protection against damage.

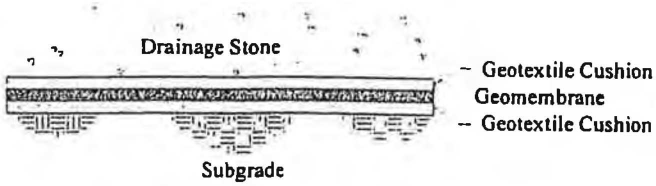

Figure 2. Typical Municipal Landfill Liner System

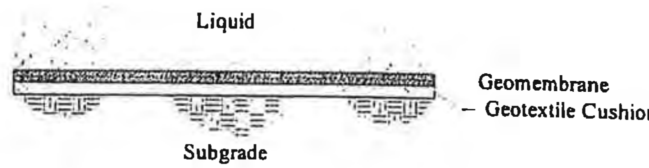

Figure 3. Typical Liquid Impoundment Liner System

STATE OF GEOMEMBRANE CUSHION DESIGN PRACTICE

State of geomembrane cushion design practice suggests using the generalized procedure developed by Koerner, et. al (1996) at the Geosynthetic Research Institute (GRI). The GRI method couples theoretical (Wilson-Fahmy, et. al., 1996) and empirical (Narejo, et. al., 1996) puncture protection analysis through use of a global factor of safety. The method directly applies to 1.5 mm (60 mil), smooth, high density polyethylene (HDPE) geomembranes protected by virgin polymer, nonwoven, needle-punched geotextiles. However, early work by Hullings and Koerner (1991) and field research by Richardson and Johnson (1998) indicate that the method may be conservative for geomembranes manufactured from more flexible polymers. Koerner, et. al. (1996) also suggest that the GRI method may be extended to other types of cushion materials.

The governing equation (Equation 1) incorporates several simplifying assumptions. For extrapolation to field design, (at least partially) subjective modification/reduction factors are required. In addition, laboratory testing used to develop the model did not incorporate dynamic loading. Therefore, the GRI method is considered adequate in cases where uniform, normal, static loading controls the design (i.e. moderate to high waste fills and most liquid impoundments) and may be under-conservative in cases where construction (dynamic) loading controls (i.e. shallow waste fills, poor construction practices, etc.). Based on field evaluation of geosynthetic cushions under construction loading, Richardson (1996) recommends modification of the GRI method such that the minimum nonwoven geotextile cushion mass selected is 405 g/m^2 (12 oz/yd^2) for 2.5 cm (1 in) maximum gravel over smooth HDPE geomembranes. This recommendation was later extended to 1.3 cm (0.5 in) gravel through additional field testing (Richardson and Johnson, 1998). Reddy et. al. (1996) performed similar field evaluations and concluded that a lighter 270 g/m^2 (8 oz/yd^2) geotextile is capable of providing adequate protection against construction loading. Based on laboratory testing, Reddy and Saichek (1998) also concluded that a 270 g/m^2 (8 oz/yd^2) may provide acceptable long-term protection under specific conditions.

Although a comprehensive review of previous research is beyond the scope of this paper, the reader is encouraged to read and understand the referenced literature prior to application or modification of the GRI method. This methodology (that forms the basis for the simplified design charts presented later in this paper) is summarized in the following steps.

Step 1: Estimate the Allowable Pressure on the Geomembrane (in terms of M_A)

$$P'_{allow} = \left(450 \cdot \frac{M_A}{H^2}\right)\left(\frac{1}{MF_S \cdot MF_{PC} \cdot MF_A}\right)\left(\frac{1}{FS_{CR} \cdot FS_{CBD}}\right) \quad \text{(Equation 1)}$$

Where:

P'_{allow} = Allowable pressure on geomembrane (kPa)
450 = Empirical constant ($kPa \cdot mm^2/(g/m^2)$)
M_A = Required mass per unit area of nonwoven, needle-punched geotextile (g/m^2)
H = Effective height of protrusion (mm)
MF_S = Modification factor for protrusion shape (dimensionless)
MF_{PC} = Modification factor for protrusion configuration (dimensionless)
MF_A = Modification factor for overburden arching effect (dimensionless)
FS_{CR} = Factor of safety for geotextile creep (dimensionless)
FS_{CBD} = Factor of safety for geotextile chemical/biological degradation (dimensionless)

Equation 1 should be solved in terms of M_A. The effective height of protrusion (H) represents the maximum height of any object in contact with the geomembrane extends relative to the overlying/underlying media. In cases where protection is sought from uniformly packed stones (such as landfill leachate collection/drainage media), H may be estimated as one-half the maximum particle diameter of the stones. However, when protection is sought from isolated protrusions (such as stones encountered in a hastily prepared subgrade), H may be estimated as the maximum particle diameter of the protrusions. In the later case, the value of H may be based on observed conditions, or specified by restricting the largest particle size allowed to remain on the prepared subgrade during geosynthetic deployment. Modification Factors for protrusion shape, protrusion configuration, and overburden arching effect may be selected based on guidelines presented by Narejo, et. al (1996):

Table 1. Recommended Modification Factor for Protrusion Shape
(Adapted from Narejo, et. al., 1996, page 647)

Protrusion Shape	Modification Factor, MF_S
Angular	1.00 ←
Subrounded	0.50
Rounded	0.25

3/16

Table 2. Recommended Modification Factor for Protrusion Configuration
(Adapted from Narejo, et. al., 1996, page 647)

Protrusion Configuration	Modification Factor, MF_{PC}
Isolated Protrusions	1.00
Uniformly Packed Surface	0.50

Table 3. Recommended Modification Factor for Overburden Arching Effect
(Adapted from Narejo, et. al., 1996, page 648)

Anticipated Arching Effect	Modification Factor, MF_A
None (i.e. Liquid Overburden)	1.00
Moderate	0.50
Maximum	0.25

Through limited creep testing, Narejo, et. al. (1996) indicated that geotextile cushion creep is primarily a function of H and M_A. Since M_A is unknown at this point, Equation 1 may be solved by assuming a reasonable value for FS_{CR} based on the anticipated M_A required. Following completion of the required calculations, the assumed value of FS_{CR} must be checked for validity. Table 4 provides recommended FS_{CR} values in the form of unique linear equations for several commonly available nonwoven, needle-punched geotextiles. It is interesting to note that the recommended upper limit with respect to H, is in general agreement (probably by coincidence) with construction limits established by Richardson (1996) and Reddy and Saichek (1996). The equations for FS_{CR} and their range of validity were interpolated/extrapolated from available geotextile cushion creep test data (Narejo, et. al., 1996).

Table 4. Factor of Safety for Geotextile Creep
(Adapted from Narejo, et. al., 1996, page 644 - 648)

Nonwoven, Needle-punched Geotextile Mass per Unit Area	Factor of Safety, FS_{CR}
270 g/m^2 (N/R for H > 12 mm)	$\approx 0.0417 \cdot H + 1.25$
405 g/m^2 (N/R for H > 19 mm)	$\approx 0.0292 \cdot H + 1.18$
540 g/m^2 (N/R for H > 25 mm)	$\approx 0.0166 \cdot H + 1.11$
675 g/m^2 (N/R for H > 29 mm)	$\approx 0.0139 \cdot H + 1.08$
745 g/m^2 (N/R for H > 31 mm)	$\approx 0.0129 \cdot H + 1.07$
810 g/m^2 (N/R for H > 32 mm)	$\approx 0.0119 \cdot H + 1.06$
945 g/m^2 (N/R for H > 35 mm)	$\approx 0.0100 \cdot H + 1.03$
1015 g/m^2 (N/R for H > 36 mm)	$\approx 0.0089 \cdot H + 1.02$
1080 g/m^2 (N/R for H > 38 mm)	$\approx 0.0080 \cdot H + 1.00$

NOTE: N/R = Not recommended

The factor of safety for chemical and biological degradation (FS_{CBD}) should be selected based on the aggressiveness of the anticipated chemical environment and the geotextile polymer composition. Table 5 provides general recommendations:

Table 5. Recommended Factor of Safety for Chemical and Biological Degradation (based on Koerner, 1994, page 151 and Synthetic Industries, 1997)

Chemical Environment	Factor of Safety for Chem/Bio Degradation, FS_{CBD}	
	Polyester (PET) Geotextiles	Polypropylene (PP) Geotextiles
Normal (i.e. 3 < pH < 10)	1.0	1.0
Aggressive (pH <3 or pH > 10)	1.5 – 2.0	1.0 – 1.5

Step 2: Estimate the Anticipated Pressure on the Geomembrane

$$P_{actual} = \gamma \cdot h \qquad \text{(Equation 2)}$$

Where:

γ = Unit weight of overburden material or liquid (kN/m^3)
h = Design height of overburden material or liquid depth (m)
P_{actual} = Estimated maximum pressure on geomembrane (kPa)

The parameters required to complete Equation 2 may be assumed or specified based on site specific considerations. The unit weight of typical municipal solid waste may be estimated to equal 12.56 kN/m^3 (80 lb/ft^3) in the absence of site specific data. Likewise, the unit weight of most liquids can be approximated by the unit weight of water, 9.81 kN/m^3 (62.4 lb/ft^3).

In some cases (i.e. shallow waste fills, poor construction practices, etc.), the dynamic ɔrces associated with construction loading may exceed those associated with long-term static loading. The exact point at which this occurs is dependent on multiple variables and difficult (if not impossible) to estimate. Therefore, caution should be exercised in selection of a geotextile cushion having a mass per unit area less than 405 g/m^2 (12 oz/yd^2), the construction limit recommended by Richardson and Johnson (1998).

Step 3: Calculate the Required Mass per Unit Area of the Cushion Geotextile

$$P'_{allow} \geq FS_{gmin} \cdot P_{actual} \qquad \text{(Equation 3)}$$

Where:

P'_{allow} = Allowable pressure on geomembrane in terms of M_A (Equation 1)
FS_{gmin} = Global Factor of Safety (dimensionless)

Equation 3 may be solved for M_A through substitution (Equation 1 and 2 results) and algebraic manipulation. The global factor of safety (FS_{gmin}) should be selected based on the protrusion configuration and H. Recommendations are provided in Table 6.

Table 6. Recommended Global Factor of Safety
(Adapted from Koerner, et. al., 1996, page 648)

Protrusion Configuration	Global Factor of Safety, FS_{gmin}
Isolated Protrusions	$= 0.22 \cdot H + 1.77$ (≥ 3.0)
Uniformly Packed Surface	3.0

Step 4: Select Appropriate Geotextile Cushion

Select a nonwoven, needle-punched geotextile having a minimum average roll value (MARV) M_A greater than or equal to that calculated in Step 3. It should be noted that the method presented herein is based on limited testing (Narejo, et. al, 1996) using virgin polymer, nonwoven, needle-punched geotextile and may not apply to all types of geotextiles and cushion materials.

Step 5: Check Assumed Value of FS_{CR} and Construction Limits

In Step 1, FS_{CR} was assumed to allow solution of Equation 1. Check Table 4 to ensure that the assumed value is valid for the geotextile selected in Step 4 (If not, revise FS_{CR} and repeat Steps 1 through 4).

In cases where solid material (i.e. rock, solid waste, etc.) will be placed on top of the geomembrane with heavy equipment, construction loading must be considered. Based on field experimentation, the minimum M_A geotextile should be between 270 g/m^2 (8 oz/yd^2) (Reddy, et. .l., 1996) and 405 g/m^2 (12 oz/yd^2) (Richardson and Johnson, 1998) to prevent construction .amage. The reader should review and understand both documents prior to selecting a geotextile having M_A less than 405 g/m^2.

SIMPLIFIED GEOMEMBRANE CUSHION SELECTION CHARTS

A series of simplified design charts have been developed for the most common geomembrane cushioning applications based on the methodology presented. These charts allow the user to quickly and conservatively select an appropriate virgin polymer, nonwoven, needle-punched geotextile cushion. The applicability and assumptions associated with these charts are provided in the notes section of each figure. In addition, the reader is encouraged to review and understand the limitations of the GRI method (discussed in the referenced literature) prior to application the charts on the following pages. Figures 4 through 7 present charts for landfill applications while Figures 8 and 9 relate to liquid impoundment applications.

EXAMPLES

The following simple design examples illustrate application of the charts and GRI ethod to three common geomembrane cushion applications. Examples 1 and 2 illustrate lection of a geotextile cushion using Figures 4 through 9. Example 3 depicts selection of a geotextile cushion for conditions other than those represented by the charts.

Example 1: Municipal Landfill Liner Cushion

A municipal solid waste (MSW) landfill cell is to be constructed over a carefully prepared subgrade (no significant isolated protrusions). The leachate collection media (to be placed above the geomembrane) is angular crushed stone with a maximum diameter of 38 mm (1.5 in). The maximum design height of the cell is 80 m (262.5 ft). Select an appropriate geotextile to protect the geomembrane.

Solution 1:

Using the design charts in Figures 4 or 5 select a needle-punched, nonwoven, polypropylene geotextile having a MARV M_A of at least 540 g/m^2 (16 oz/yd^2).

Example 2: Liquid Impoundment Liner Cushion

A liquid impoundment is to be constructed over a subgrade containing isolated, angular stone protrusions. The impoundment is to be lined with a geomembrane underlain by a 540 'm^2 (16.0 oz/yd^2) needle-punched, nonwoven, polypropylene geotextile for protection against : subgrade stones. No stone or other solid material will be placed on the geomembrane. ɪherefore, construction loading is not a concern. It is anticipated that the maximum liquid depth will be 20 m (65.6 ft). For specification purposes, determine the largest stone which may safely remain on the subgrade without damaging the geomembrane.

Solution 2:

Based on the design charts in Figures 8 or 9, stones larger than 23 mm (0.9 in) in diameter might damage the geomembrane. Thus, the construction specification could be written to require removal of all protruding subgrade stones larger than approximately 25 mm (1 in).

Example 3: Industrial Landfill Liner Cushion

A portion of the cell described in Example 1 is to be used as a monofill for automobile shredder fluff (average unit weight equal to 10.2 kN/m^3 (65 lb/ft^3)). This portion of the cell is design to be filled to a height of 25 m (82 ft). In addition, a finer 25 mm (1 in) angular, crushed stone will be used for leachate collection media. Assuming all other liner components (except the cushion) remain unchanged, select an appropriate geotextile to protect the geomembrane.

Solution 3:

The design charts are not applicable to this problem since $\gamma \neq 12.6$ kN/m^3 (80 lb/ft^3). In ,dition, construction loading may control geotextile selection given the relatively shallow fill ,ight and low unit weight of waste. Consequently, the problem must be solved by equation.

A. Determine P'_{allow} in terms of M_A, where:

H	= ½ of maximum overlying particle diameter = 12.5 mm
MF_S	= 1.0 (Table 1 - angular stone)
MF_{PD}	= 0.5 (Table 2 - uniformly packed surface)
MF_A	= 0.75 (Table 3 - moderate arching of waste materials)
FS_{CR}	= 1.6 (assumed, corresponds to 270 g/m^2 - to be checked against Table 4)
FS_{CBD}	= 1.2 (Table 5 - polypropylene geotextile in waste application)

$$P'_{allow} = \left(450 \cdot \frac{M_A}{12.5^2}\right)\left(\frac{1}{1.0 \cdot 0.5 \cdot 0.75}\right)\left(\frac{1}{1.6 \cdot 1.2}\right) = 4.0 \cdot M_A$$

B. Determine anticipated pressure on geomembrane, where:

γ	= 10.2 kN/m^3 (given)
h	= 25 m (given)

$$P_{actual} = 10.2 \cdot 25 = 255 \cdot \text{kPa} \quad \text{(Equation 2)}$$

C. Solve for minimum geotextile M_A through manipulation of Equation 3, where:

FS_{gmin}	= 3.0 (Table 6 – uniform packed stones, no isolated subgrade protrusions)
P'_{allow}	= 4.0· M_A (Equation 1)

$$4.0 \cdot M_A \geq 3.0 \cdot 255 \quad \text{(Equation 3)} \qquad \text{or:} \quad M_A \geq \frac{3.0 \cdot 255}{4.0}$$

Thus, $M_A \geq 191.3$ g/m^2 (5.7 oz/yd^2)

D. Check result against Creep limits established in Table 4 and Construction Limits:

From Table 4, the minimum acceptable M_A = 405 g/m^2 (12 oz/yd^2). Coincidentally, this agrees with the construction limits recommended by Richardson and Johnson (1998). Thus, select a nonwoven, needle-punched geotextile having a MARV M_A of at least 405 g/m^2. Although, FS_{CR} was selected based on a 270 g/m^2 (8 oz/yd^2) geotextile, the problem need not be reevaluated in this case since a 405 g/m^2 (12 oz/yd^2) geotextile is the minimum acceptable material based on creep limits (Table 4).

SUMMARY AND APPLICABILITY

The design charts and methodology provided herein are intended to provide a quick and nservative method to select an appropriate geomembrane cushion. Prior to applying the sign charts or method, the reader should review and understand the limitations and assumptions discussed in the referenced literature. In circumstances where site specific conditions deviate significantly from the research forming the basis for the charts and GRI method, it is recommended that a project specific testing program be conducted and evaluated by a qualified professional. Geosynthetic materials, testing parameters, etc. should be modeled after anticipated field conditions.

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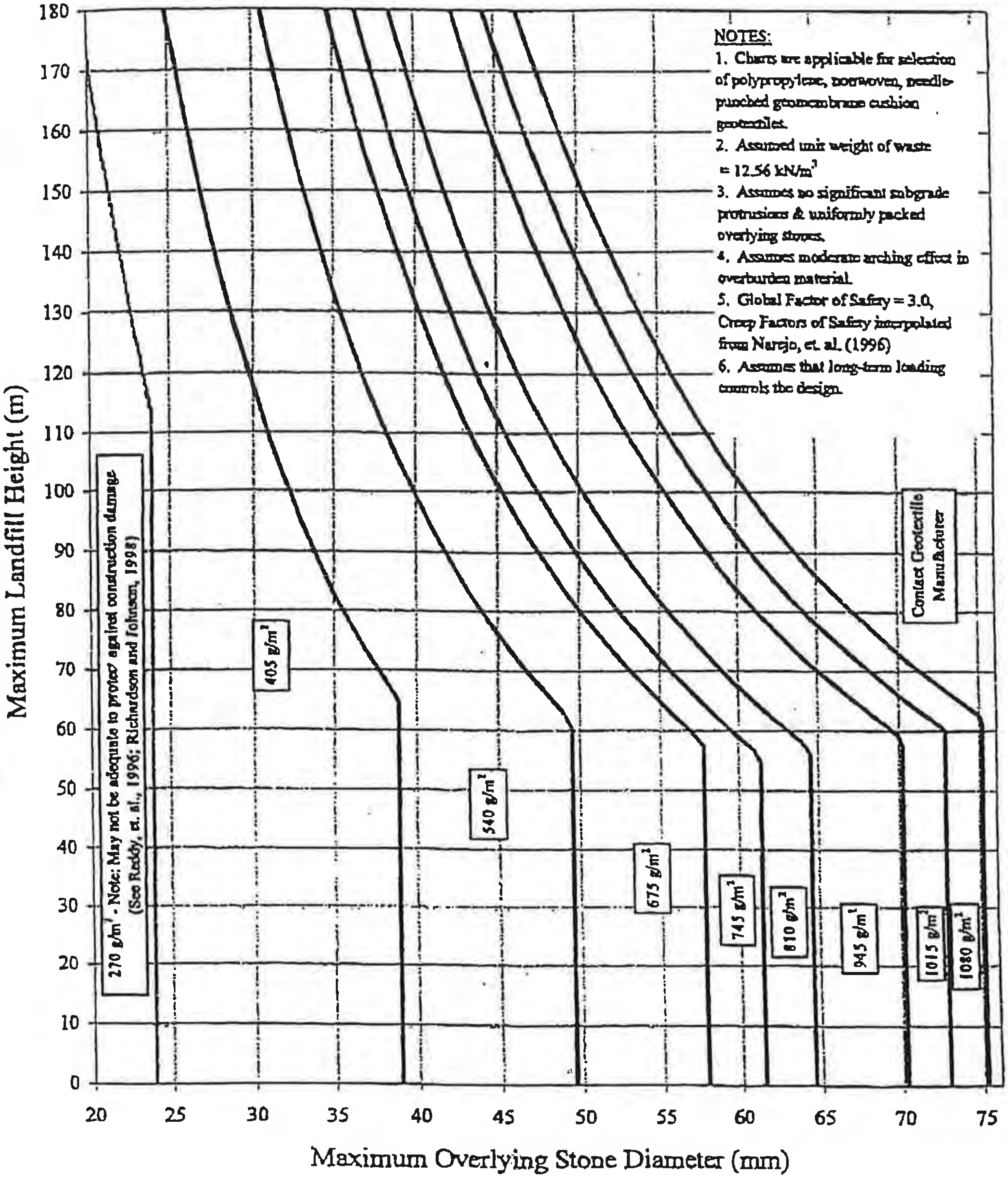

Figure 4. Geomembrane Cushion Selection Chart - Landfill Application, Rounded Overlying Stones (SI Units)

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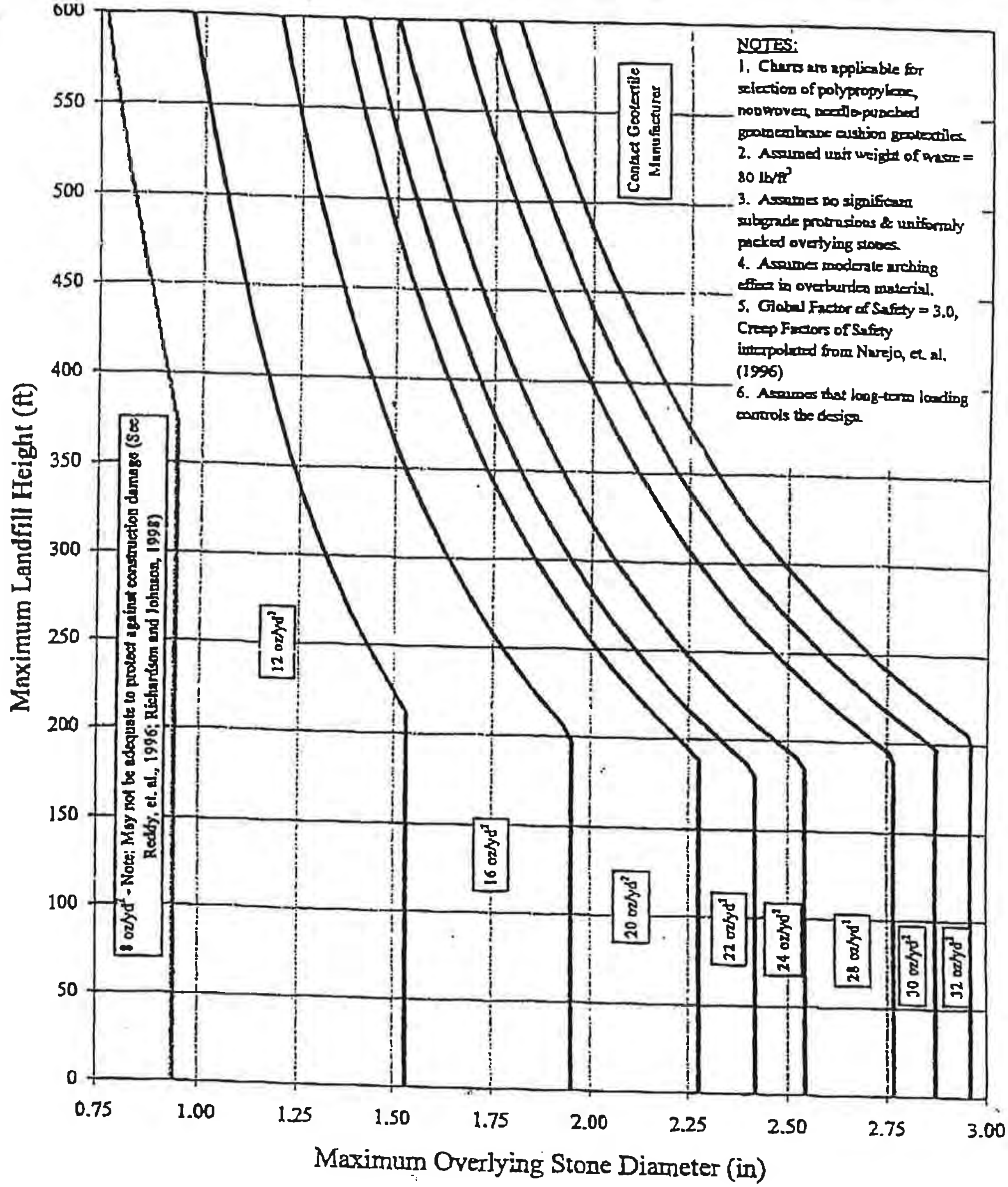

Figure 5. Geomembrane Cushion Selection Chart - Landfill Application, Rounded Overlying Stones (US Units)

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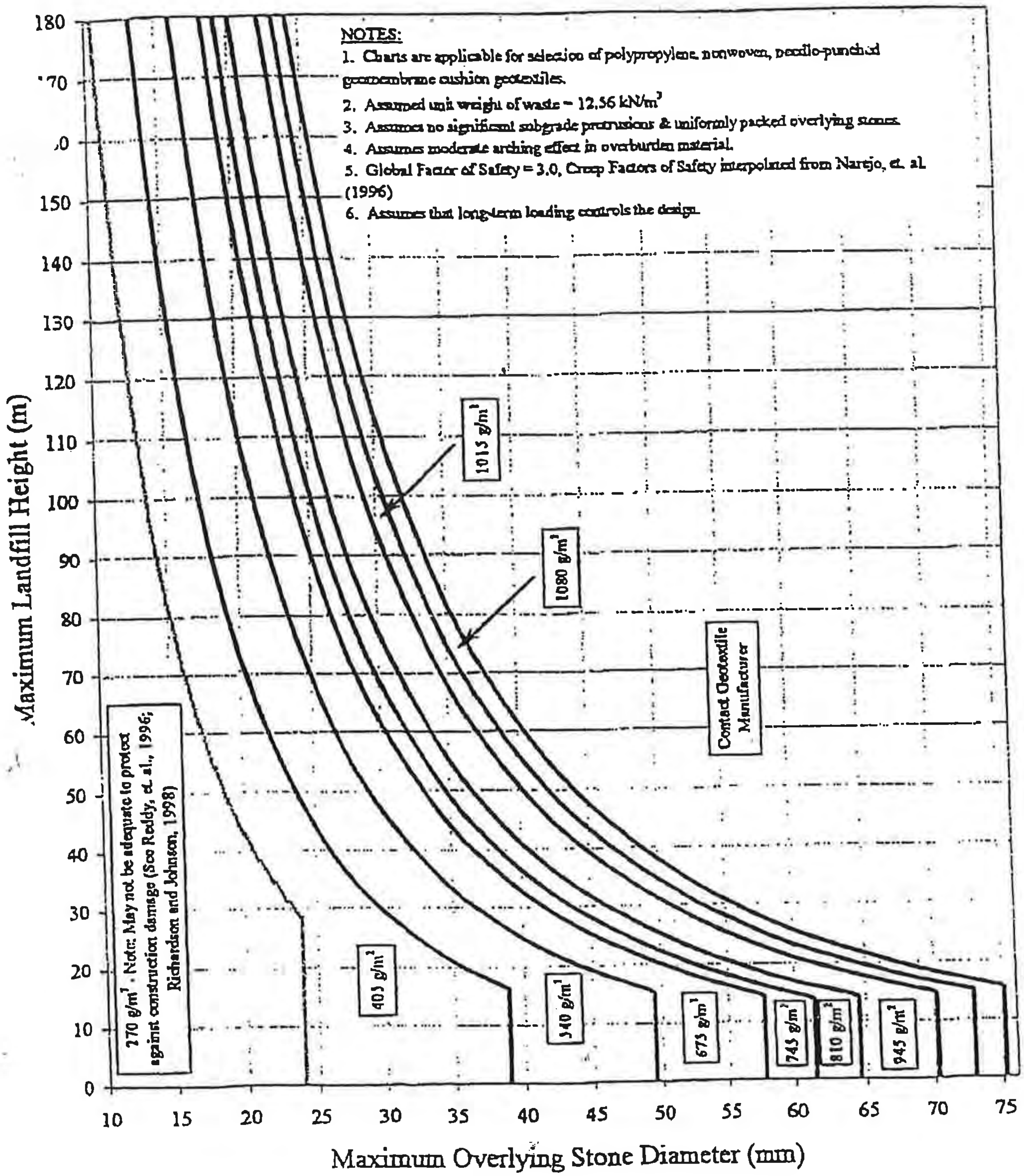

Figure 6. Geomembrane Cushion Selection Chart - Landfill Application, Angular Overlying Stones (SI Units)

13/16

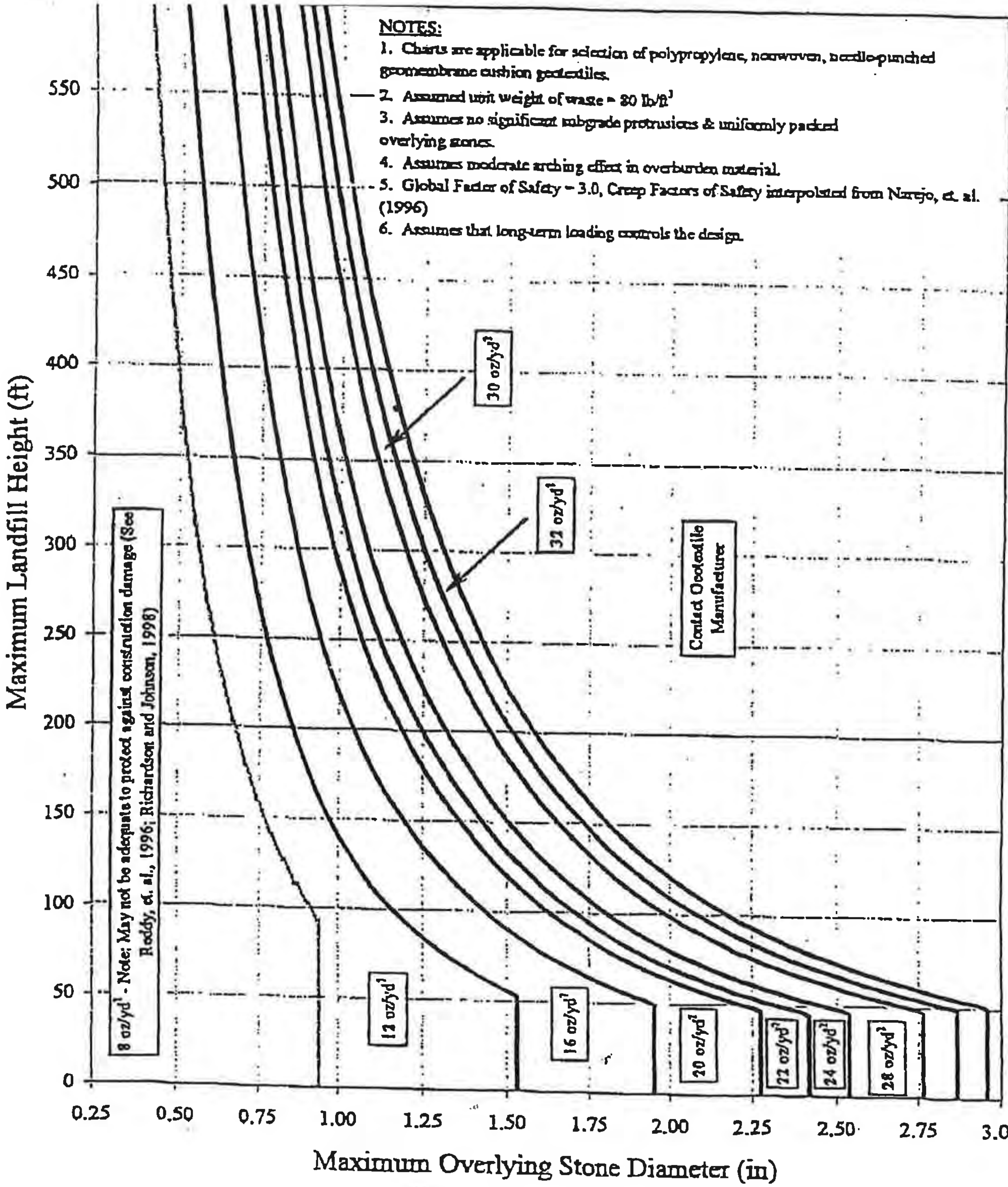

Figure 7. Geomembrane Cushion Selection Chart - Landfill Application, Angular Overlying Stones (US Units)

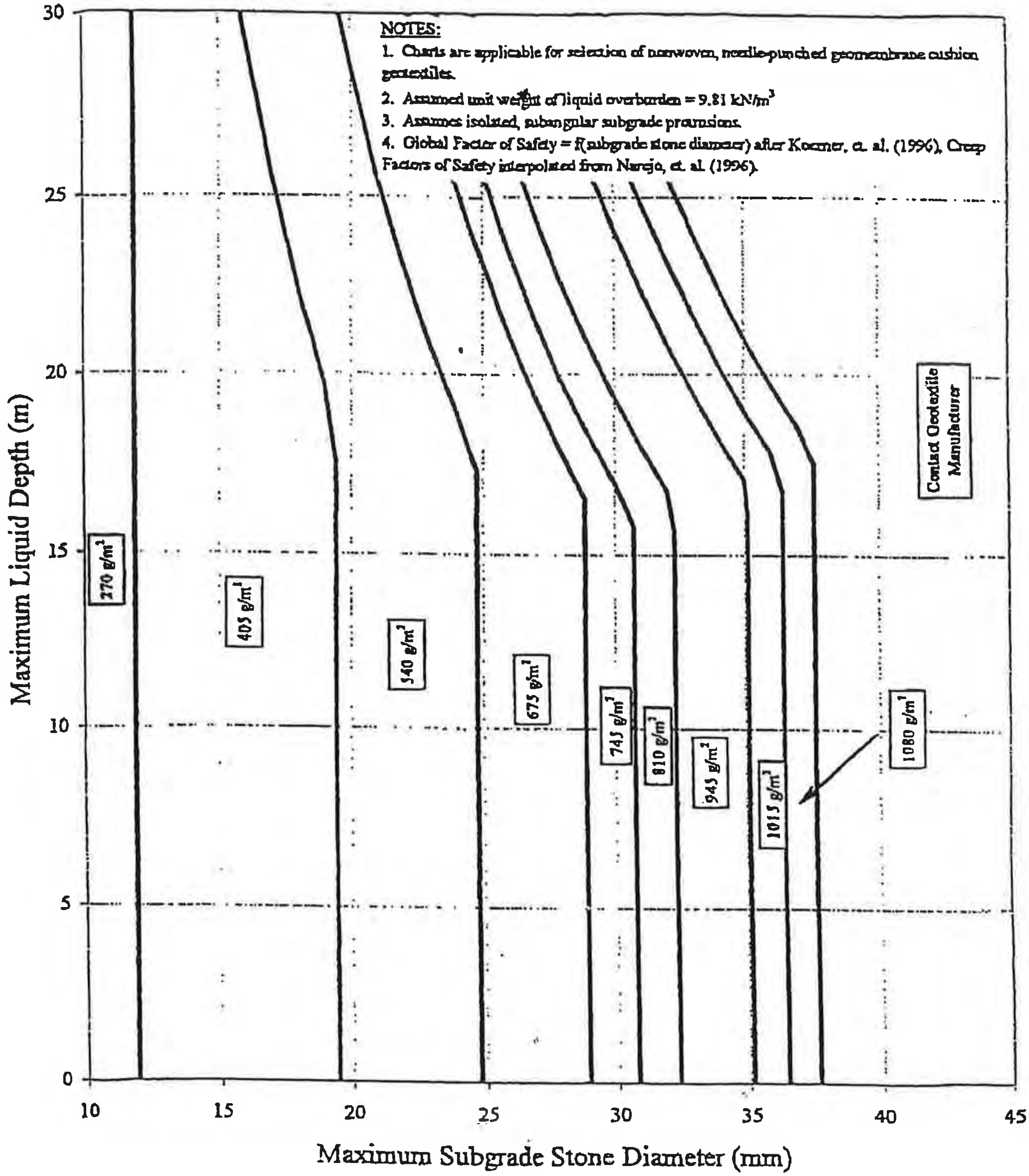

Figure 8. Geomembrane Cushion Selection Chart - Liquid Impoundment Application, Subangular Subgrade Stones (SI Units)

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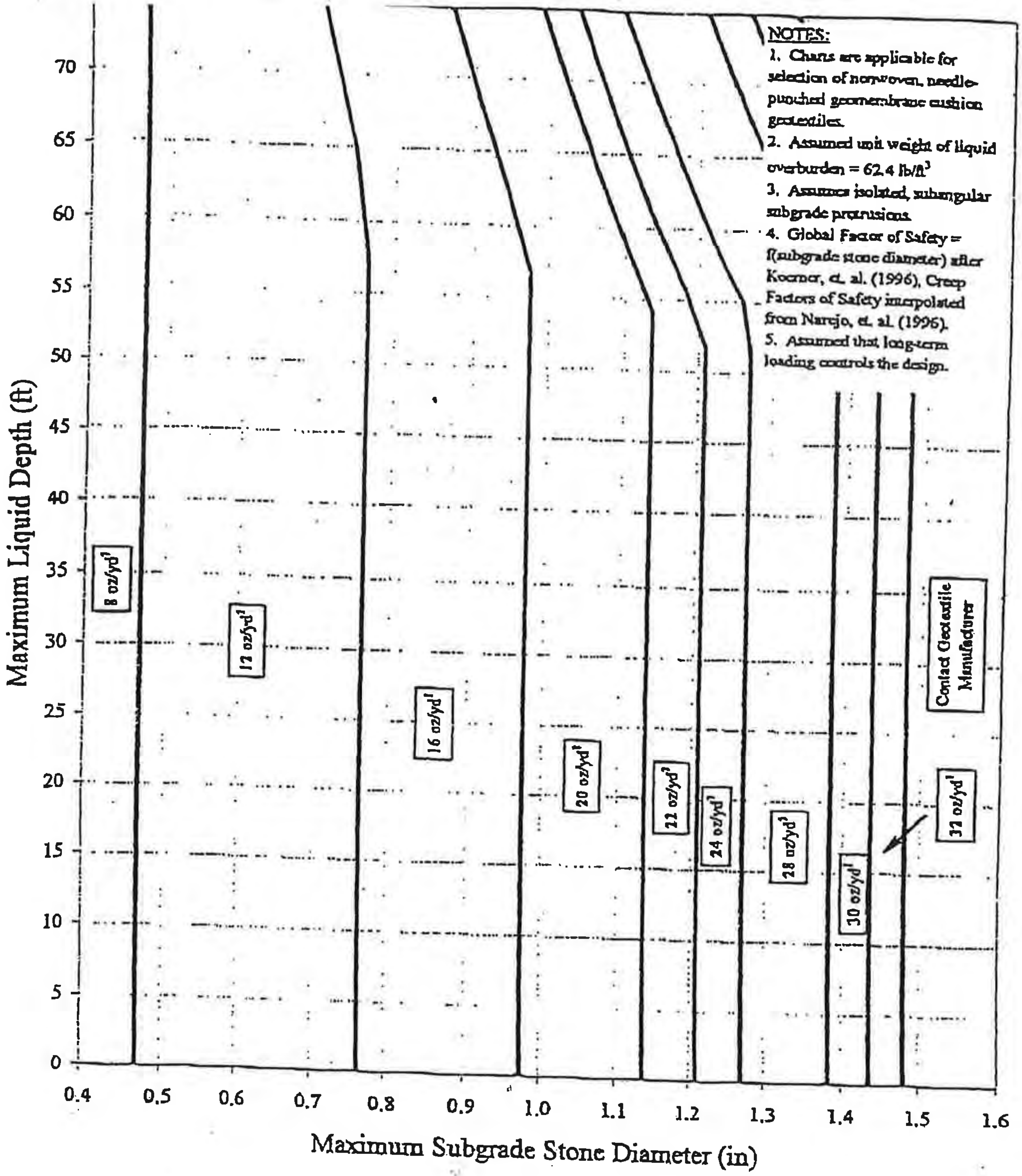

Figure 9. Geomembrane Cushion Selection Chart - Liquid Impoundment Application, Subangular Subgrade Stones (US Units)

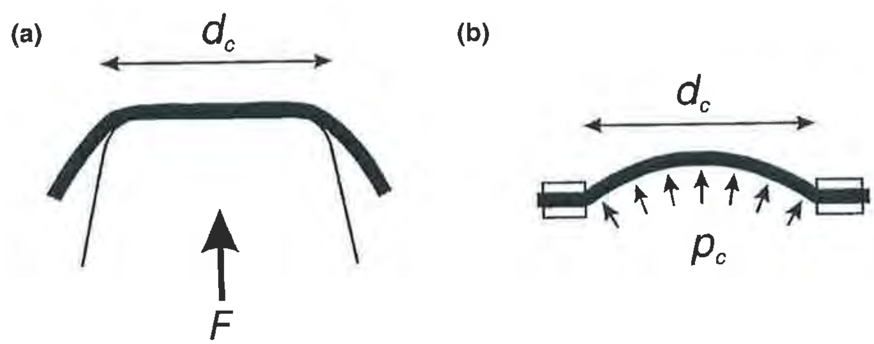

Figure 1. Geomembrane puncture: (a) contact between geomembrane and puncturing object; (b) analogy with the burst test.

where: ε = geomembrane strain; and Z_ε = function of ε implicitly defined by the following equation:

$$\varepsilon = \frac{\sin^{-1} Z_\varepsilon}{Z_\varepsilon} - 1 \qquad (3)$$

Since Z_ε cannot be expressed explicitly, it is convenient to tabulate its values. The values of Z_ε presented in Table 1 were obtained by trial and error using Equation 3. It should be noted that the function Z_ε exists only in the range $0 \leq \varepsilon \leq 57\%$.

Eliminating p_c between Equations 1 and 2 gives:

$$F = \pi d_c T Z_\varepsilon \qquad (4)$$

The geomembrane tension, T, is expressed as follows:

$$T = \sigma t_{GM} \qquad (5)$$

where: σ = tensile stress in the geomembrane; and t_{GM} = thickness of the geomembrane.

Combining Equations 4 and 5 gives:

$$F = \pi\ d_c \sigma\ t_{GM}\ Z_\varepsilon \qquad (6)$$

Geomembrane failure in the puncture mode occurs when the stress, σ, and the strain, ε, in the geomembrane reach their values at the peak of the stress-strain curve, σ_{peak} and ε_{peak}, respectively. These peak values are the stress and strain at yield (σ_Y and ε_Y) for geomembranes that yield or the stress and strain at break (σ_b and ε_b) for geomembranes that do not yield. Therefore:

Attachment C (1/5)

Table 1. Function Z_ε .

ε (%)	Z_ε (-)	ε (%)	Z_ε (-)	ε (%)	Z_ε (-)
0	0.000	2.6	0.381	12	0.728
0.2	0.109	2.8	0.395	13	0.749
0.3	0.134	3	0.408	14	0.768
0.4	0.154	3.2	0.420	15	0.785
0.5	0.172	3.4	0.432	16	0.801
0.6	0.188	3.6	0.443	17	0.816
0.8	0.217	3.8	0.454	18	0.830
1	0.242	4	0.465	19	0.844
1.2	0.264	5	0.513	20	0.856
1.4	0.284	6	0.555	25	0.905
1.6	0.303	7	0.591	30	0.940
1.8	0.321	8	0.624	35	0.964
2	0.337	9	0.654	40	0.980
2.2	0.353	10	0.681	50	0.997
2.4	0.367	11	0.705	57	1.00

Note: The values of Z_ε were calculated using Equation 3.

$$F_P = \pi\, d_c\, \sigma_{peak}\, t_{GM}\, Z_{\varepsilon\, peak} \qquad (7)$$

where: F_p = geomembrane puncture resistance measured in a probe test; and $Z_{\varepsilon peak}$ = value of Z_ε for $\varepsilon = \varepsilon_{peak}$.

Equation 7 is the general relationship between the puncture resistance F_P and the following parameters: the diameter of the contact area, d_c , between the puncturing object and the geomembrane; and the geomembrane characteristics, σ_{peak} , ε_{peak} , and t_{GM} . This relationship is used in subsequent sections to develop specific relationships for various practical cases. The use of Equation 7 is limited to values of the geomembrane strain at peak, ε_{peak} , not greater than 57%, which is the limit of validity of the function Z_ε . This limits the applicability of the method to geomembranes that rupture or yield at a strain not greater than 57%, such as high density polyethylene (HDPE) geomembranes that yield at a strain on the order of 10 to 15%, and geomembranes reinforced with a woven fabric, such as chlorosulfonated polyethylene (CSPE) geomembranes, that typically break at approximately 20% strain.

It should be noted that Equation 7 generally applies to homogeneous geomembranes, which are characterized by the parameters σ_{peak} , ε_{peak} , and t_{GM} . In the case of geomembranes that are not homogeneous, i.e. geomembranes which comprise layers of different materials, such as reinforced geomembranes, it is not appropriate to use σ_{peak} and t_{GM} ; these geomembranes are characterized by the geomembrane tension at peak, T_{peak} , and by ε_{peak} . Using the relationship between tension and tensile stress expressed by

Attachment C (2/5)

10. However, the puncture force is not the same in the two cases because the contact diameter, d_{cs}, in the case of a stone, is not the same as the probe diameter, d_p. Eliminating σ_{peak} and ε_{peak} between Equations 9 and 10 gives:

$$\frac{F_{Ps}}{F_P} = \frac{d_{cs}\, t_{GMs}}{d_p\, t_{GMp}} \tag{11}$$

where: t_{GMs} = thickness of the geomembrane in contact with stones; and t_{GMp} = thickness of the geomembrane tested with a probe.

The next step of the analysis is the evaluation of the force applied to the geomembrane by a stone in contact with the geomembrane. It is assumed that one surface of the geomembrane is subjected to a pressure, p, applied by a liquid and the other surface of the geomembrane is in contact with a layer of stones of uniform size and identical shape (Figure 3). Such a layer is referred to as a "uniform stone layer" in this paper. The stone shapes are assumed to be three-dimensional, i.e. the stones are assumed to have similar dimensions in all directions; in other words, flat stones such as slates are not considered. Three-dimensional shapes are typical of rounded or crushed stones (but, in a given "uniform stone layer", all stones are assumed to have the same shape).

The force applied to the geomembrane by a given stone depends on the stone arrangement. In Figure 4, three-dimensional stones are schematically represented by circles in a plan view. The average surface area of geomembrane associated with one stone is expressed by the following equation if the stone arrangement is hexagonal (Figure 4a):

$$A_{avg} = \frac{\sqrt{3}}{2}\, d_s^2 \tag{12}$$

where d_s is the diameter of a stone. (The classical definition of the diameter of a stone is the diameter of a circular hole, or the side length of a square hole, through which, the stone would just pass.)

If the stone arrangement is square (Figure 4b), the average surface area of geomembrane associated with one stone is:

$$A_{avg} = d_s^2 \tag{13}$$

More generally, the average surface area of geomembrane associated with a stone can be expressed by the following equation:

$$A_{avg} = \lambda\, d_s^2 \tag{14}$$

where λ is a dimensionless term that is a function of the stone arrangement. The parameter λ is close to one in the case of a uniform stone layer:

- For a dense (hexagonal) arrangement, according to Equations 12 and 14:

Attachment C (3/5)

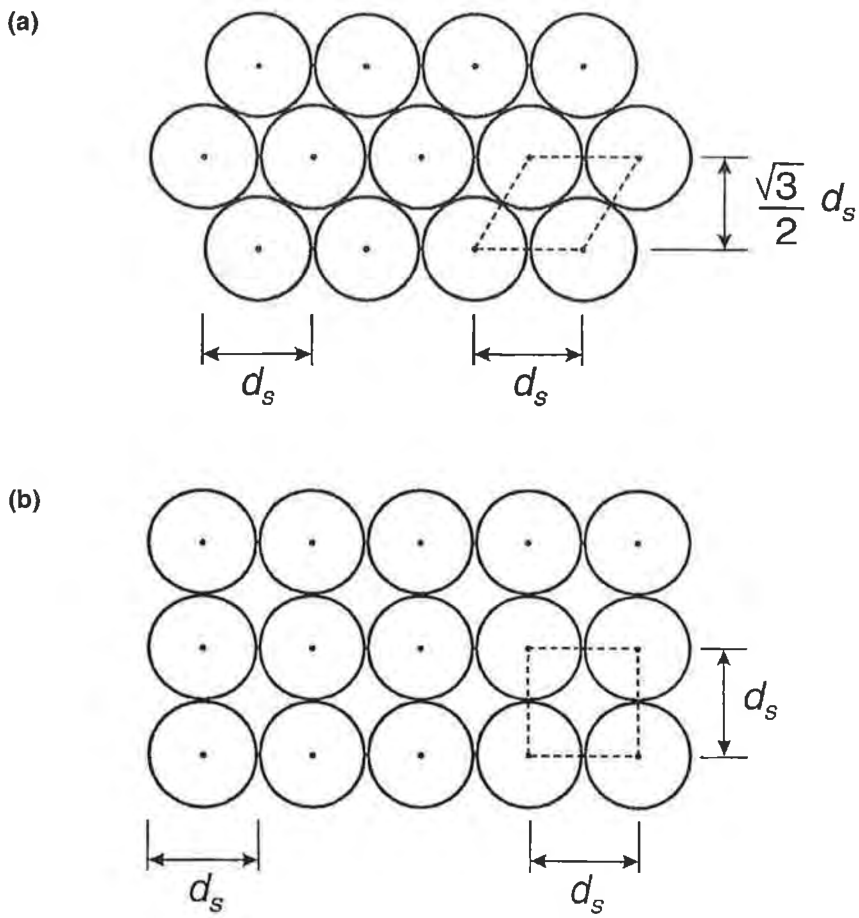

Figure 4. Arrangement of spherical particles: (a) hexagonal arrangement; (b) square arrangement.
(Note: The parallelogram in Figure 4a or the square in Figure 4b delineate the area associated with one particle.)

$$\lambda = \sqrt{3}/2 = 0.87 \tag{15}$$

*

• For a loose (square) arrangement, according to Equations 13 and 14:

$$\lambda = 1 \tag{16}$$

Attachment C (4/5)

hence:

$$d_{cround} = d_{sround} Z_\varepsilon \tag{26}$$

where Z_ε is the function of ε implicitly defined by Equation 3 and the numerical values of which are given in Table 1.

Combining Equations 21 and 26, with $d_s = d_{sround}$ and $d_{cs} = d_{cround}$, gives the following relationship when puncture occurs, i.e. when $\varepsilon = \varepsilon_{peak}$:

$$\frac{\lambda \, d_{sround} \, p_P}{t_{GMs}} = \frac{F_P \, Z_{\varepsilon \, peak}}{d_p \, t_{GMp}} \tag{27}$$

Like Equation 21, Equation 27 expresses a relationship between parameters related to the stones, on the left, and parameters related to the probe test, on the right. In addition, there is a factor related to the geomembrane on the right ($Z_{\varepsilon peak}$). Equation 21 is valid for any stone shape, whereas Equation 27 is valid for rounded stones and was developed assuming the rounded stones are spherical.

Example 2. The same case as for Example 1 is considered. To withstand a pressure of 830 kPa what should the maximum size of rounded stones be ?

Assuming that yield of a typical HDPE geomembrane occurs at a strain of 11%, Table 1, for $\varepsilon_{peak} = 11\%$, gives:

$$Z_{\varepsilon peak} = 0.705$$

Equation 27 can then be used as follows:

$$d_{sround} = \frac{1.5}{(\sqrt{3}/2)(830,000)} \; \frac{(290)(0.705)}{(6.35 \times 10^{-3})(1.0)} = 0.067 \text{ m} = 67 \text{ mm}$$

The stone size of 67 mm calculated in the case of rounded stones is significantly larger than the stone sizes of 17 to 24 mm obtained in Example 1 in the case of angular stones, which is consistent with the fact that a geomembrane has a larger contact area with a rounded stone than with an angular stone.

END OF EXAMPLE 2

In the case of rounded stones, it should be noted that failure in the puncture mode may not be the worst case. It is possible that the geomembrane is more likely to fail in the burst mode between the stones. Design engineers should always consider the possibility for the geomembrane to burst between stones when a geomembrane, subjected to a liquid pressure, rests on a layer of stones of approximately uniform size, and they should

Attachment C (5/5)

High Density Polyethylene Drain Liner™

Product Data

Property	Test Method	Values			
Thickness (min. ave.), mil (mm)	ASTM D5994*	50 (1.25)	60 (1.5)	80 (2.0)	100 (2.5)
Thickness (lowest indiv.), mil (mm)	ASTM D5994*	50 (1.25)	54 (1.35)	72 (1.8)	90 (2.25)
*The thickness values may be changed due to project specifications (i.e., absolute minimum thickness)					
Drainage Stud Height (min. ave.), mil (mm)	ASTM D7466	130 (3.30)	130 (3.30)	130 (3.30)	130 (3.30)
Density, g/cc, minimum	ASTM D792, Method B	0.94	0.94	0.94	0.94
Tensile Properties (ave. both directions)	ASTM D6693, Type IV				
Strength @ Yield (min. ave.), lb/in width (N/mm)	2 in/minute	110 (19.3)	132 (23.1)	176 (30.8)	220 (38.5)
Elongation @ Yield (min. ave.), % (GL=1.3in)	5 specimens in each direction	13	13	13	13
Strength @ Break (min. ave.), lb/in width (N/mm)		110 (19.3)	132 (23.1)	176 (30.8)	220 (38.5)
Elongation @ Break (min. ave.), % (GL=2.0in)		300	300	300	300
Tear Resistance (min. ave.), lbs. (N)	ASTM D1004	38 (169)	40 (178)	53 (236)	64 (285)
Puncture Resistance (min. ave.), lbs. (N)	ASTM D4833	80 (355)	95 (422)	126 (560)	158 (703)
Carbon Black Content (range in %)	ASTM D4218	2 - 3	2 - 3	2 - 3	2 - 3
Carbon Black Dispersion (Category)	ASTM D5596	Only near spherical agglomerates for 10 views: 9 views in Cat. 1 or 2, and 1 view in Cat. 3			
Stress Crack Resistance (Single Point NCTL), hours	ASTM D5397, Appendix	300	300	300	300
Oxidative Induction Time, minutes	ASTM D3895, 200°C, 1 atm O_2	≥100	≥100	≥100	≥100
Melt Flow Index, g/10 minutes	ASTM D1238, 190°C, 2.16kg	≤1.0	≤1.0	≤1.0	≤1.0
Oven Aging with HP OIT, (% retained after 90 days)	ASTM D5721 ASTM D5885, 150°C, 500psi O_2	80	80	80	80
UV Resistance	GRI GM11	20hr. Cycle @ 75°C/4 hr. dark condensation @ 60°C			
with HP OIT, (% retained after 1600 hours)	ASTM D5885, 150°C, 500psi O_2	50	50	50	50

These product specifications meet or exceed GRI's GM13

Supply Information (Standard Roll Dimensions)

Thickness mil	Thickness mm	Width ft	Width m	Length ft	Length m	Area (approx.) ft²	Area (approx.) m²	Weight (average)* lbs	Weight (average)* kg
50	1.25	23	7	300	91.435	6,900	640.05	2,600	1,178.34
60	1.5	23	7	300	91.435	6,900	640.05	2,900	1,315.42
80	2.0	23	7	300	91.435	6,900	640.05	3,600	1,632.93
100	2.5	23	7	300	91.435	6,900	640.05	4,000	1,814.37

Notes:

All rolls are supplied with two slings. All rolls are wound on a 6 inch core. Special lengths are available on request. All roll lengths and widths have a tolerance of ±1%
**The weight values may change due to project specifications (i.e. absolute minimum thickness or special roll lengths) or shipping requirements (i.e. international containerized shipments).*

All information, recommendations and suggestions appearing in this literature concerning the use of our products are based upon tests and data believed to be reliable; however, it is the users responsibility to determine the suitability for their own use of the products described herein. Since the actual use by others is beyond our control, no guarantee or warranty of any kind, expressed or implied, is made by Agru/America as to the effects of such use or the results to be obtained, nor does Agru/America assume any liability in connection herewith. Any statement made herein may not be absolutely complete since additional information may be necessary or desirable when particular or exceptional conditions or circumstances exist or because of applicable laws or government regulations. Nothing herein is to be construed as permission or as a recommendation to infringe any patent.

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Attachment D (1/1)

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **Energy Fuels**	Project: **White Mesa Mill – Cells 5A and 5B**	Project/ Proposal No.: **SC0634**	Task No. **02**

Title of Computations **SEISMIC DEFORMATION ANALYSIS**

Computations by:	Signature	[signature]	12/18/12 Date
	Printed Name	Jay L. Griffin	
	Title	Senior Staff Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature	[signature]	12/21/12 Date
	Printed Name	Steven M. Fitzwilliam, P.E.	
	Title	Associate Engineer	
Computations Checked by:	Signature	[signature]	12/21/12 Date
	Printed Name	Steven M. Fitzwilliam, P.E.	
	Title	Associate Engineer	
Computations backchecked by: (originator)	Signature	[signature]	12/18/12 Date
	Printed Name	Jay L. Griffin	
	Title	Senior Staff Engineer	
Approved by: (pm or designate)	Signature	[signature]	12/12/12 Date
	Printed Name	Gregory Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	J. Griffin	Date:	11/28/12	Reviewed by:	S. Fitzwilliam	Date:	12/21/12
Client:	Energy Fuels	Project:	White Mesa Mill– Cells 5A &5B	Project/ Proposal No.:	SC0634	Task No.:	02

PERMANENT SEISMIC DEFORMATION ANALYSIS
CELLS 5A AND 5B
WHITE MESA MILL
BLANDING, UTAH

OBJECTIVE

The objective of this analysis is to evaluate the seismically induced permanent deformation of the embankments for Cells 5A and 5B at the White Mesa Mill Facility located in Blanding, Utah.

METHOD OF ANALYSIS

Seismic deformation is a function of average acceleration of the sliding mass and the yield acceleration. Geosyntec used the Makdisi and Seed (Attachment A) method to estimate permanent seismic deformations, based on yield accelerations determined from pseudo-static limit equilibrium analyses, design earthquake motions determined from documented sources, and the attached design charts (Makdisi and Seed, 1978).

Three cross-sections were selected for analysis and are shown in Figure 1. The first cross section, Section A-A', is a west-east cross section that models Cell 5A filled with tailings and Cell 5B empty. The section spans Cells 5A and 5B, with berm slopes inclined at approximately 2:1 (Horizontal:Vertical) and a base grade sloping toward the berm at approximately 1 percent. The second cross section, Section B-B', is a north-south cross section that models Cell 5A before filling and spans the berm separating the southern portion of existing Cell 4B and Cell 5A. Section B-B' was modeled with Cell 4B full of tailings and Cell 5A empty. Both sections were modeled without a liner on the empty cell in order to evaluate berm stability. The third cross section, Section C-C' is a north-south cross section that spans the embankment on the south side of Cell 5A. Section C-C' is modeled with Cell 5A filled with tailings. The embankment back slope is inclined at 3:1.

DESIGN CRITERION

In accordance with the current state of practice, acceptable seismically induced permanent deformations are less than 6 to 12 inches for waste mass configurations

Written by:	J. Griffin	Date:	11/28/12	Reviewed by:	S. Fitzwilliam	Date:	12/21/12
Client:	Energy Fuels	Project:	White Mesa Mill–Cells 5A &5B	Project/ Proposal No.:	SC0634	Task No.:	02

(Seed and Bonaparte, 1992). To evaluate seismically induced permanent deformations at Cells 5A and 5B, Geosyntec established a maximum seismically induced deformation of 6 inches as the design criterion.

The peak ground acceleration (PGA) at the site was previously evaluated in the Cell 4 Design Report (UMETCO, 1988) as referenced by MFG, Inc. in a letter to International Uranium Corporation (presently Energy Fuels) dated 27 November 2006 (Attachment C). The design report indicates that the maximum acceleration at the site is 0.10 g, representing a 2 percent probability of exceedance within 50 years (approximate return period of 2,500 years). The report states that this design acceleration is suitable for operational conditions at site.

DEFORMATION ANALYSES

Estimating the seismically induced deformations includes the following steps, summarized in Table 1:

1. Perform pseudostatic slope stability analyses to evaluate the yield acceleration (k_y) resulting in a factor of safety of 1.0 for the critical cross sections. The results of the pseudostatic slope stability evaluation for each cross section are provided in Table 1. These values were determined using the computer software SLOPE/W 2004 (Version 6.22) developed by Geo-Slope International Ltd. (2004).

2. Estimate k_{max} (the maximum average acceleration for a potential sliding mass extending to a specified depth y) using the upper bound for observed motions at earth dams reported by Harder (Harder, 1991), through the following two steps:

   a. Estimate value of acceleration at the top of the embankment, $\ddot{u}_{max}$ based on the Harder (1991) curve (included in Attachment D), the acceleration at the crest of the berm, $\ddot{u}_{max}$, is estimated to be 0.35 g;

   b. Calculate k_{max} as 0.35 times $\ddot{u}_{max}$ based on the Makdisi and Seed curve in Attachment A (Figure 7 in Makdisi and Seed, 1978).

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Client:	Energy Fuels	Project:	White Mesa Mill– Cells 5A &5B	Project/ Proposal No.:	SC0634	Task No.:	02

3. Calculate the ratio of k_y/k_{max} for each cross section and compute resulting deformations based on the Makdisi and Seed Simplified Method (see Figure 10 in Attachment A). Figure 10 displays an upper bound of 1.0 for k_y/k_{max}; therefore, if the ratio of k_y/k_{max} exceeds 1.0, seismically induced deformations are estimated to be minimal (less than 1 centimeter or 0.4 inches).

Table 1: Seismic Deformation Analyses Results

Cross Section	PGA (g)	k_y	$\ddot{u}_{max}$	k_{max}	k_y/k_{max}	δ (cm)
A-A'	0.1	0.65g	0.35g	0.12g	5.4	<1
B-B'	0.1	0.66g	0.35g	0.12g	5.5	<1
C-C'	0.1	0.51g	0.35g	0.12g	4.2	<1

RESULTS AND CONCLUSIONS

Results of the permanent deformation analysis indicate that the expected seismically induced permanent deformation is expected to be minimal, and significantly less than the design criterion of 6 inches.

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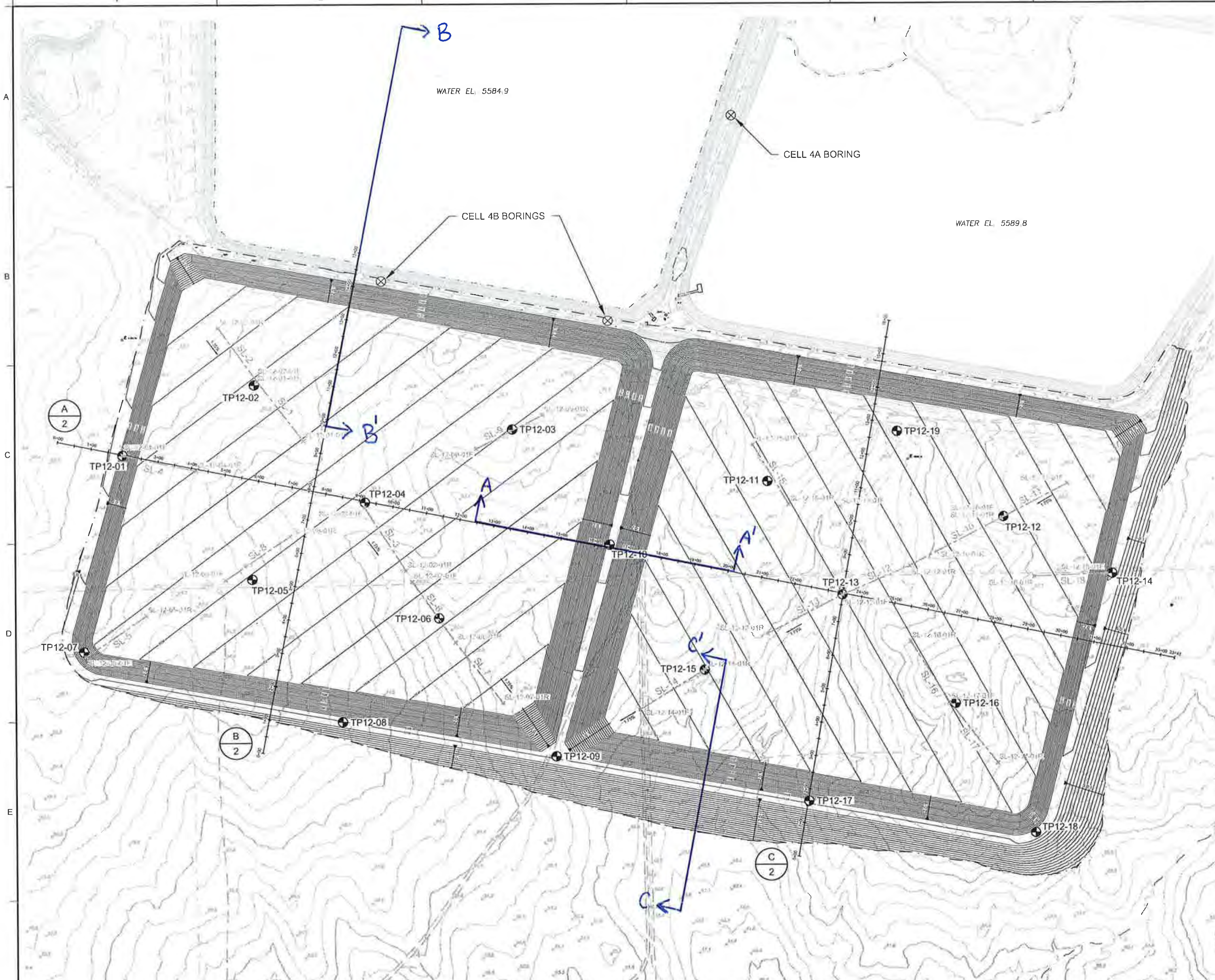
Harder, L.F., Jr. [1991], "Performance of Earth Dams During the Loma Prieta Earthquake," Proc. Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, University of Missouri, Rolla, pp. 11-15.

Makdisi and Seed [1978], "Simplified Procedure for Estimating Dam and Embankment Earthquake Induced Deformation," *Journal of the Geotechnical Engineering Division,* ASCE, Vol 104, No. GT7, pp 849-867.

MFG, Inc. [2006], "White Mesa Uranium Facility, Cell 4 Seismic Study, Blanding, Utah," letter to International Uranium (USA) Corporation, dated 27 November 2006.

Seed, H.B., and Bonaparte, R., [1992], "Seismic Analysis and Design of Lined Waste Fills: Current Practice," Proceedings of ASCE Specialty Conference on Stability and Performance of Slopes and Embankments – II, pp. 1521 – 1545.



LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- PROPOSED GRADING MAJOR CONTOUR (10')
- PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- 1 AS-BUILT TRENCH LOCATION
- AS-BUILT SEISMIC LINES

PRELIMINARY VOLUME REPORT

JUNE 2011 EXISTING SURFACE VS. REVISED CELL 5A PROPOSED GRADING:

CUT = 1,228,929 CUBIC YARDS

FILL = 196,323 CUBIC YARDS

NET = 1,032,606 CUBIC YARDS <CUT>

JUNE 2011 EXISTING SURFACE VS. REVISED CELL 5B PROPOSED GRADING

CUT = 704,105 CUBIC YARDS

FILL = 240,573 CUBIC YARDS

NET = 463,532 CUBIC YARDS <CUT>

0 150' 300'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUTE 200
SAN DIEGO, CA 92127
PHONE 858 674 6559

ENERGY FUELS INC.
6425 S. HIGHWAY 191
P.O. BOX 809
BLANDING, UTAH 84511
PHONE: 858.674.6559

TITLE: CELL 5A AND 5B PROPOSED GRADING

PROJECT: CELL 5A AND 5B PRELIMINARY CELL DESIGN

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	GTC	DATE:	OCTOBER 2012
DRAWN BY:	MMC	PROJECT NO.:	SC0349
CHECKED BY:	GTC	FILE:	
REVIEWED BY:	GTC	FIGURE NO.:	
APPROVED BY:	GTC	1 OF 2	

FIGURE 1

PRELIMINARY DESIGN DRAWINGS
NOT FOR CONSTRUCTION

P:\PRJ\SDCad\CADD\SC0349\SC0349-07-01\Working\10-2-12 CELL 5A & 5B REVISED GRADING.dwg

JOURNAL OF THE GEOTECHNICAL ENGINEERING DIVISION

Simplified Procedure for Estimating Dam and Embankment Earthquake-Induced Deformations

1973

By Faiz I. Makdisi,[1] A. M. ASCE and H. Bolton Seed,[2] F. ASCE

Introduction

In the past decade major advances have been achieved in analyzing the stability of dams and embankments during earthquake loading. Newmark (13) and Seed (18) proposed methods of analysis for predicting the permanent displacements of dams subjected to earthquake shaking and suggested this as a criterion of performance as opposed to the concept of a factor of safety based on limit equilibrium principles. Seed and Martin (26) used the shear beam analysis to study the dynamic response of embankments to seismic loads and presented a rational method for the calculation of dynamic seismic coefficients for earth dams. Ambraseys and Sarma (1) adopted the same procedure to study the response of embankments to a variety of earthquake motions.

Later the finite element method was introduced to study the two-dimensional response of embankments (5,7) and the equivalent linear method (21) was used successfully to represent the strain-dependent nonlinear behavior of soils. In addition the nature of the behavior of soils during cyclic loading has been the subject of extensive research (10,20,23,29). Both the improvement in the analytical tools to study the response of embankments and the knowledge of material behavior during cyclic loading led to the development of a more rational approach to the study of stability of embankments during seismic loading. Such an approach was used successfully to analyze the Sheffield Dam failure during the 1925 Santa Barbara earthquake (24) and the behavior of the San Fernando Dams during the 1971 earthquake (25). This method has since been used extensively in the design and analysis of many large dams in the State of California and elsewhere.

Note.—Discussion open until December 1, 1978. To extend the closing date one month, a written request must be filed with the Editor of Technical Publications, ASCE. This paper is part of the copyrighted Journal of the Geotechnical Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 104, No. GT7, July, 1978. Manuscript was submitted for review for possible publication on August 30, 1977.

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[2] Prof. of Civ. Engrg., Univ. of California, Berkeley, Calif.

Attachment A 1/9

From the study of the performance of embankments during strong earthquakes, two distinct types of behavior may be discerned: (1) That associated with loose to medium dense sandy embankments, susceptible to rapid increases in pore pressure due to cyclic loading resulting in the development of pore pressures equal to the overburden pressure in large portions of the embankment, associated reductions in shear strength, and potentially large movements leading to almost complete failure; and (2) the behavior associated with compacted cohesive clays, dry sands, and some dense sands; here the potential for buildup of pore pressures is much less than that associated with loose to medium dense sands, the resulting cyclic strains are usually quite small, and the material retains most of its static undrained shearing resistance so that the resulting post-earthquake behavior is a limited permanent deformation of the embankment.

The dynamic analysis procedure proposed by Seed, et al. (25) has been used to predict adequately both types of embankment behavior using the "Strain Potential" concept. Procedures for integrating strain potentials to obtain the overall deformation of an embankment have been proposed by Seed, et al. (25), Lee (9), and Serff, et al. (27).

The dynamic analysis approach has been recommended by the Committee on Earthquakes of the International Commission on Large Dams (3): "high embankment dams whose failure may cause loss-of-life or major damage should be designed by the conventional method at first, followed by a dynamic analysis in order to investigate any deficiencies which may exist in the pseudo-statical design of the dam." For low dams in remote areas the Committee recommended the use of conventional pseudostatic methods using a constant horizontal seismic coefficient selected on the basis of the seismicity of the area. However, the inadequacy of the pseudostatic approach to predict the behavior of embankments during earthquakes has been clearly recognized and demonstrated (19,24,25,26, 28). Furthermore in the same report (3) the Commission refers to the conventional method as follows: "There is a need for early revision of the conventional method since the results of dynamic analyses, model tests and observations of existing dams show that the horizontal acceleration due to earthquake forces varies throughout the height of the dam . . . in several instances, this method predicts a safe condition for dams which are known to have had major slides."

It is this need for a simple yet rational approach to the seismic design of small embankments that prompted the development of the simplified procedure described herein.

This approximate method uses the concept originally proposed by Newmark (13) for calculating permanent deformations but it is based on an evaluation of the dynamic response of the embankment as proposed by Seed and Martin (26) rather than rigid body behavior. It assumes that failure occurs on a well-defined slip surface and that the material behaves elastically at stress levels below failure but develops a perfectly plastic behavior above yield. The method involves the following steps:

1. A yield acceleration, i.e., an acceleration at which a potential sliding surface would develop a factor of safety of unity is determined. Values of yield acceleration are a function of the embankment geometry, the undrained strength of the material (or the reduced strength due to shaking), and the location of the potential sliding mass.

Attachment A, 2/9

2. Earthquake induced accelerations in the embankment are determined using dynamic response analyses. Finite element procedures using strain-dependent soil properties can be used for calculating time histories of acceleration, or simpler one-dimensional techniques might be used for the same purpose. From these analyses, time histories of average accelerations for various potential sliding masses can be determined.

3. For a given potential sliding mass, when the induced acceleration exceeds the calculated yield acceleration, movements are assumed to occur along the direction of the failure plane and the magnitude of the displacement is evaluated by a simple double integration procedure.

The method has been applied to dams with heights in the range of 100 ft–200 ft (30 m–60 m), and constructed of compacted cohesive soils or very dense cohesionless soils, but may be applicable to higher embankments. A similar approach has been proposed by Sarma (16) using the assumption of a rigid block on an inclined plane rather than a deformable earth structure that responds with differential motions to the imposed base excitation.

In the following sections the steps involved in the analyses will be described in detail and design curves prepared on the basis of analyzed cases will be presented, together with an example problem to illustrate the use of the method. Note, however, that the method is an approximate one and involves simplifying assumptions. The design curves are averages based on a limited number of cases analyzed and should be updated as more data become available and more cases are studied.

Determination of Yield Acceleration

The yield acceleration, k_y, is defined as that average acceleration producing a horizontal inertia force on a potential sliding mass so as to produce a factor of safety of unity and thus cause it to experience permanent displacements.

For soils that do not develop large cyclic strains or pore pressures and maintain most of their original strength after earthquake shaking, the value of k_y can be calculated by stability analyses using limiting equilibrium methods. In conventional slope stability analyses the strength of the material is defined as either the maximum deviator stress in an undrained test, or the stress level that would cause a certain allowable axial strain, say 10%, in a test specimen. However, the behavior of the material under cyclic loading conditions is different than that under static conditions. Due to the transient nature of the earthquake loading, an embankment may be subjected to a number of stress pulses at levels equal to or higher than its static failure stress that simply produce some permanent deformation rather than complete failure. Thus the yield strength is defined, for the purpose of this analysis, as that maximum stress level below which the material exhibits a near elastic behavior (when subjected to cyclic stresses of numbers and frequencies similar to those induced by earthquake shaking) and above which the material exhibits permanent plastic deformation of magnitudes dependent on the number and frequency of the pulses applied. Fig. 1 shows the concept of cyclic yield strength. The material in this case has a cyclic yield strength equal to about 90% of its static undrained strength and as shown in Fig. 1(*a*) the application of 100 cycles of stress amounting to 80%

of the undrained strength resulted in essentially an elastic behavior with very little permanent deformation. On the other hand, the application of 10 cycles of stress level equal to 95% of the static undrained strength led to substantial permanent strain as shown in Fig. 1(*b*). On loading the material monotonically to failure after the series of cyclic stress applications, the material was found to retain the original undrained strength. This type of behavior is associated with various types of soils that exhibit small increases in pore pressure during cyclic loading. This would include clayey materials, dry or partially saturated cohesionless soils, or very dense saturated cohesionless materials that will not undergo significant deformations, even under cyclic loading conditions, unless the undrained static strength of the soil is exceeded.

Seed and Chan (20) conducted cyclic tests on samples of undisturbed and compacted silty clays and found that for conditions of no stress reversal and for different values of initial and cyclic stresses, the total stress required to produce large deformations in 10 cycles and 100 cycles ranged between 90%–110% of the undrained static strength.

Sangrey, et al. (15) investigated the effective stress response of clay under repeated loading. They tested undisturbed samples of clay (LL = 28, PI = 10) and found that the cyclic yield strength of this material was of the order of 60% of its static undrained strength.

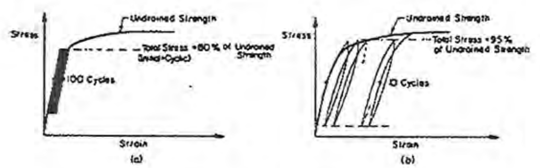

FIG. 1.—Determination of Dynamic Yield Strength

Rahman (14) performed similar tests on remolded samples of a brittle silty clay (LL = 91, PI = 49) and found that the cyclic yield strength was a function of the initial effective confining pressure. For practical ranges of effective confining pressures the cyclic yield strength for this material ranged between 80%–95% of its static undrained strength. At cyclic stress levels below the yield strength, in all cases, the material reached equilibrium and assumed an elastic behavior at strain levels less than 2% irrespective of the number of stress cycles applied.

Thiers and Seed (28) performed tests on undisturbed and remolded samples of different clayey materials to determine the reduction in static undrained strength due to cyclic loading. Their results are summarized in Fig. 2 which shows the reduction in undrained strength after cyclic loading as a function of the ratio of the "maximum cyclic strain" to the "static failure strain." These results were obtained from strain controlled cyclic tests; after the application of 200 cycles of a certain strain amplitude, the sample was loaded to failure monotonically at a strain rate of 3%/min. Thus from Fig. 2 it could be argued that if a clay is subjected to 200 cycles of strain with an amplitude less than half its static failure strain, the material may be expected to retain at least 90% of its original static undrained strength.

Andersen (2), on the basis of cyclic simple shear tests on samples of Drammen clay, determined that the reduction in undrained shear strength was found to be less than 25% as long as the cyclic shear strain was less than ±3% even after 1,000 cycles. Some North Sea clays, however, have shown a strength reduction of up to 40% for the same level of cyclic loading.

On the basis of the experimental data reported previously and for values

TABLE 1.—Maximum Cyclic Shear Strains Calculated from Dynamic Finite Element Response Analyses

Magnitude (1)	Embankment height, in feet (2)	Slope, $H:V$ (3)	Maximum base acceleration, g (4)	Maximum shear strain, as a percentage (5)
6-1/2 (Caltech record)	75	2:1	0.5	0.2–0.4
6-1/2 (Caltech record)	150	2:1	0.2	0.1–0.15
6-1/2 (Caltech record)	150	2:1	0.5	0.2–0.3
6-1/2 (Lake Hughes record)	150	2:1	0.2	0.1–0.15
6-1/2 (Caltech record)	150	2-1/2:1	0.5	0.2–0.3
7-1/2 (Taft record)	150	2:1	0.5	0.2–0.5
7-1/2 (Taft record)	150	2:1	0.2	0.1–0.2
8-1/4 (S-I record)	150	2:1	0.75	0.4–1.0
8-1/4 (S-I record)	135	—	0.4	0.2–0.5

Note: 1 ft = 0.305 m.

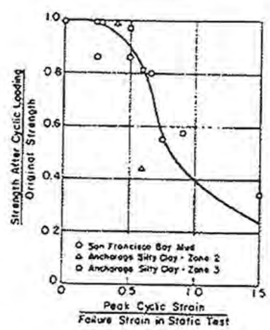

FIG. 2.—Reduction in Static Undrained Strength Due to Cyclic Loading (29)

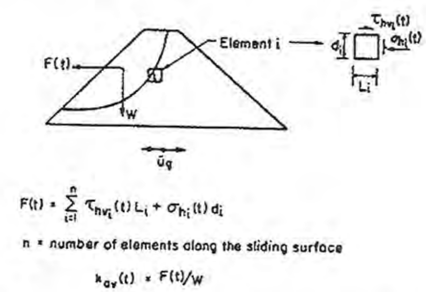

FIG. 3.—Calculation of Average Acceleration from Finite Element Response Analysis

of cyclic shear strains calculated from earthquake response analyses, the value of cyclic yield strength for a clayey material can be estimated. In most cases this value would appear to be 80% or more of the static undrained strength. This value in turn may be used in an appropriate method of stability analysis to calculate the corresponding yield acceleration.

Finite element response analyses (as will be described later) have been carried out to calculate time histories of crest acceleration and average acceleration

Attachment A 3/9

for various potential sliding masses. The method of analysis employs the equivalent linear technique with strain-dependent modulus and damping. The ranges of calculated maximum shear strains, for different magnitude earthquakes and different embankment characteristics, are presented in Table 1. It can be seen from Table 1 that the maximum cyclic shear strain induced during the earthquakes ranged between 0.1% for a magnitude 6-1/2 earthquake with a base acceleration of 0.2 g and 1% for a magnitude 8-1/4 earthquake with a base acceleration of 0.75 g. For the compacted clayey material encountered in dam embankments "static failure strain" values usually range between 3%–10%, depending on whether the material was compacted on the dry or wet side of the optimum moisture content. Thus in both instances the ratio of the "cyclic strain" to "static failure strain" is less than 0.5.

It seems reasonable, therefore, to assume that for these compacted cohesive soils, very little reduction in strength may be expected as a result of strong earthquake loading of the magnitude described previously.

Once the cyclic yield strength is defined, the calculation of the yield acceleration can be achieved by using one of the available methods of stability analysis. In the present study the ordinary method of slices has been used to calculate the yield acceleration for circular slip surfaces using a pseudostatic analysis. As an alternative one of the writers (18) has suggested a method of combining both effective and total stress approaches, where the shear strength on the failure plane during the earthquake is considered to be a function of the initial effective normal stress on that same plane before the earthquake. This method is applicable to noncircular slip surfaces and the horizontal inertia force resulting in a factor of safety of unity can readily be calculated.

Having determined the yield acceleration for a certain location of the slip surface, the next step in the analysis is to determine the time history of earthquake-induced average accelerations for that particular sliding mass. This will be treated in the following section.

Determination of Earthquake Induced Acceleration

In order for the permanent deformations to be calculated for a particular slip surface, the time history of earthquake induced average accelerations must first be determined.

Two-dimensional finite element procedures using equivalent linear strain-dependent properties are available (6) and have been shown to provide response values in good agreement with measured values (8) and with closed-form one-dimensional wave propagation solutions (17).

For most of the case studies of embankments used in the present analysis, the response calculation was performed using the finite element computer program QUAD-4 (6) with strain-dependent modulus and damping. The program uses the Rayleigh damping approach and allows for variable damping to be used in different elements.

To calculate the time history of average acceleration for a specified sliding mass, the method described by Chopra (4) was adopted in the present study. The finite element calculation provides time histories of stresses for every element in the embankment. As shown in Fig. 3, at each time step the forces acting along the boundary of the sliding mass are calculated from the corresponding

(Attachment A, 4/9)

normal and shear stresses of the finite elements along that boundary. The resultant of these forces divided by the weight of the sliding mass would give the average acceleration, $k_{av}(t)$, acting on the sliding mass at that instant in time. The process is repeated for every time step to calculate the entire time history of average acceleration.

For a 150-ft (46-m) high dam subjected to 30 sec of the Taft earthquake record scaled to produce a maximum base acceleration of 0.2 g, the variation

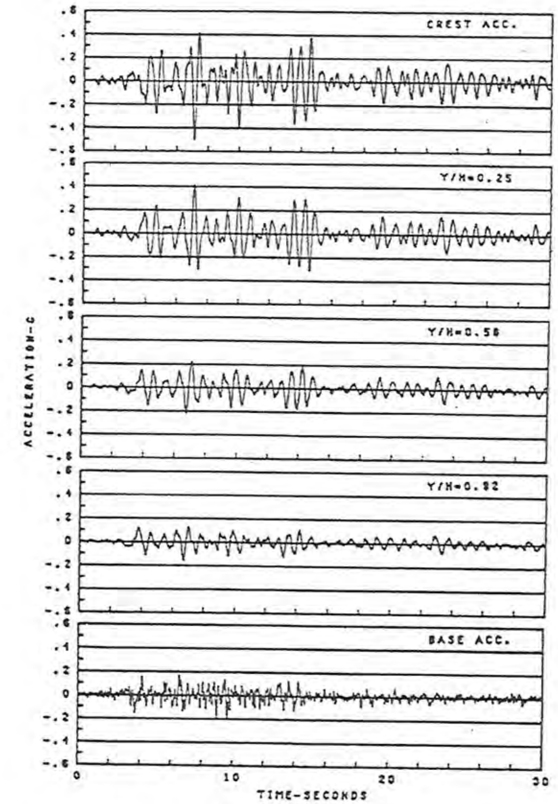

FIG. 4.—Time Histories of Average Acceleration for Various Depths of Potential Sliding Mass

of the time history of k_{av} with the depth of the sliding mass within the embankment, together with the time history of crest accelerations, is shown in Fig. 4.

Comparing the time history of crest acceleration with that of the average acceleration for different depths of the potential sliding mass, the similarity in the frequency content is readily apparent (it generally reflects the first natural period of the embankment), while the amplitudes are shown to decrease as the depth of the sliding mass increases towards the base of the embankment. The maximum crest acceleration is designated by $\ddot{u}_{max}$, and k_{max} is the maximum average acceleration for a potential sliding mass extending to a specified depth, y.

It would be desirable to establish a relationship showing the variation of the maximum acceleration ratio, $k_{max}/\ddot{u}_{max}$, with depth for a range of embankments and earthquake loading conditions. It would then be sufficient, for design purposes, to estimate the maximum crest acceleration in a given embankment due to a specified earthquake and use this relationship to determine the maximum average acceleration for any depth of the potential sliding mass. A simplified procedure to estimate the maximum crest acceleration and the natural period

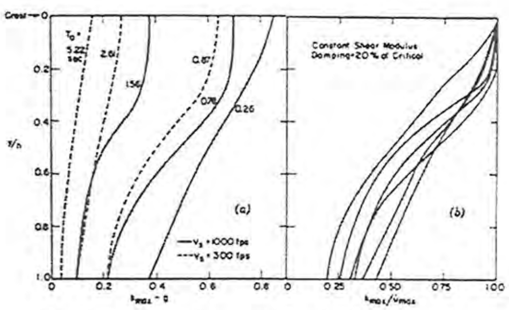

FIG. 5.—El Centro Record (12): (*a*) Variation of Maximum Average Acceleration with Depth of Sliding; (*b*) Variation of Ratio of Average Acceleration to Maximum Crest Acceleration with Depth of Sliding Surface

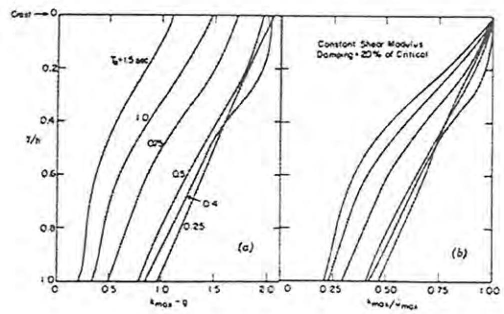

FIG. 6.—Average of Eight Strong Motion Records (1): (*a*) Variation of Maximum Average Acceleration with Depth of Sliding Mass; (*b*) Variation of Ratio of Maximum Average Acceleration to Maximum Crest Acceleration with Depth of Sliding Surface

of an embankment subjected to a given base motion is described in Appendix A of Ref. 11.

To determine the variation of maximum acceleration ratio with depth, use was made of published results of response computations using the one-dimensional shear slice method with visco-elastic material properties (1,26). Martin (12) calculated the response of embankments ranging in height between 100 ft–600 ft (30 m–180 m) and with shear wave velocities between 300 fps–1,000 fps (92 m/s–300 m/s). Using a constant shear modulus and a damping factor of 0.2,

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the average acceleration histories for various levels were computed for embankments subjected to ground accelerations recorded in the El Centro earthquake of 1940. The variation of the maximum average acceleration, k_{max}, with depth for these embankments with natural periods ranging between 0.26 sec–5.22 sec is presented in Fig. 5(*a*). The maximum average acceleration in Fig. 5(*a*) is normalized with respect to the maximum crest acceleration and the ratio, $k_{max}/\ddot{u}_{max}$, plotted as a function of the depth of the sliding mass is presented in Fig. 5(*b*).

Ambraseys and Sarma (1) used essentially the same method reported by Seed and Martin (26) and calculated the response of embankments with natural periods ranging between 0.25 sec and 3.0 sec. They presented their results in terms of average response for eight strong motion records. The variation of maximum average acceleration with depth based on the results reported by Ambraseys and Sarma (1) is shown in Fig. 6(*a*) and that for the maximum acceleration ratio, $k_{max}/\ddot{u}_{max}$, is shown in Fig. 6(*b*). A summary of the results obtained

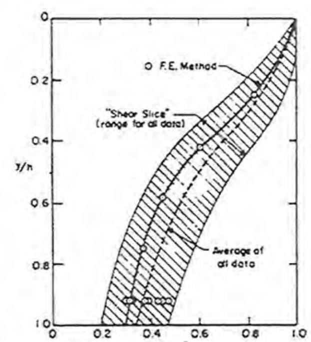

FIG. 7.—Variation of Maximum Acceleration Ratio with Depth of Sliding Mass

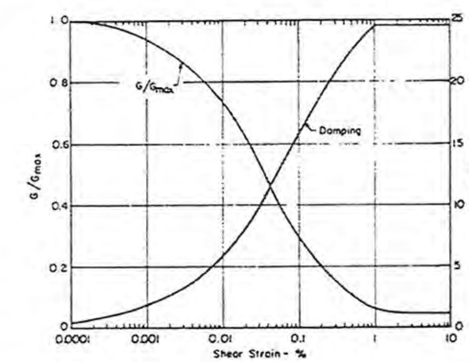

FIG. 8.—Shear Modulus and Damping Characteristics Used in Response Computations

from the different shear slice response calculations mentioned previously is presented in Fig. 7 together with results obtained from finite element calculations made in the present study. As can be seen from Fig. 7 the shape of the curves obtained using the shear slice method and the finite element method are very similar. The dashed curve in Fig. 7 is an average relationship of all data considered. The maximum difference between the envelope of all data and the average relationship ranges from ±10% to ±20% for the upper portion of the embankment and from ±20% to ±30% for the lower portion of the embankment.

Considering the approximate nature of the proposed method of analysis, the use of the average relationship shown in Fig. 7 for determining the maximum average acceleration for a potential sliding mass based on the maximum crest acceleration is considered accurate enough for practical purposes. For design computations where a conservative estimate of the accelerations is desired the upper bound curve shown in Fig. 7 may be used leading to values that are 10%–30% higher than those estimated using the average relationship.

CALCULATION OF PERMANENT DEFORMATIONS

Once the yield acceleration and the time history of average induced acceleration for a potential sliding mass have been determined, the permanent displacements can readily be calculated.

By assuming a direction of the sliding plane and writing the equation of

TABLE 2.—Embankment Characteristics for Magnitude 6-1/2 Earthquake

Case number (1)	Embankment description (2)	Height, in feet (3)	Base acceleration, g (4)	T_o, in seconds (5)[a]	k_{max}, g (6)[b]	Symbol[c] (7)
1	Example slope = 2:1 k_{2max} = 60	150	0.2 (Caltech record)	0.8	(1) 0.31 (2) 0.12	● ■
2	Example slope = 2:1 k_{2max} = 60	150	0.5 (Caltech record)	1.08	(1) 0.4 (2) 0.18	○ □
3	Example slope = 2:1 k_{2max} = 80	150	0.5 (Lake Hughes record)	0.84	(1) 0.33 (2) 0.16	⊙ △
4	Example slope = 2-1/2:1 k_{2max} = 80	150	0.5 (Caltech record)	0.95	(1) 0.49 (2) 0.22	◇ ▽
5	Example slope = 2:1 k_{2max} = 60	75	0.5 (Caltech record)	0.6	(1) 0.86 (2) 0.26	◑ ◪

[a]Calculated first natural period of the embankment.
[b]Maximum value of time history of: (1) Crest acceleration; and (2) average acceleration for sliding mass extending through full height of embankment.
[c]Legend used in Fig. 9(a).
Note: 1 ft = 0.305 m.

motion for the sliding mass along such a plane, the displacements that would occur any time the induced acceleration exceeds the yield acceleration may be evaluated by simple numerical integration. For the purposes of the soil types considered in this study, the yield acceleration was assumed to be constant throughout the earthquake.

The direction of motion for a potential sliding mass once yielding occurs

was assumed to be along a horizontal plane. This mode of deformation is not uncommon for embankments subjected to strong earthquake shaking, and is manifested in many cases in the field by the development of longitudinal cracks along the crest of the embankment. However studies made for other directions of the sliding surface showed that this factor had little effect on the computed displacements (11).

To calculate an order of magnitude of the deformations induced in embankments due to strong shaking a number of cases have been analyzed during the course of this study. The height of embankments considered ranged between 75 ft–150 ft (23 m–46 m) with varying slopes and material properties. The embankments were subjected to ground accelerations representing three different earthquake magnitudes: 6-1/2, 7-1/2, and 8-1/4.

The method used for calculating the response, as mentioned earlier, is a time-step finite element analysis using the equivalent linear method. The strain-dependent modulus and damping relations for the soils used in this study are

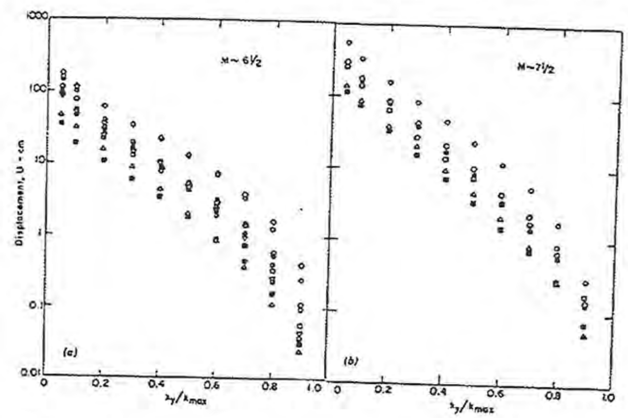

FIG. 9.—Variation of Permanent Displacement with Yield Acceleration: (a) Magnitude 6-1/2 Earthquake; (b) Magnitude 7-1/2 Earthquake

presented in Fig. 8. The response computation for each base motion was repeated for a number of iterations (mostly 3–4) until strain compatible material properties were obtained. In each case both time histories of crest acceleration and the average acceleration for a potential sliding mass extending through almost the full height of the embankment were calculated, together with the first natural period of the embankment. In one case however, time histories of average acceleration for sliding surfaces at five different levels in the embankment were obtained (see Fig. 4), and the corresponding permanent deformations for each time history were calculated for different values of yield acceleration. It was found that for the same ratio of yield acceleration to maximum average acceleration at each level, the computed deformations varied uniformly between a maximum value obtained using the crest acceleration time history to a minimum value obtained using the time history of average acceleration for a sliding mass extending through the full height of the embankment. Thus it was considered

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sufficient for the remaining cases to compute the deformations only for these two levels.

Table 2 shows details of the embankments analyzed using ground motions representative of a magnitude 6-1/2 earthquake. The two rock motions used were those recorded at the Cal Tech Seismographic Laboratory (S90W Component) and at Lake Hughes Station No. 12 (N12E) during the 1971 San Fernando earthquake, with maximum accelerations scaled to 0.2 *g* and 0.5 *g*. The computed natural periods and maximum values of the acceleration time histories are also presented in Table 2. The computed natural periods ranged between a value of 0.6 sec for the 75-ft (23-m) high embankment to a value of 1.08 sec for the 150-ft (46-m) high embankment. Because of the nonlinear strain-dependent behavior of the material, the response of the embankment is highly dependent on the amplitude of the base motion. This is clearly demonstrated in the first two cases in Table 2, where the same embankment was subjected to the same ground acceleration history but with different maximum accelerations for each case. In one instance, for a base acceleration of 0.2 *g* the calculated maximum crest accelerations was 0.3 *g* with a magnification of 1.5 and a computed natural period of the order of 0.8 sec. In the second case, for a base acceleration of 0.5 *g* the computed maximum crest acceleration was 0.4 *g* with an attenuation of 0.8 and a computed natural period of 1.1 sec.

From the time histories of induced acceleration calculated for all the cases described in Table 2 and for various ratios of yield acceleration to maximum average acceleration, k_y/k_{max}, the permanent deformations were calculated by numerical double integration. The results are presented in Fig. 9(*a*) which shows that for relatively low values of yield acceleration, k_y/k_{max} of 0.2 for example, the range of computed permanent displacements was of the order of 10 cm–70 cm (4 in.–28 in.). However, for larger values of k_y/k_{max}, say 0.5 or more, the calculated displacements were less than 12 cm (4.8 in.). It should be emphasized that for very low values of yield accelerations (in this case $k_y/k_{max} \leq 0.1$) the basic assumptions used in calculating the response by the finite element method, i.e., the equivalent linear behavior and the small strain theory, become invalid. Consequently, the acceleration time histories calculated for such a case do not represent the real field behavior and the calculated displacements based on these time histories may not be realistic.

The procedure described previously was repeated for the case of a magnitude 7-1/2 earthquake. The base acceleration time history used for this analysis was that recorded at Taft during the 1952 Kern County earthquake and scaled to maximum accelerations of 0.2 *g* and 0.5 *g*. The details of the three cases analyzed are presented in Table 3 and the results of the computations of the

TABLE 3.—Embankment Characteristics for Magnitude 7-1/2 Earthquake

Case number (1)	Embankment description (2)	Height, in feet (3)	Base acceleration, *g* (4)	T_0, in seconds (5)[a]	k_{max}, *g* (6)[b]	Symbol[c] (7)
1	Example slope = 2:1 k_{2max} = 60	150	0.2 (Taft record)	0.86	(1) 0.41 (2) 0.13	● ■
2	Example slope = 2:1 k_{2max} = 60	150	0.5 (Taft record)	1.18	(1) 0.54 (2) 0.21	○ □
3	Example slope = 2-1/2:1 k_{2max} = 80	150	0.2 (Taft record)	0.76	(1) 0.46 (2) 0.15	⊙ △

[a]Calculated first natural period of the embankment.
[b]Maximum value of time history of: (1) Crest acceleration; and (2) average acceleration for sliding mass extending through full height of embankment.
[c]Legend used in Fig. 9(*b*).
Note: 1 ft = 0.305 m.

TABLE 4.—Embankment Characteristics of Magnitude 8-1/4 Earthquake

Case number (1)	Embankment description (2)	Height, in feet (3)	Base acceleration, *g* (4)	T_0, in seconds (5)[a]	k_{max}, *g* (6)[b]	Symbol[c] (7)
1	Chabot Dam (average properties)	135	0.4 (S-I Synth. record)	0.99	(1) 0.57	○
	Chabot Dam (Lower bound)	135	0.4 (S-I Synth. record)	1.07	(1) 0.53	△
	Chabot Dam (Upper bound)	135	0.4	0.83	(1) 0.68	□
2	Example slope = 2:1 k_{2max} = 60	150	0.75	1.49	(1) 0.74 (2) 0.34	● ■

[a]Calculated first natural period of the embankment.
[b]Maximum value of time history of: (1) Crest acceleration; and (2) average acceleration for sliding mass extending through full height of embankment.
[c]Legend used in Fig. 10(*a*).
Note: 1 ft = 0.305 m.

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permanent displacements are shown in Fig. 9(*b*). For a ratio of k_y/k_{max} of 0.2 the calculated displacements in this case ranged between 30 cm–200 cm (12 in.–80 in.), and for ratios greater than 0.5 the displacements were less than 25 cm (0.8 ft).

In the cases analyzed for the 8-1/4 magnitude earthquake, an artificial accelerogram proposed by Seed and Idriss (21) was used with maximum base accelerations of 0.4 *g* and 0.75 *g*. Two embankments were analyzed in this case and their calculated natural periods ranged between 0.8 sec and 1.5 sec. Table 4 shows the details of the calculations and in Fig. 10(*a*) the results of the permanent displacement computations are presented. As can be seen from Fig. 10(*a*) the permanent displacements computed for a ratio of k_y/k_{max} of 0.2 ranged between 200 cm–700 cm (80 in.–28 in.), and for ratios higher than 0.5 the values were less than 100 cm (40 in.). Note in this case that values of deformations calculated for a yield ratio less than 0.2 may not be realistic.

An envelope of the results obtained for each of the three earthquake loading

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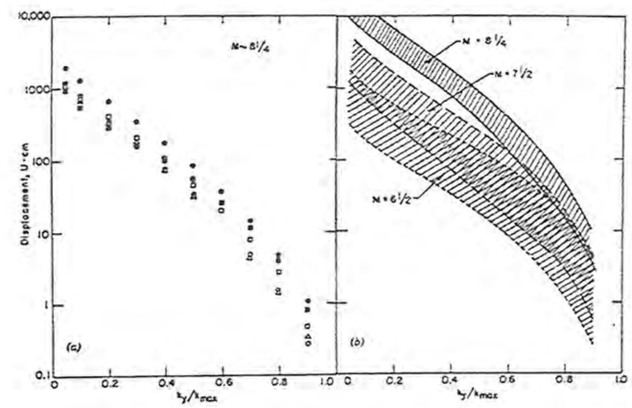

FIG. 10.—Variation of Permanent Displacement with Yield Acceleration: (*a*) Magnitude 8-1/4 Earthquake; (*b*) Summary of All Data

conditions is presented in Fig. 10(*b*) and reveals a large scatter in the computed results reaching, in the case of the magnitude 6-1/2 earthquake, about one order of magnitude.

It can reasonably be expected that for a potential sliding mass with a specified yield acceleration, the magnitude of the permanent deformation induced by a certain earthquake loading is controlled by the following factors: (1) The amplitude of induced average accelerations, which is a function of the base motion, the amplifying characteristics of the embankment, and the location of the sliding mass within the embankment; (2) the frequency content of the average acceleration time history, which is governed by the embankment height and stiffness characteristics, and is usually dominated by the first natural frequency of the embankment; and (3) the duration of significant shaking, which is a function of the magnitude of the specified earthquake.

Thus to reduce the large scatter exhibited in the data in Fig. 10(*b*), the permanent

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displacements for each embankment were normalized with respect to its calculated first natural period, T_0, and with respect to the maximum value, k_{max}, of the average acceleration time history used in the computation. The resulting normalized permanent displacements for the three different earthquakes are presented in Fig. 11(*a*). It may be seen that a substantial reduction in the scatter of the data is achieved by this normalization procedure as evidenced by comparing the results in Figs. 10(*b*) and 11(*a*). This shows that for the ranges of embankment heights considered in this study [75 ft–150 ft (50 m–65 m)] the first natural period of the embankment and the maximum value of acceleration time history may be considered as two of the parameters having a major influence on the calculated permanent displacements. Average curves for the normalized permanent displacements based on the results in Fig. 11(*a*) are presented in Fig. 11(*b*). Although some scatter still exists in the results as shown in Fig. 11(*a*), the average curves presented in Fig. 11(*b*) are considered adequate to provide an order of magnitude of the induced permanent displacements for different

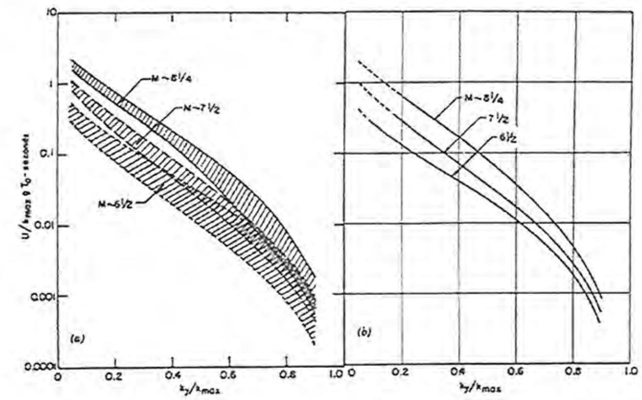

FIG. 11.—Variation of Yield Acceleration with: (*a*) Normalized Permanent Displacement—Summary of All Data; and (*b*) Average Normalized Displacement

magnitude earthquakes. At yield acceleration ratios less than 0.2 the average curves are shown as dashed lines since, as mentioned earlier, the calculated displacements at these low ratios may be unrealistic.

Thus, to calculate the permanent deformation in an embankment constructed of a soil that does not change in strength significantly during an earthquake, it is sufficient to determine its maximum crest acceleration, $\ddot{u}_{max}$, and first natural period, T_0, due to a specified earthquake. Then by the use of the relationship presented in Fig. 7, the maximum value of average acceleration history, k_{max}, for any level of the specified sliding mass may be determined. Entering the curves in Fig. 11(*b*) with the appropriate values of k_{max} and T_0, the permanent displacements can be determined for any value of yield acceleration associated with that particular sliding surface.

It has been assumed earlier in this paper that in the majority of embankments, permanent deformations usually occur due to slip of a sliding mass on a horizontal failure plane. For those few instances where sliding might occur on an inclined strength of the material and in estimating the maximum accelerations in the embankment, the calculated deformations for this 135-ft (40-m) clayey embankment ranged between 0.1 ft–1.5 ft (0.3 m–0.46 m). These approximate displacement values are in good accord with the actual performance of the embankment during the earthquake.

Whereas the method described herein provides a rational approach to the design of embankments and offers a significant improvement over the conventional pseudostatic approach, the nature of the approximations involved requires that it be used with caution and good judgment especially in determining the soil characteristics of the embankment to which it may be applied.

For large embankments, for embankments where failure might result in a loss of life or major damage and property loss, or where soil conditions cannot be determined with a significant degree of accuracy to warrant the use of the method, the more rigorous dynamic method of analysis described earlier might well provide a more satisfactory alternative for design purposes.

Acknowledgment

The study described in this paper was conducted under the sponsorship of the National Science Foundation (Grant ENV 75-21875). The support of the National Science Foundation is gratefully acknowledged.

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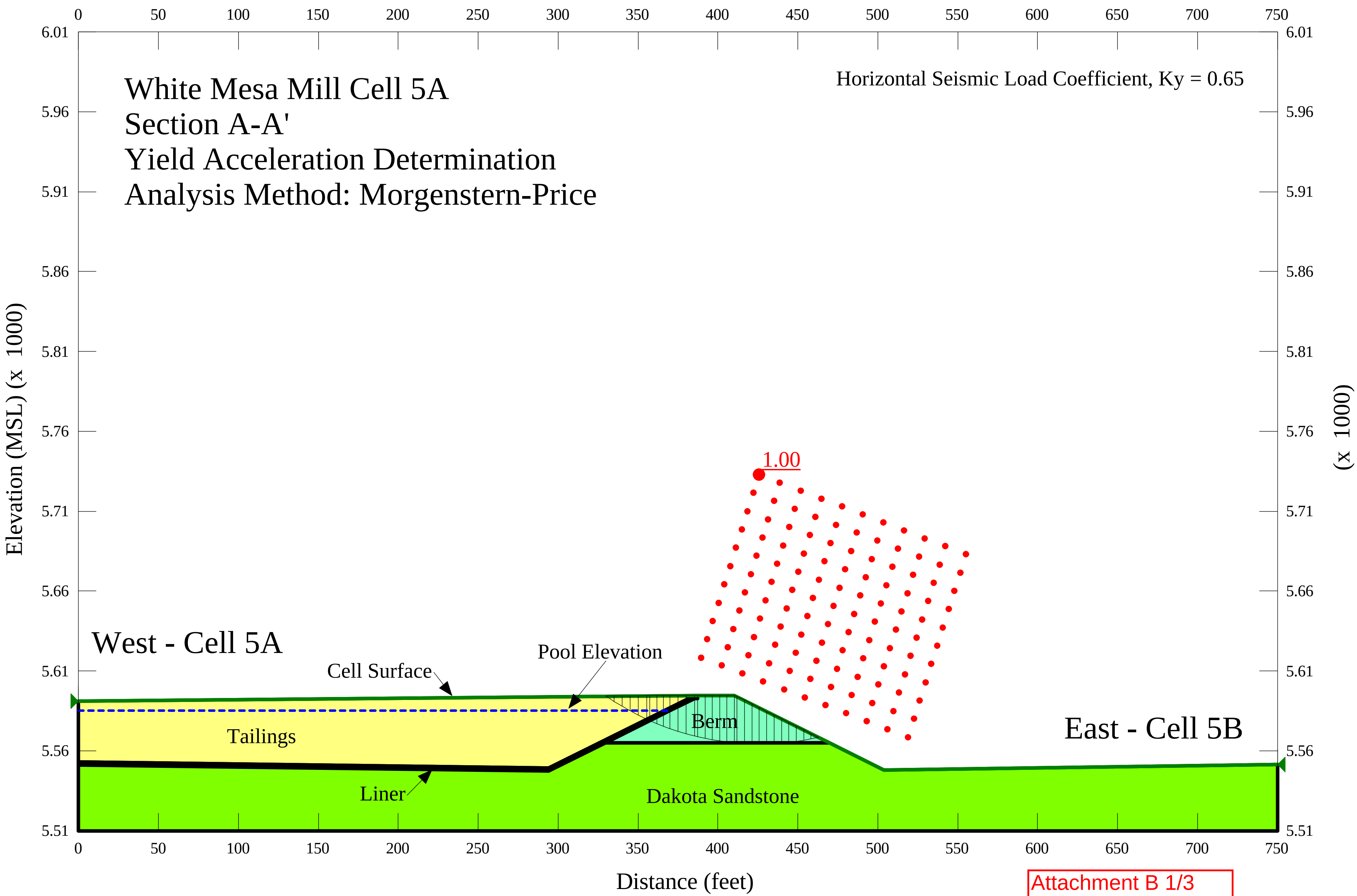

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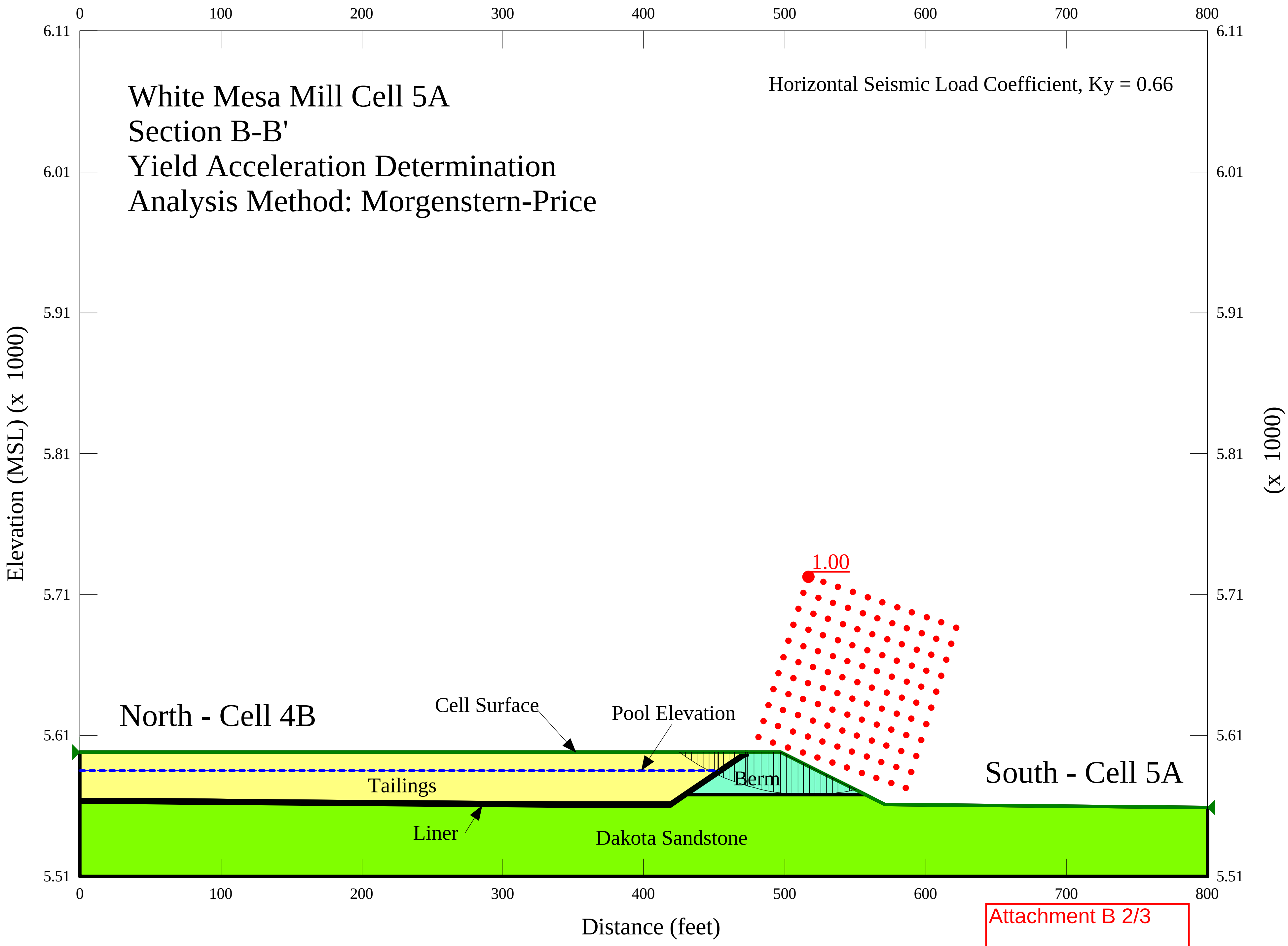

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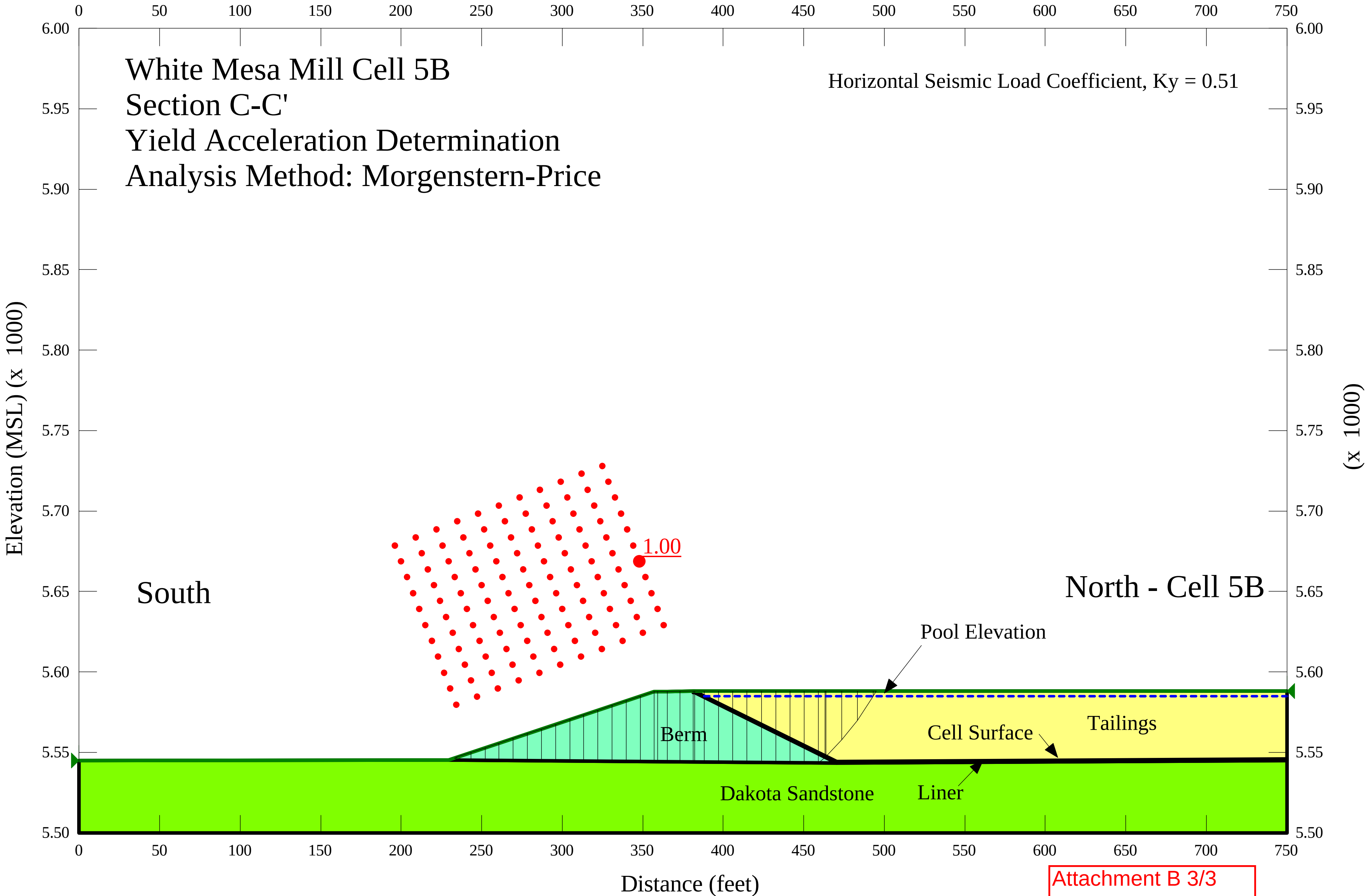

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Mr. Harold R. Roberts
International Uranium (USA) Corporation
1050 Seventeenth Street, Suite 950
Denver, CO 80265

**Subject: White Mesa Uranium Facility
Cell 4 Seismic Study
Blanding, Utah**

Dear Mr. Roberts:

This document has been prepared to examine the seismicity of the White Mesa site and to recommend a design peak ground acceleration (PGA) to be incorporated in the Cell 4A design. This letter addresses concerns brought forth in comments by Utah Department of Environmental Quality (UDEQ) as documented in Interrogatory IUC R313-24-4-05/05: Dike Integrity.

Comments in Interrogatory IUC R313-24-4-05/05

Comments from UDEQ state that the seismic loading used (0.10 g) for stability analysis of the Cell 4A slopes is based on an outdated seismic analysis presented in the 1988 Cell 4 Design Report (UMETCO), and that updated seismic hazard analysis should be performed. As stated in the Interrogatory 05, it is not thought that there is any new information on active faults that would impact the hazard at White Mesa. However, UDEQ requested ground motion attenuation relationships be updated to reflect current evaluation methods.

Original Design Basis for Cell 4

This original design report for Cell 4 (UMETCO, 1988), characterized the geologic conditions at the site. Section 1.3.4 identified potential earthquake hazards to the project. The specified hazards include minor random earthquakes not associated with a known seismic structure, and an unnamed fault located 57 km north of the project site (north of Monticello), with a fault length well defined for 3 km, and possibly as long as 11 km. The fault is considered a suspected Quaternary fault, but does not have strong evidence for Quaternary movement. Estimates of the maximum credible earthquake (MCE) associated with this fault were estimated to have a magnitude of 6.4 based on relationships developed by Slemmons in 1977. Ground motions at the project site were estimated using attenuation curves established in 1982 by Seed and Idriss. Peak horizontal accelerations at the site from the fault were estimated to be 0.07 g.

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Updated attenuation relationships

A search of the Quaternary Fault and Fold Database (USGS 2006) lists Shay graben faults as a Class B (suspected) Quaternary fault. No other faults within 50 km of the site are included in the database. Shay graben faults were included in the Lawrence Livermore National Laboratory (LLNL) report. Other faults considered as possible seismic sources include the unnamed fault north of Monticello that was the design basis of the design accelerations in the 1988 report.

Many attenuation relationships have been developed within the last ten years and are currently being used to estimate ground motions. Three relationships are used in this report to estimate the peak ground motion at the White Mesa site. Abrahamson and Silva (1997) is a well accepted relationship used for shallow crustal earthquakes in Western North America. In addition, Spudich et al. (1999) is used because it has been specifically developed for extensional tectonic regimes, such as those encountered in the area of the site. Campbell and Bozorgnia (2003), is also examined as a current, applicable model, which accounts for normal faulting. In all cases, mean values plus one standard deviation are reported. A comparison of the three methods can be found in Table 1.

Design Peak Ground Acceleration for Cell 4

The above discussion is based on the PGA associated with MCE predicted for a known tectonic feature, and as such, cannot be correlated to a specific return period. 10 CFR 100 Appendix A and 10 CFR 40 Appendix A of Nuclear Regulatory Commission (NRC) regulations are interpreted to apply to long-term, reclaimed impoundments. A distinction should be made between seismic conditions that apply to operational conditions versus long-term conditions. Disposal areas are required to demonstrate closure performance that provides control of radiological hazards to be effective for one thousand years, to the extent reasonably achievable, and, in any case, for at least 200 years. However, this standard should not apply to the operational time-period of the disposal cell. In 2002, the USGS updated the National Seismic Hazard Maps (NSHM), which show peak ground and spectral accelerations at 2 percent and 10 percent probability of exceedance in 50 years. From these maps, the PGA for the White Mesa site is shown to be 0.090 g with a 2 percent probability of exceedance in 50 years. The probability of exceedance can be represented by the following equation:

$$PE = 1 - e^{-(n/T)}$$

Where PE = probability of exceedance, n = time period, in years, and T = return period, in years.

It can be shown that the return period associated with a PGA of 0.090 g is equivalent to 2,475 years, and if the life of the project is conservatively taken to be 100 years, the probability of exceedance of 0.090 g is approximately 4 percent. Therefore, the PGA taken from the USGS maps is an appropriate design acceleration to use for operational conditions of the disposal cell.

Conclusions

The seismic loading of 0.1 g used in analysis of the Cell 4A dikes exceeds the PGA associated with a 2 percent probability of exceedance within 50 years, and is appropriate for the operational life of the disposal cell. At the time when design of closure is implemented, design PGA based on the MCE associated with known or suspected Quaternary features and the background seismicity of the area should be incorporated into the design long-term seismic loading.

References

Abrahamson, N.A., and W.J. Silva (1997). Empirical Response Spectral Attenuation Relations for Shallow crustal Earthquakes, Seismologcal Research Letters, Vol. 68, No. 1, pp. 94-127, January/February.

Campbell, K.W., and Y. Bozorgnia (2003). Updated Near-Source Ground-Motion (Attenuation) Relations for the Horizontal and Vertical Components of Peak Ground Acceleration and Acceleration Response Spectra, Bulletin of the Seismological Society of America, Vol. 93, No. 1, pp. 314-331, February.

Spudich, P., W.B. Joyner, A.G. Lindh, D.M. Boore, B.M. Margaris, and J.B. Fletcher (1999). SEA99: A Revised Ground Motion Prediction Relation for Use in Extensional Tectonic Regimes, Bulletin of the Seismological Society of America, Vol. 89, No. 5, pp. 1156-1170, October.

UMETCO, 1988. Cell 4 Design, Appendix A, White Mesa Project.

U.S. Geological Survey (USGS) 2002. Quaternary Fault and Fold Database: http://Qfaults.cr.usgs.gov/.

If we can be of further assistance, please do not hesitate to contact the undersigned.

Sincerely,

TETRA TECH COMPANY
MFG, INC.

Roslyn Stern

Roslyn Stern
Senior Staff Geotechnical Engineer

Reviewed by:

REGISTERED PROFESSIONAL ENGINEER No. 6232722-2202 THOMAS A. CHAPEL 11-27-06 STATE OF UTAH

Thomas A. Chapel, CPG, PE
Senior Geotechnical Engineer

cc: Tetra Tech EM
Ms. JoAnn Tischler

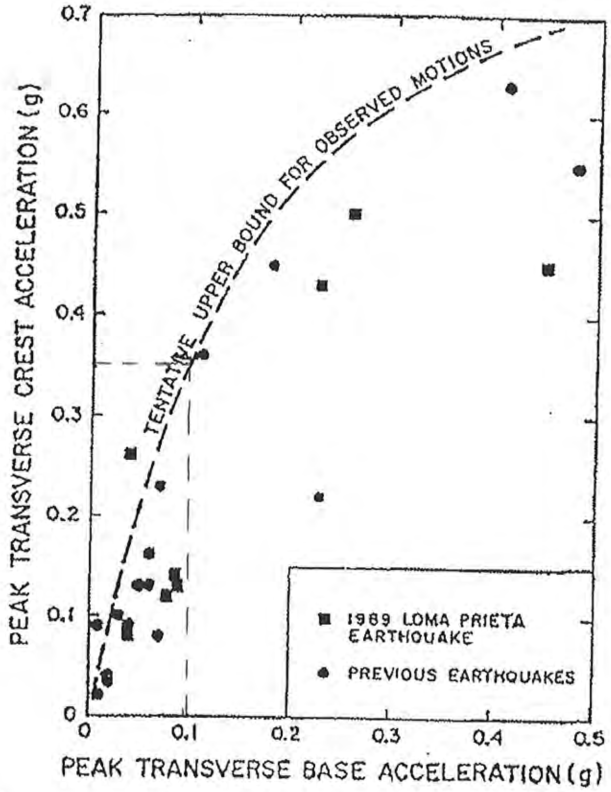
Attachment(s)

Table 1: Peak Ground Accelerations – White Mesa

Name	Fault Length (km)	Fault Type[1]	Site Class[2]	Distance from site (km)	MCE (Wells and Coppersmith, 1994)	PGA Mean plus 1 SD (Spudich et al., 1999)	PGA Mean plus 1 SD (Abrahamson and Silva, 1997)	PGA Mean plus 1 SD, Campbell-Bozorgnia 2003	PGA Mean plus 1 SD average
unnamed fault north of Monticello, defined length	3.0	N	R	57.4	5.49	0.034	0.027	0.037	0.032
unnamed fault north of Monticello, possible total length	11.0	N	R	57.4	6.23	0.050	0.059	0.055	0.055
unnamed fault north of Monticello, 1/2 total rupture	5.5	N	R	57.4	5.84	0.041	0.039	0.044	0.041
Shay graben faults (Class B)	40.0	N	R	44.6	6.97	0.096	0.116	0.113	0.108

[1]Fault Type: N = Normal
[2]Site Class: R =Rock or shallow soils

Att C, 4/4



Source: Harder [1991]

GEOSYNTEC CONSULTANTS

PEAK TRANSVERSE CREST ACCELERATION VERSUS PEAK TRANSVERSE BASE ACCELERATION	FIGURE NO.
	PROJECT NO. SC0349
	DATE: April 2008

Attachment D 1/1

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF**	Project: **White Mesa Mill – Cells 5A and 5B**	Project/ Proposal No.:	**SC0634**
		Task No.	**02**

Title of Computations **SETTLEMENT ANALYSIS OF BERMS**

Computations by:	Signature		Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		Date 12/20/12
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations Checked by:	Signature		Date 12/18/12
	Printed Name	Jay Griffin	
	Title	Senior Staff Engineer	
Computations backchecked by: (originator)	Signature		Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature		Date 12/18/12
	Printed Name	Gregory T. Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	11/9/12	Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	Cells 5A and 5B	Project No.:	SC0634	Task No.:	02

SETTLEMENT EVALUATION OF BERMS

OBJECTIVE

The objective of this calculation is to evaluate the differential settlement under the loading from the berms at the perimeter of the cells to assess the potential effect on the system.

SUMMARY OF DESIGN

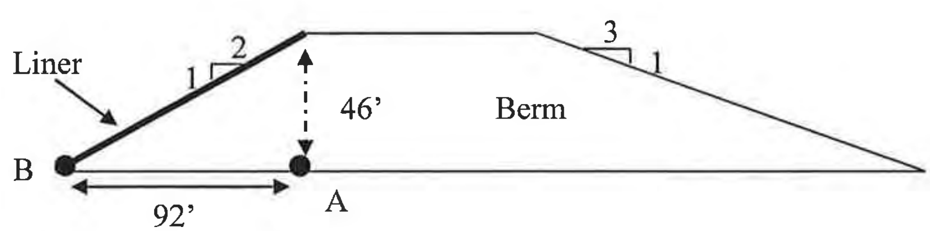
Based on the assumptions and calculations presented herein, the differential settlement of the berms will be approximately 0.20 inches at the toe of the slope and approximately 0.33 inches at the top of the slope, causing a strain of approximately 0.01% of the liner, when the cell is empty. When the cell is full, the differential settlement of the berms will be approximately 2.89 inches at the toe of the slope and approximately 3.13 inches at the top of the slope, causing a strain of approximately 0.002% of the liner.

ANALYSIS

Task 1: Evaluate the settlement of the berm in empty conditions.

Evaluate the settlement under the center of the berm versus at the toe of the berm.

Based on the proposed grading for Cells 5A and 5B (Attachment A), the following cross-section can be evaluated for the highest berm of the two cells (the south berm of Cell 5B).



Written by:	R. Flynn	Date:	11/9/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project No.:	SC0634	Task No.:	02

A unit weight of 137 pounds per cubic foot (pcf) for the berm material was estimated using data from a boring advanced in the existing berm between Cell 4A and 4B (Attachment B):

$$P, load = \gamma \times H = (137\,pcf)(46\,ft) = 6{,}302\ psf$$

Assuming the foundation for the berm consists of formational soil consisting of silty and clayey coarse to fine sandstone with layered shale (Attachment C), and based on the dense nature of the soil and underlying sandstone, the conservative stress-strain modulus is assumed to be as follows:

E_s = 1500 MPa (Boyles, 5th Ed., Attachment D)

$$E_S = 1500\ MPa \times \frac{145\frac{lb}{in^2}}{1\ MPa} \times \frac{144 in^2}{1 ft^2} \times \frac{1 kip}{1000 lb} = 31{,}320\ ksf$$

The settlement, S, is calculated in Table 1 using the elastic theory (Attachment E,1/2).

Elastic Theory: $\Delta = \dfrac{PL}{AE_E}$

Where:
- Δ = deformation
- P = force (F)
- L = length of material column (L)
- A = area of material column (L^2)
- E_E = Modulus of Elasticity (F/L^2)

For this analysis, the Boussinesq case for influence under a triangular load will be used, as presented in DM7.1-171. (Attachment E, 1/2). Translating the terms from Elastic Theory to apply to the Boussinesq approach to settlement calculation, the following equation is derived:

$$S = \frac{(4I \times P)(\Delta H)}{(A)(Es)} \times (\frac{12\ in}{1\ ft})$$ (Attachment E, 2/2)

Where:
- S = Settlement (Δ in Elastic Theory)
- P = 6302 lb

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Client:	EF	Project:	Cells 5A and 5B	Project No.:	SC0634	Task No.:	02

A = 1 ft^2
ΔH = incremental depth, ft (L in Elastic Theory)
E_S = Soil Modulus, = E_E in Elastic Theory
I = Boussinesq zone of influence, obtained from Figure 7 on page DM7.1-171 using m and n parameters (Attachment F, 1/2).

To Find I:

n = B/z (Attachment F)
m = L/z (Attachment F)
B = 92 ft, distance from outer edge of berm
L = 1,410 ft, length along berm edge
z = depth, ft
σz = 4I*P, ksf

Table 1. Settlement due to load under the embankment at the top of the slope, using Figure 7, "Beneath Corner O" chart, (Point A):

z (ft)	n = B/z	m = L/z	I	4I	σz=4I*P (ksf)	E_s (ksf)	ΔH (ft)	S (in)
5	18.4	282.0	0.240	0.96	6.0	31,320	5	0.012
10	9.2	141.0	0.235	0.94	5.9	31,320	5	0.011
15	6.1	94.0	0.230	0.92	5.8	31,320	5	0.011
20	4.6	70.5	0.220	0.88	5.5	31,320	5	0.011
40	2.3	35.3	0.200	0.80	5.0	31,320	20	0.039
60	1.5	23.5	0.175	0.70	4.4	31,320	20	0.034
80	1.2	17.6	0.158	0.63	4.0	31,320	20	0.031
100	0.9	14.1	0.140	0.56	3.5	31,320	20	0.027
150	0.6	9.4	0.108	0.43	2.7	31,320	50	0.052
200	0.5	7.1	0.075	0.30	1.9	31,320	50	0.036
250	0.4	5.6	0.046	0.18	1.2	31,320	50	0.022
300	0.3	4.7	0.042	0.17	1.1	31,320	50	0.020
350	0.3	4.0	0.028	0.11	0.7	31,320	50	0.014
400	0.2	3.5	0.028	0.11	0.7	31,320	50	0.014
							Total S, in.	0.333

Settlement under A (S_A), the center of the berm, is approximately **0.33inches**.

The calculation is repeated in Table 2 for settlement at the toe of the berm also using Figure 7, but the influence chart used is "Beneath Corner Q" chart.

Written by:	R. Flynn	Date:	11/9/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project No.:	SC0634	Task No.:	02

Table 2. Settlement due to load at toe of the slope (Point B):

z (ft)	n = B/z	m = L/z	I	4I	σz=4I*P (ksf)	E_s (ksf)	ΔH (ft)	S (in)
5	18.4	282.0	0.080	0.32	2.0	31,320	5	0.004
10	9.2	141.0	0.080	0.32	2.0	31,320	5	0.004
15	6.1	94.0	0.080	0.32	2.0	31,320	5	0.004
20	4.6	70.5	0.080	0.32	2.0	31,320	5	0.004
40	2.3	35.3	0.080	0.32	2.0	31,320	20	0.015
60	1.5	23.5	0.080	0.32	2.0	31,320	20	0.015
80	1.2	17.6	0.080	0.32	2.0	31,320	20	0.015
100	0.9	14.1	0.077	0.31	1.9	31,320	20	0.015
150	0.6	9.4	0.061	0.24	1.5	31,320	50	0.029
200	0.5	7.1	0.053	0.21	1.3	31,320	50	0.026
250	0.4	5.6	0.042	0.17	1.1	31,320	50	0.020
300	0.3	4.7	0.041	0.16	1.0	31,320	50	0.020
350	0.3	4.0	0.029	0.12	0.7	31,320	50	0.014
400	0.2	3.5	0.028	0.11	0.7	31,320	50	0.014
							Total S, in.	0.199

Settlement under point B (S_B), the toe of the berm, is approximately **0.20 inches**.

Evaluate the elastic strain of the side slope liner system related to settlement.

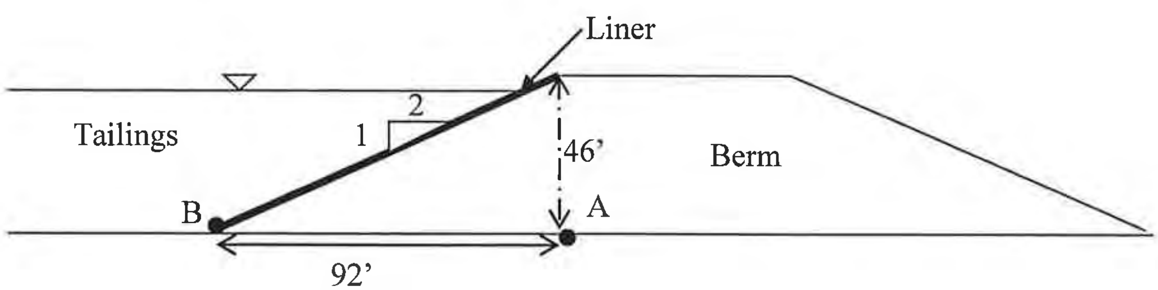
ΔS = 0.33-0.20 = 0.13 inches.

The liner is $\sqrt{[(92\,ft)^2 + (46\,ft)^2]} = 103\ ft$ in length.

Therefore, the strain in the liner is $\dfrac{0.13\,in}{103\,ft \times \dfrac{12in}{1\,ft}} = 0.01\%$

Task 2: Evaluate the settlement under the berm upon filling of the Cell.

Upon filling the Cell, the foundation may show differential settlement between Point A and Point B on the liner.



Written by: **R. Flynn** Date: **11/9/12** Reviewed by: **G. Corcoran** Date: 12/18/12

Client: **EF** Project: **Cells 5A and 5B** Project No.: **SC0634** Task No.: **02**

Assume the following conditions:

Berm Material: $\gamma = 137\ psf$
Tailing Material: $\gamma = 125\ psf$
Foundation Soil: E_s = 31,320 ksf
Length L = 1,410 ft
Width B = 1,000 ft

Load over Point A:

P_A = 6,302 *psf* at a distance of 92 ft

Load over Point B:

P_B = (125 *psf*)(46 *ft*) = 5,750 *psf*

Calculations are performed using the equation defined in the previous section. Calculations are shown in Table 3 use influence values obtained from Figure 3 on page 7.1-167 of DM 7.1 (Attachment F, 2/2) for infinitely long footing.

Table 3. Settlement due to load under the embankment (filled condition)

z (ft)	z/B	I	σz=I*P (ksf)	E_s (ksf)	ΔH (ft)	S (in)
5	0.01	1.00	6.30	31,320	5	0.012
10	0.01	1.00	6.30	31,320	5	0.012
15	0.02	1.00	6.30	31,320	5	0.012
20	0.02	1.00	6.30	31,320	5	0.012
40	0.04	1.00	6.30	31,320	20	0.048
60	0.06	1.00	6.30	31,320	20	0.048
80	0.08	1.00	6.30	31,320	20	0.048
100	0.10	0.97	6.11	31,320	20	0.047
150	0.15	0.92	5.80	31,320	50	0.111
200	0.20	0.90	5.67	31,320	50	0.109
300	0.30	0.89	5.61	31,320	100	0.215
400	0.40	0.85	5.36	31,320	100	0.205
500	0.50	0.75	4.73	31,320	100	0.181

Written by: R. Flynn Date: 11/9/12 Reviewed by: G. Corcoran Date: 12/18/12

Client: EF Project: Cells 5A and 5B Project No.: SC0634 Task No.: 02

z (ft)	z/B	I	σz=I*P (ksf)	Es (ksf)	ΔH (ft)	S (in)
600	0.60	0.70	4.41	31,320	100	0.169
700	0.70	0.66	4.16	31,320	100	0.159
800	0.80	0.61	3.84	31,320	100	0.147
900	0.90	0.58	3.66	31,320	100	0.140
1000	1.00	0.53	3.34	31,320	100	0.128
1100	1.10	0.50	3.15	31,320	100	0.121
1200	1.20	0.49	3.09	31,320	100	0.118
1300	1.30	0.44	2.77	31,320	100	0.106
1400	1.40	0.40	2.52	31,320	100	0.097
1500	1.50	0.39	2.46	31,320	100	0.094
1600	1.60	0.37	2.33	31,320	100	0.089
1700	1.70	0.35	2.21	31,320	100	0.085
1800	1.80	0.34	2.14	31,320	100	0.082
1900	1.90	0.32	2.02	31,320	100	0.077
2000	2.00	0.30	1.89	31,320	100	0.072
2100	2.10	0.29	1.83	31,320	100	0.070
2200	2.20	0.28	1.76	31,320	100	0.068
2300	2.30	0.27	1.70	31,320	100	0.065
2400	2.40	0.26	1.64	31,320	100	0.063
2500	2.50	0.25	1.58	31,320	100	0.060
2600	2.60	0.24	1.51	31,320	100	0.058
					Total	3.130

Settlement under A (S_A), the center of the berm, is **3.13 inches.**

For point B, assume uniform loading (aerial fill) and B = 1000 feet for infinitely long footing, again using Figure 3 on page DM7.1-167 (Attachment D, 2/2). The calculation of settlement for this condition is shown in Table 4.

Table 4. Settlement due to load under the toe of the slope (filled condition)

z (ft)	z/B	I	σz=I*P (ksf)	E_s (ksf)	ΔH (ft)	S (in)
5	0.01	1.00	5.75	31,320	5	0.011
10	0.01	1.00	5.75	31,320	5	0.011
15	0.02	1.00	5.75	31,320	5	0.011
20	0.02	1.00	5.75	31,320	5	0.011
40	0.04	1.00	5.75	31,320	20	0.044

Written by:	R. Flynn	Date:	11/9/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project No.:	SC0634	Task No.:	02

z (ft)	z/B	I	σz=I*P (ksf)	Es (ksf)	ΔH (ft)	S (in)
60	0.06	1.00	5.75	31,320	20	0.044
80	0.08	1.00	5.75	31,320	20	0.044
100	0.10	0.98	5.64	31,320	20	0.043
150	0.15	0.95	5.46	31,320	50	0.105
200	0.20	0.92	5.29	31,320	50	0.101
300	0.30	0.90	5.18	31,320	100	0.198
400	0.40	0.83	4.77	31,320	100	0.183
500	0.50	0.75	4.31	31,320	100	0.165
600	0.60	0.71	4.08	31,320	100	0.156
700	0.70	0.69	3.97	31,320	100	0.152
800	0.80	0.61	3.51	31,320	100	0.134
900	0.90	0.60	3.45	31,320	100	0.132
1000	1.00	0.55	3.16	31,320	100	0.121
1100	1.10	0.52	2.99	31,320	100	0.115
1200	1.20	0.49	2.82	31,320	100	0.108
1300	1.30	0.46	2.65	31,320	100	0.101
1400	1.40	0.41	2.36	31,320	100	0.090
1500	1.50	0.39	2.24	31,320	100	0.086
1600	1.60	0.37	2.13	31,320	100	0.082
1700	1.70	0.35	2.01	31,320	100	0.077
1800	1.80	0.34	1.96	31,320	100	0.075
1900	1.90	0.32	1.84	31,320	100	0.070
2000	2.00	0.31	1.78	31,320	100	0.068
2100	2.10	0.29	1.67	31,320	100	0.064
2200	2.20	0.28	1.61	31,320	100	0.062
2300	2.30	0.27	1.55	31,320	100	0.059
2400	2.40	0.26	1.50	31,320	100	0.057
2500	2.50	0.25	1.44	31,320	100	0.055
2600	2.60	0.24	1.38	31,320	100	0.053
					Total	2.891

Settlement under point B (S_B), the toe of the berm, is **2.89 inches**.

<u>Evaluate for strain</u>

ΔS = 3.13-2.89 = 0.24 inches.

Written by:	**R. Flynn**	Date:	**11/9/12**	Reviewed by:	**G. Corcoran**	Date:	12/18/12
Client:	**EF**	Project:	**Cells 5A and 5B**	Project No.:	**SC0634**	Task No.:	**02**

The liner is $\sqrt{[(92\,ft)^2 + (46\,ft)^2]} = 103\ ft$ in length.

Therefore, the strain in the liner is $\dfrac{0.24\,in}{103\ ft \times \dfrac{12in}{1ft}} = 0.002\%$

REFERENCES

Bowles, Joseph E., *Foundation Analysis and Design, 5th Edition,* Mc-Graw-Hill, 1996.

Holtz, Robert D. and Kovacs, William D., *An Introduction to Geotechnical Engineering,* Prentice- Hall International, 1981.

Navy Design Manual DM-7.1

PEEL Environmental Services, *WMMW-16 Boring and Well Construction Log,* December, 1992.

LEGEND

	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
	EXISTING DIRT ROAD
	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	PROPOSED GRADE BREAK
	LIMIT OF LINER
5570	APPROXIMATE TOP OF ROCK CONTOUR (1') (SEE NOTES 4 AND 5)
21 / 06	SPLASH PAD
TP12-03	EXPLORATORY TRENCH LOCATION
	SEISMIC LINE LOCATIONS (SEE NOTE 4)
⊗	CELL 4B SOIL BORINGS

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BE ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
4. SEISMIC LINE DATA IS PROVIDED IN SECTION 02200 OF THE TECHNICAL SPECIFICATIONS.
5. APPROXIMATE TOP OF ROCK CONTOURS WITH QUESTION MARKS REFER TO CONTOURS THAT WERE ESTIMATED.

Attachment A (2/2)

0 100' 200'
SCALE IN FEET

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc

TITLE: CELL 5B PROPOSED GRADING

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

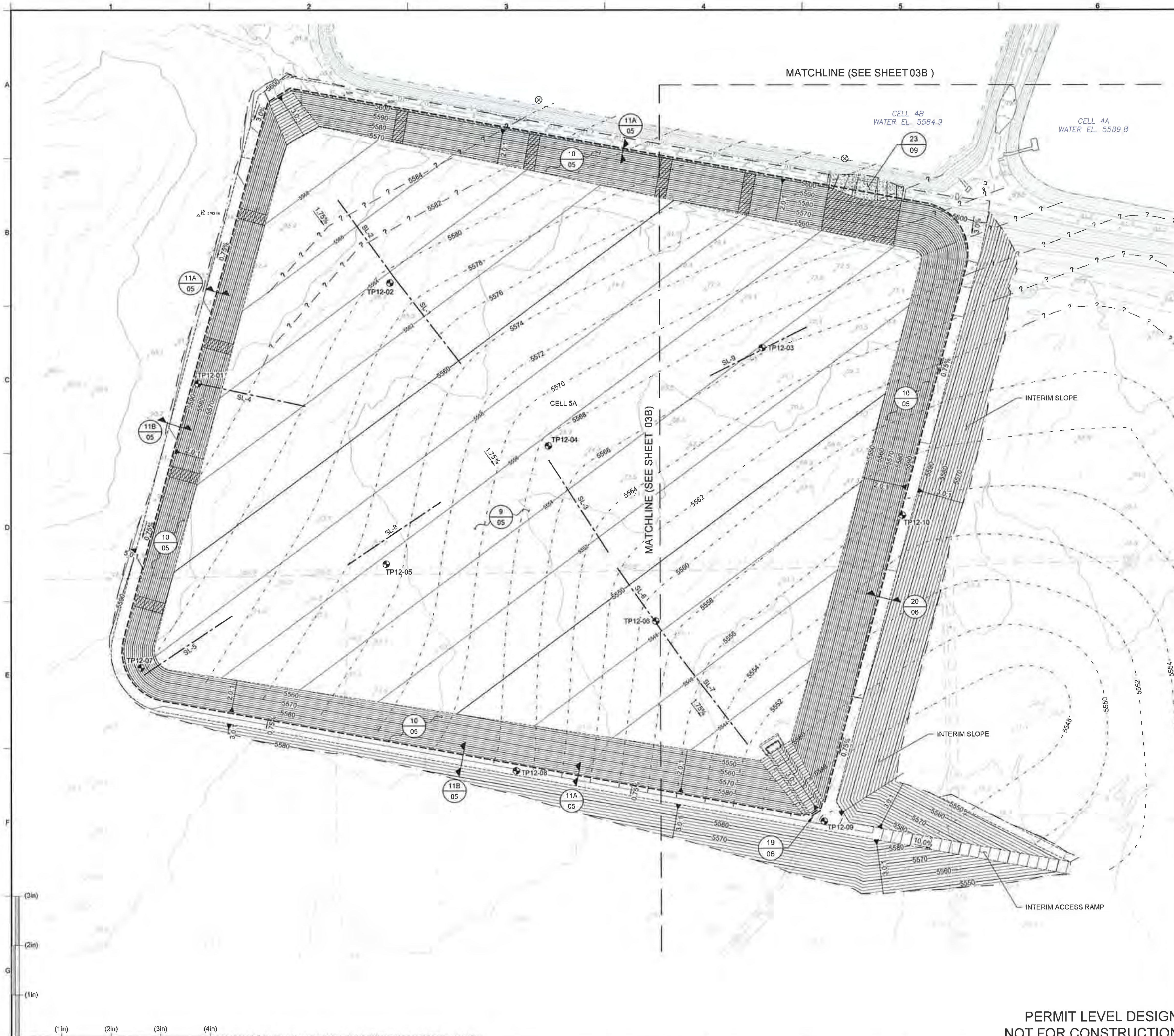
SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION UNLESS SEALED

SIGNATURE

DATE

DESIGN BY	GTC	DATE	JANUARY 2013
DRAWN BY	MMC	PROJECT NO.	SC0634
CHECKED BY	RBF	FILE	SC0634 - 03A-04B
REVIEWED BY	GTC	DRAWING NO.	
APPROVED BY	GTC	03B OF 12	



LEGEND

5610	JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
	EXISTING DIRT ROAD
	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	PROPOSED GRADE BREAK
	LIMIT OF LINER SYSTEM
5570	APPROXIMATE TOP OF ROCK CONTOUR (1') (SEE NOTES 4 AND 5)
	SPLASH PAD 21/06
TP12-03	EXPLORATORY TRENCH LOCATION
	SEISMIC LINE LOCATIONS (SEE NOTE 4)
⊗	CELL 4B SOIL BORINGS

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011 THIS INFORMATION WAS PROVIDED BE ENERGY FUELS RESOURCES (USA) INC
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT
4. SEISMIC LINE DATA IS PROVIDED IN SECTION 02200 OF THE TECHNICAL SPECIFICATIONS
5. APPROXIMATE TOP OF ROCK CONTOURS WITH QUESTION MARKS REFER TO CONTOURS THAT WERE ESTIMATED

ATTACHMENT A (1/2)

0 100' 200'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE 858 674 6559

Energy Fuels Resources (USA) Inc

TITLE: CELL 5A PROPOSED GRADING

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION UNLESS SEALED

SIGNATURE

DATE

DESIGN BY	GTC	DATE	JANUARY 2013
DRAWN BY	MMC	PROJECT NO	SC0634
CHECKED BY	RBF	FILE	SC0634 - 03A-04B
REVIEWED BY	GTC	DRAWING NO	
APPROVED BY	GTC	03A OF 12	

M
F
G
consulting
scientists and
engineers

MFG, Inc.
A TETRA TECH COMPANY
Fort Collins Office
3801 Automation Way, Suite 100
Fort Collins, CO 80525
970.223.9600
Fax: 970.223.7171

July 13, 2006

Tetra Tech EM, Inc.
950 17th Street, 22nd Floor
Denver, Colorado 80202

MFG Project No. 181413x

Attn: Ms. JoAnn Tischler

Subject: Draft
Soil Property Verification and
Slope Stability Analyses
Earthen Embankment between Cells 4A and 4B,
IUC White Mesa Project
Blanding, Utah

Tetra Tech MFG prepared a technical memorandum dated June 7, 2006, and a letter dated June 9, 2006 describing slope stability analyses, assumptions, and recommendations for verification of soil properties for an earthen embankment at the International Uranium (USA) Corporation, White Mesa Project near Blanding, Utah.

On June 15, 2006, Tetra Tech drilled an exploratory boring in the embankment between Cell 4A and Cell 4B at the approximate location shown on Figure 1 (attached). Descriptions of soils encountered in the boring are shown on the Borehole log (also attached). The boring was drilled to a depth of 30 feet and sampled at 5 foot intervals using a 2 inch diameter California sampler driven into the soil by a 140 pound weight dropped 30 inches (a Standard Penetration Test, SPT). Samples were examined by a geotechnical engineer in our soils laboratory. Samples were selected and tested for moisture and density and Atterberg Limits to determine their classification and similarity to properties identified in previous geotechnical reports for the project. A triaxial test was performed to compare the angle of internal friction and cohesion of the in-place soil with the values determined by the original designers in 1981.

The moisture and density of the samples tested are shown in Table 1 below:

Attachment B (1/3)

Table 1. Soil Properties

Depth	Description	Wet Density (pcf)	Dry Density (pcf)	Moisture content (%)
10	Silty sand	136.5	125.0	9.2
20	Silty sand	140.5	126.3	11.3
25	Silty sand	134.7	122.6	9.9
-	Average	137.2	124.6	10.1

Atterberg limits tests indicate a liquid limit of 25, and a Plasticity Index of 13, with 50 percent silt and clay sized particles (passing the number 200 sieve). Triaxial testing indicated an effective angle of internal friction of 26.5 degrees and a drained cohesion of 957.5 psf.

These test results indicate although the samples were visually classified as silty sand, laboratory tests indicate the embankment soils tested are a very sandy clay rather than sand and silty sand as reported by others and assumed in our initial analysis.

We performed additional slope stability analyses using the following soil properties: an average moist unit weight of 137 pcf, an angle of internal friction of 26 degrees, and an effective cohesion of 900 psf. We calculated the minimum factors of safety shown in Table 2.

Table 2. Revised Minimum Factors of Safety

Condition	Calculated Minimum Factor of Safety
Unlined alternative, static, steady state	2.45
Unlined Alternative, 0.1g seismic	1.67
Lined Alternative, static	4.61
Lined Alternative, 0.1g seismic	3.21

Therefore the factors of safety calculated and presented in our June 2 Technical Memorandum are conservative. In fact, analyses using the measured soil properties indicate that the embankment exceeds typical minimum acceptable safety factors even in the event leakage were to occur from the liner and produce a saturated condition as shown in Figure 3 of our previous memorandum.

If you have any questions regarding our analysis, our previous correspondence, or this letter, please contact the undersigned.

Respectfully submitted,

Tetratech MFG, Inc.

Thomas A. Chapel, CPG, PE
Senior Geotechnical Engineer

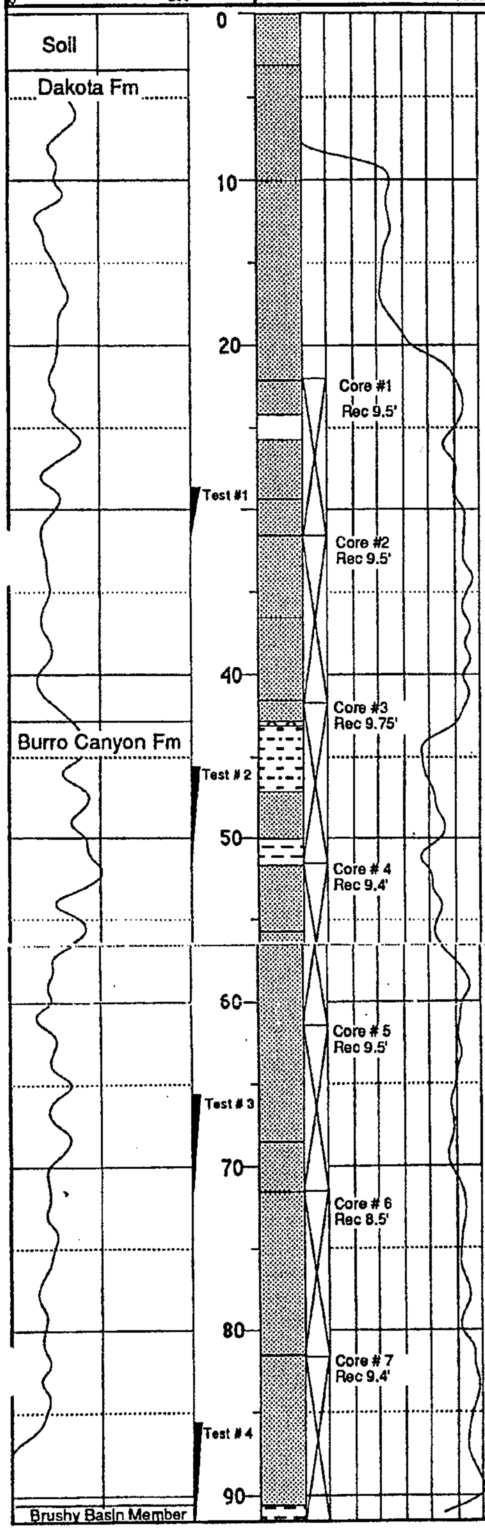
2 copies sent

Attachment B (3/3)

PEEL Environmental Services
Arvada, CO (303)422-5116

Bore Hole No. :	WMMW-16
Project: White Mesa	Surface Elev. 5588.18
T. D. = 91.5	UMETCO Minerals Corporation
Date: 12/07/92	Depth to Water: Dry
Geologist: F. A. Peel	

Gamma (Nat) 0–250	Depth	Graphic Description	Neutron - API 0–7000	Sample Description	Comments	Well Costruction



Sample Description

Sand: quartz,reddish brown,fine-grained subrounded silty.

Sandstone: quartz, reddish brown, very fine grained, subround, silty friable.

Sandstone: quartz, light buff, very fine- to fine-grained, subangular to angular, friable, good inter granular porosity.

Sandstone: quartz, light buff to light gray, very fine- to fine-grained,kaolinitic, massive to thin bedded,trough cross bedding trace porosity.

Claystone: light gray, silty, slightly sandy,thin carbonaceous partings, hard.

Sandstone: quartz, light gray, very fine grained, subrounded, kaolinitic, thin cross bedding, hard.

Sandstone: quartz, light yellow gray, fine to medium grained, subrounded to round kaolinitic, tr iron staining, thin cross bedding.

Sandstone: quartz, light gray, medium to coarse grained, kaolinitic, conglomeratic pebbles are angular lithic fragments.

Sandstone: quartz, light gray, fine to medium grained, subrounded, silty, trace intergranular porosity, occasionally coarse grained, occasional pebble.

Sandstone: quartz, light gray, fine- to medium-grained, subround to rounded,
Conglomerate: Brownish gray, angular to subangular, chert & sandstone clasts,
Siltstone: greenish gray,sandy in part, occasional iron staining.

Sandstone: quartz, light greenish gray, very fine grained silty.

Shale: greenish gray, thinbedded soft, bentonitic.

Sandstone: quartz, light buff to light gray, very fine grained, sub angular, trace intergranular porosity, limonite concreations, trace iron staining.

Sandstone: quartz, light brownish gray, fine grained, thin cross bedding, trace porosity, becomming greenish gray & very fine grained toward base, shale parting at 64'

Sandstone: quartz, light brownish gray, fine grained, well sorted, good intergranular porosity, 1" shale iron stained shale parting at top.

Sandstone: quartz, light gray, grading downward from very fine grained to medium grained, subrounded, layers vell sorted, kaolinitic, conglomeratic in part, trace iron staining.

Sandstone: quartz, light gray, medium grained, subangular to subround, well sorted, kaolinitic, poor to good intergranular porosity, occasional coarse sand grains and pebble conglomerate stringers, trace iron staining.

Shale: dark green, thinbedded, soft.

Comments

1/4" Steel Surface Csg

Cement/Bentonite Grout

4" schedual 40 PVC

K= 9.1E-4 cm/sec

K= 5.1E-5 cm/sec

Centralizer

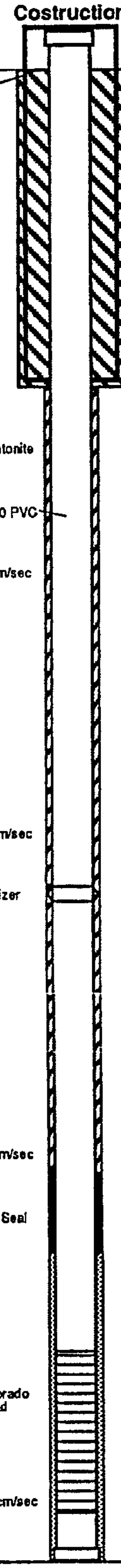
K= 7.8E-5 cm/sec

Bentonite Seal

10-20 Colorado Silica Sand

K= 2.9E-5 cm/sec

Well Dry



Screened Interval

Attachment C (M1)

TABLE 2-8
Value range* for the static stress-strain modulus E_s for selected soils (see also Table 5-6)

Field values depend on stress history, water content, density, and age of deposit

Soil	E_s, MPa
Clay	
Very soft	2–15
Soft	5–25
Medium	15–50
Hard	50–100
Sandy	25–250
Glacial till	
Loose	10–150
Dense	150–720
Very dense	500–1440
Loess	15–60
Sand	
Silty	5–20
Loose	10–25
Dense	50–81
Sand and gravel	
Loose	50–150
Dense	100–200
Shale	150–5000 ← Use 1500 MPa
Silt	2–20

*Value range is too large to use an "average" value for design.

in situ, it is reasonable for confined compression tests to produce better "elastic" parameters. Although it is difficult to compare laboratory and field E_s values, there is some evidence that field values are often four to five times larger than laboratory values from the unconfined compression test. For this reason, current practice tends to try to obtain "field" values from in situ testing whenever possible. This topic will be taken up in more detail in the next chapter.

Table 2-8 gives a range of E_s values that might be obtained. Note that the range is very large, owing to the foregoing factors as well as those factors given on the table. With this wide range of values the reader should not try to use "averaged" values from this table for design.

If laboratory test plots similar to Fig. 2-43*a* are used, it is most common to use the initial tangent modulus to compute the stress-strain modulus E_s for the following reasons:

1. Soil is elastic only near the origin.
2. There is less divergence between all plots in this region.
3. The largest values are obtained—often three to five times larger than a tangent or secant modulus from another point along the curve.

Bowles, Joseph E. Foundation Analysis and Design, 5th Ed., 1996,
Attachment D (1/1)

Definition

n index (Eq. 8-8)
(Eq. 8-15); C_E and C_s are sometimes used
on index
netric modulus (Eq. 8-6)
ratio

a soil layer (Eq. 8-3)
f a soil layer (Eq. 8-3)
8-30)
(Eq. 8-23)
(Eq. 8-20)
width to depth (Eqs. 8-28 and 8-29)
change (Eq. 8-6)
8-25)
8-34)
io (Eq. 8-2)

4)
ss (Eq. 8-27)
om load to a point (Eq.8-24)

ent (Eq. 8-1)
n settlement (Eq. 8-1)
n (Eq. 8-1)
8-1)

ore water pressure

8-
)
33)
ss (Eq. 8-22)
olidation stress
stress or maximum past
(Eq. 8-2); p'_c and σ'_{om}

rburden stress (Eq. 8-2)
z (Eq. 8-22)

MENT

ample by a structure or a otal vertical deformation at *tlement*. The movement may ward (called *swelling*) with a

decrease in load. Temporary construction excavations and permanent excavations such as highway cuts will cause a reduction in the stress, and swelling may result. As shown in Chapter 7, a lowering of the water table will also cause an increase in the effective stresses within the soil, which will lead to settlements. Another important aspect about settlements of especially fine-grained soils is that they are often time-dependent.

In the design of foundations for engineering structures, we are interested in how much settlement will occur and how fast it will occur. Excessive settlement may cause structural as well as other damage, especially if such settlement occurs rapidly. The total settlement, s_t, of a loaded soil has three components, or

$$s_t = s_i + s_c + s_s \tag{8-1}$$

where s_i = the *immediate*, or *distortion*, settlement,
s_c = the *consolidation* (time-dependent) settlement, and
s_s = the *secondary* compression (also time-dependent).

The immediate, or distortion, settlement although not actually elastic is usually estimated by using elastic theory. The equations for this component of settlement are in principle similar to the deformation of a column under an axial load P, where the deformation is equal to PL/AE. In most foundations, however, the loading is usually three dimensional, which causes some distortion of the foundation soils. Problems arise concerning the proper evaluation of a compression modulus and the volume of soil that is stressed. Immediate settlements must be considered in the design of shallow foundations, and procedures for dealing with this problem can be found in textbooks on foundation engineering.

The consolidation settlement is a time-dependent process that occurs in saturated fine-grained soils which have a low coefficient of permeability. The rate of settlement depends on the rate of pore water drainage. Secondary compression, which is also time-dependent, occurs at constant effective stress and with no subsequent changes in pore water pressure. Settlement computations are discussed in this chapter; the time rate of consolidation and secondary compression are discussed in Chapter 9.

8.3 COMPRESSIBILITY OF SOILS

Assume for the time being that the deformations of our compressible soil layer will occur in only one dimension. An example of one-dimensional compression would be the deformation caused by a fill covering a very large area. Later on we shall discuss what happens when a structure of finite size loads the soil and produces deformation.

Holtz, Robert D. and Kovacs, William M., An Introduction to Geotechnical Engineering, 1981.

Attachment E (1/2)

b. Find the vertical stress under the center of the footing at a depth of 2 m.

c. Compare results with Fig. Ex. 8.17a.

Solution:

a. $x = 3$ m
$y = 4$ m
$z = 2$ m: therefore from Eqs. 8-28 and 8-29,

$$m = \frac{x}{z} = \frac{3}{2} = 1.5$$

$$n = \frac{y}{z} = \frac{4}{2} = 2$$

From Fig. 8.21, find $I = 0.223$. From Eq. 8-30,

$$\sigma_z = q_o I$$
$$= 117 \times 0.223$$
$$= 26 \text{ kPa}$$

b. To compute the stress under the center, it is necessary to divide the 3×4 m rectangular footing into four sections of 1.5×2 m in size. Find the stress under one corner and multiply this value by 4 to take into account the four quadrants of the uniformly loaded area. We can do this because, for an elastic material, superposition is valid.

$x = 1.5$ m
$y = 2$ m
$z = 2$ m; then

$$m = \frac{x}{z} = \frac{1.5}{2} = 0.75$$

$$n = \frac{y}{z} = \frac{2}{2} = 1$$

The corresponding value of I from Fig. 8.21 is 0.159. From Eq. 8-30,

$$\sigma_z = 4q_o I = 4 \times 117 \times 0.159 = 74 \text{ kPa}$$

Thus the vertical stress under the center for this case is about three times that under the corner. This seems reasonable since the center is loaded from all sides but under the corner it is not.

c. At a depth of 2 m below the 3×4 m footing, the vertical stress according to the 2:1 theory is 47 kPa (see Fig. Ex. 8.17b). This value represents the *average* stress beneath the footing at -2 m. The average of the corner and center stress by elastic theory is $(26 + 74.2)/2 = 50.1$ kPa.

ATTACHMENTE (2/2)

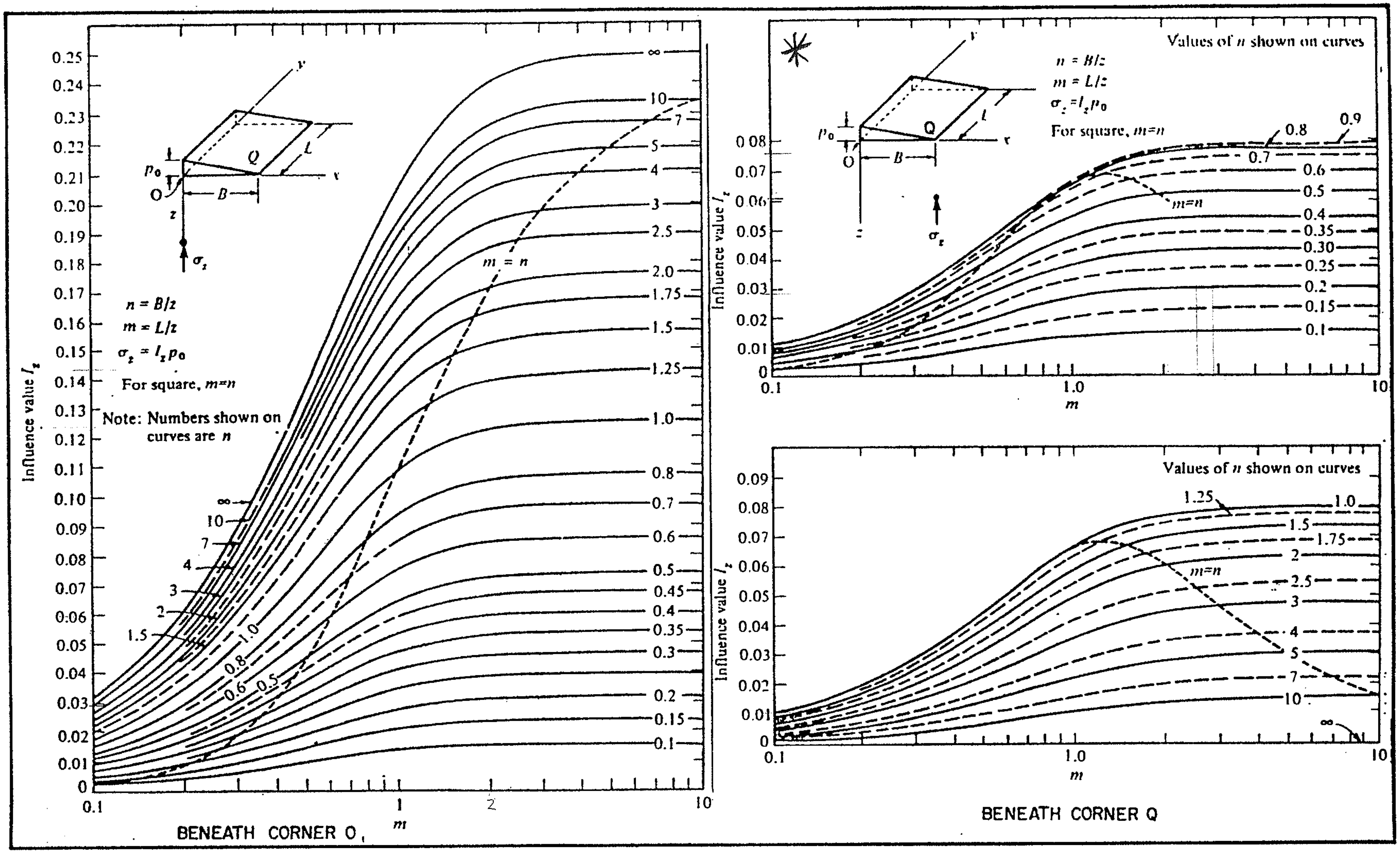
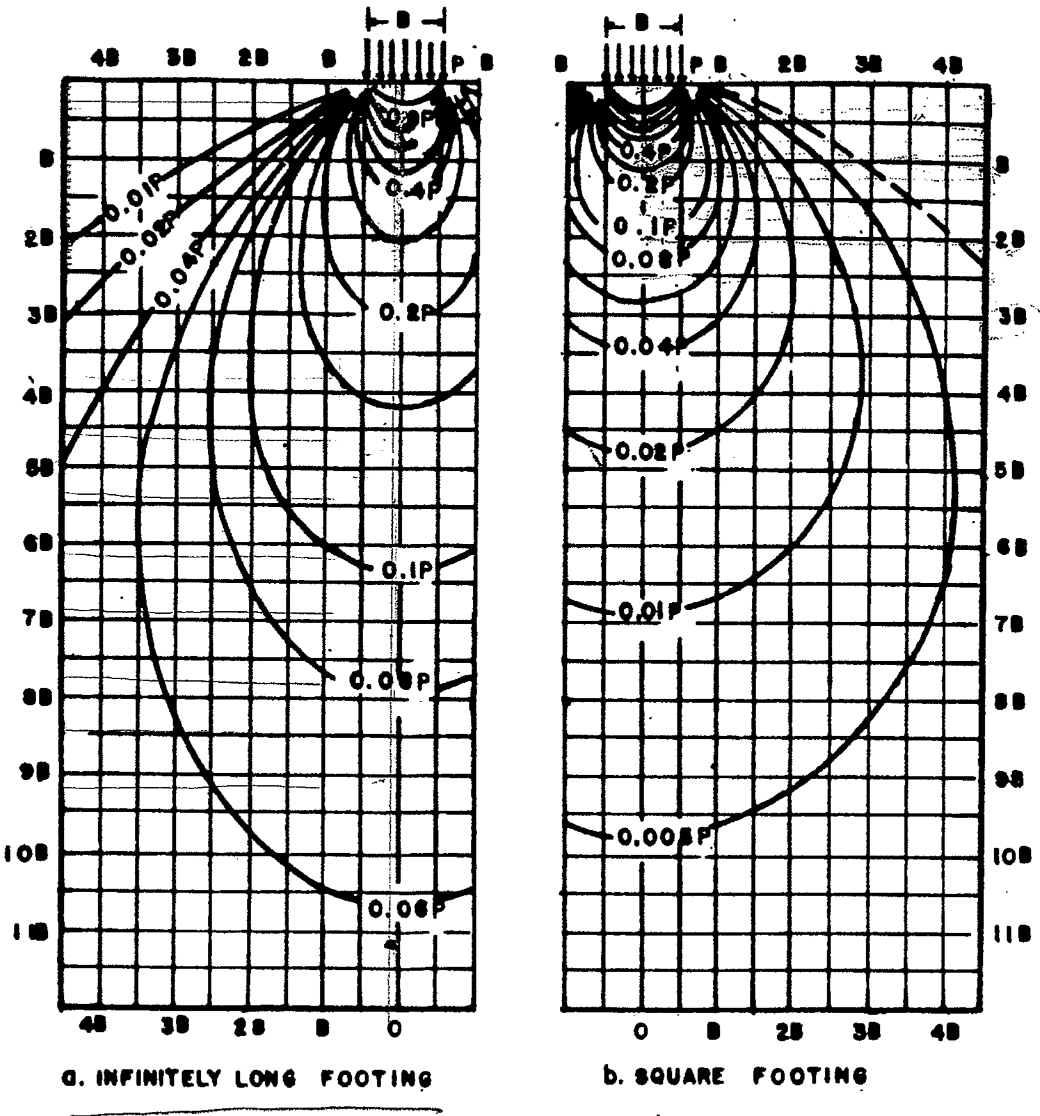


FIGURE 7
Influence Value for Vertical Stress Beneath Triangular Load
(Boussinesq Case)

ATTACHMENT F 1/2



B = 20' P = 2 TSF

SQUARE FOOTING

GIVEN

FOOTING SIZE = 20'X 20'

UNIT PRESSURE P=2TSF

FIND

PROFILE OF STRESS INCREASE BENEATH CENTER OF FOOTING DUE TO APPLIED LOAD

Z (FT)	Z/B	σ_z TSF
10	0.5	0.70 X 2 = 1.4
20	1	0.38 X 2 = 0.76
30	1.5	0.19 X 2 = 0.38
40	2.0	0.12 X 2 = 0.24
50	2.5	0.07 X 2 = 0.14
60	3.0	0.05 X 2 = 0.10

Z/B : 2.5

FIGURE 3
Stress Contours and Their Application

ATTACHMENT F 2/2

Geosyntec consultants

COMPUTATION COVER SHEET

Client:	**Energy Fuels**	Project:	**White Mesa Mill – Cells 5A and 5B**	Project/ Proposal No.:	**SC0634**
				Task No.	**02**

Title of Computations **SLOPE STABILITY ANALYSIS**

Computations by:	Signature		Date 12/18/12
	Printed Name	Jay L. Griffin	
	Title	Senior Staff Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		Date 12/18/12
	Printed Name	Steven M. Fitzwilliam, P.E.	
	Title	Associate Engineer	
Computations Checked by:	Signature		Date 12/18/12
	Printed Name	Steven M. Fitzwilliam, P.E.	
	Title	Associate Engineer	
Computations backchecked by: (originator)	Signature		Date 12/18/12
	Printed Name	Jay L. Griffin	
	Title	Senior Staff Engineer	
Approved by: (pm or designate)	Signature		Date 12/18/12
	Printed Name	Gregory Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	J. Griffin	Date:	11/28/12	Reviewed by:	S. Fitzwilliam	Date:	12/18/12
Client:	Energy Fuels	Project:	White Mesa Mill-Cell 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

SLOPE STABILITY ANALYSES
CELLS 5A AND 5B
WHITE MESA MILL
BLANDING, UTAH

OBJECTIVE

This calculation includes slope stability analyses for the final earthen berms associated with construction of Cells 5A and 5B at the White Mesa Mill facility located in Blanding, Utah. The purpose of the stability analyses is to evaluate final slope stability and operational conditions required to maintain a minimum factor of safety of approximately 1.5 for final berm slope conditions, 1.3 for interim and temporary slope conditions, and 1.1 for seismically-loaded slope conditions based on the proposed design of the cell and its liner system.

METHODOLOGY

Two-dimensional slope stability analyses were performed using the computer program SLOPE/W 2004 (Version 6.22) developed by Geo-Slope International Ltd. (2004). The results of the slope stability analyses are based on the Morgenstern-Price method that satisfies both moment and force equilibrium. The analyzed slopes were kinematically modeled using either circular or linear/circular sliding surfaces.

For each condition analyzed, the program searched for the critical sliding surface that produces the lowest factor of safety using the grid and radius method available in SLOPE/W. Factors of safety are defined as the ratio of the shear forces/moments resisting movement along a sliding surface to the forces/moments driving the instability.

To model the various stability conditions encountered in Cells 5A and 5B before and after filling, three cross-sections were selected for analysis and are shown in Figure 1. The first cross section, Section A-A', is a west-east cross section that models Cell 5A filled with tailings and Cell 5B empty. The section spans Cells 5A and 5B, with berm slopes inclined at approximately 2:1 (Horizontal:Vertical) and a base grade sloping toward the berm at approximately 1 percent. The second cross section, Section B-B', is a north-south cross section that models Cell 5A before filling and spans the berm separating the southern portion of existing Cell 4B and Cell 5A. Section B-B' was modeled with Cell 4B full of tailings and Cell 5A empty. Both sections were modeled without a liner on the empty cell in order to evaluate berm stability. The third cross section, Section C-C' is a north-south cross section that spans the embankment on the south side of Cell 5A. Section C-C' is modeled with Cell 5A filled with tailings. The embankment back slope is inclined at 3:1.

Sections A-A', B-B', and C-C' were modeled for four conditions. These four conditions included static analyses, pseudo-static evaluation of the seismic loading conditions, interim construction loading, and evaluation of the yield acceleration.

Pseudo-static evaluations for slope stability were performed for a seismic acceleration of 0.1g in accordance with the Cell 4 Design Report (UMETCO, 1988) as referenced by MFG, Inc. in a letter to International Uranium Corporation (presently Energy Fuels) dated 27 November 2006.

Interim loading was considered for the four cross sections from construction and maintenance vehicle traffic on the access roads and haul roads on top of the embankment berms. AASHTO H 20 loading was assumed for the interim construction and maintenance vehicle loading (Attachment A). Two 16-kip loads were applied 6-feet apart to model a vehicle traveling along the top of the berm. The first load was applied 2-feet from the top of the slope.

Cells 5A and 5B will be constructed with the following liner system on the bottom area (from top to bottom):

- Slimes Drain System;
- 60 mil smooth HDPE geomembrane;
- 300 mil geonet
- 60 mil smooth HDPE geomembrane;
- 60 mil HDPE Drain Liner™; and
- Prepared Subgrade.

Cells 5A and 5B will be constructed with the following liner system on the side slope areas (from top to bottom):

- 60 mil smooth HDPE geomembrane;

Written by:	J. Griffin	Date:	11/28/12	Reviewed by:	S. Fitzwilliam	Date:	12/18/12
Client:	Energy Fuels	Project:	White Mesa Mill-Cell 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

- 60 mil HDPE Drain Liner™;
- 60 mil HDPE Drain Liner™; and
- Prepared Subgrade.

During operations, tailings/waste deposits are expected to be pumped into the cells below the water surface where the tailings will settle out creating a gradual build-up of solids along the base of the cell. Generally, the tailings will be pumped into the cells from north to south, beginning at splash pads located along the northern slopes of the cells. We have assumed that the tailings will extend up to the top of the berm. In the modeling, the phreatic surface (water surface) is assumed to apply to only the waste and liner materials, since the composite liner system minimizes infiltration of liquids into the underlying subgrade/foundation. The phreatic surface is set at elevation 5585, which is three feet below the top of the south berm. Groundwater at the site is reportedly greater than 50 feet below the ground surface.

MATERIAL PARAMETERS

Based on existing operations at the site, tailings/waste deposits are anticipated to be primarily fine sands with silt and some clay (Attachment B). We have estimated a total unit weight of 125 pounds per cubic foot (pcf) for this material based on Table 6 from the Naval Design Manual for Soil Mechanics DM7-01, (Attachment C). The value selected is based on the minimum wet weight (under loose placement to simulate the tailings settling underwater) for a similar type of material. Based on Figure 3.7 (Attachment D) for a 0% relative density silty sand, a friction angle of 26 degrees could be expected. We have conservatively estimated a friction angle of 25 degrees, with no cohesion, for these materials.

Laboratory interface friction testing for the proposed liner system resulted in a friction angle of 11 degrees for the base liner (smooth geomembrane to geonet) and 15 degrees for the side slope liner (Drain Liner™ to smooth geomembrane) (Attachment G). A unit weight of 90 pcf and a cohesion of 0 are used with the friction angles of 15 and 11 degrees to model the liner system.

Geosyntec reviewed previous geotechnical investigations for the site performed by others, including a memorandum from MFG, Inc. (MFG) dated 13 June 2006 and a follow-up letter dated 7 July 2006 (Attachments E and F). MFGs follow-up letter described their geotechnical investigation at the site, which included an exploratory boring through the existing berm between Cell 4A and 4B and a triaxial compression test on the recovered soil samples. Based on material parameters selected for the design of Cell 4B (Geosyntec, 2009), our field investigation for the design of Cells 5A and 5B, and our review of previous geotechnical investigations, we have selected material properties for the fill material in the berm that are consistent with the properties used previous slope stability analyses (unit weight = 137 pcf, friction angle = 26°, cohesion = 900 psf). As the embankment fill material will be derived from on-site soil, similar to the embankment between Cell 4A and 4B, the same berm material properties were used for the embankment fills associated with Cells 5A and 5B.

The foundation material (Dakota Sandstone) is modeled as bedrock within the SLOPE/W (i.e., impenetrable) to force slip surfaces to occur within the earth fill portion of the berms.

The following table summarizes the material parameters used for slope stability analysis. These parameters are generally consistent with the parameters used in slope stability analysis for the design of Cell 4B.

Material	Unit Weight (pcf)	Friction Angle (degrees)	Cohesion (psf)
Tailings	125	25	0
Liner	90	15 (side) 11 (base)	0
Berm	137	26	900
Dakota Sandstone	Impenetrable Bedrock		

SLOPE STABILITY RESULTS/RECOMMENDATIONS

As discussed above, four cross-sections were analyzed which represent critical conditions for Cells 5A and 5B.

Numerous potential failure surfaces were performed to evaluate various slip surface geometries and to identify the critical slip surface for each cross-section and conditions. The results of the slope stability analyses for Cross Sections A-A', B-B', and C-C' are presented in Table 1. Table 1 also presents the results of interim stability analysis for

Written by:	J. Griffin	Date:	11/28/12	Reviewed by:	S. Fitzwilliam	Date:	12/18/12
Client:	Energy Fuels	Project:	White Mesa Mill-Cell 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

The slope stability analysis results are presented as Figures 2 through 14. Slope stability analysis for interim loading conditions from construction and maintenance vehicles was evaluated for deep-seated failure surfaces. Temporary wheel loading at the top of the embankment may results in surficial failures; however this condition is considered a maintenance issue and not a global stability concern.

For the cross sections evaluated to assess the yield acceleration of the slope, the critical failure surface tends to recede from the slope face with respect to the static analyses for the cross section. For these conditions the computer program was allowed to search for the critical failure surface with the lowest factor of safety provided that the base of the failure surface remained within the berm. If allowed to search for the critical failure surface with the absolute lowest factor of safety for the cross sections analyzed, the critical failure surface would extend down onto the liner of the adjacent cell. As this is not a kinematically feasible condition for the cross sections analyzed in these analyses, the base of the critical failure surface was fixed to remain within the berm to evaluate the yield acceleration of the slopes.

These results indicate the minimum factors of safety are met during and after filling operations for Cells 5A and 5B. We recommend that operations at the site limit the tailings/waste deposits slopes to inclinations of 7:1 or flatter.

Written by:	**J. Griffin**	Date:	**11/28/12**	Reviewed by:	**S. Fitzwilliam**	Date:	12/18/12
Client:	**Energy Fuels**	Project:	**White Mesa Mill-Cell 5A and 5B**	Project/ Proposal No.:	**SC0634**	Task No.:	**02**

REFERENCES

GeoSlope International, LTD (2004) SLOPE/W Version 6.17.

Geosyntec Consultants, 2009. "Round 1 – Interrogatory Response for the Cell 4B Design Report, White Mesa Mill, Blanding, Utah," dated January 2009.

MFG, Inc. 2006. "Technical Memorandum: White Mesa Stability Analysis," dated 7 June 2006.

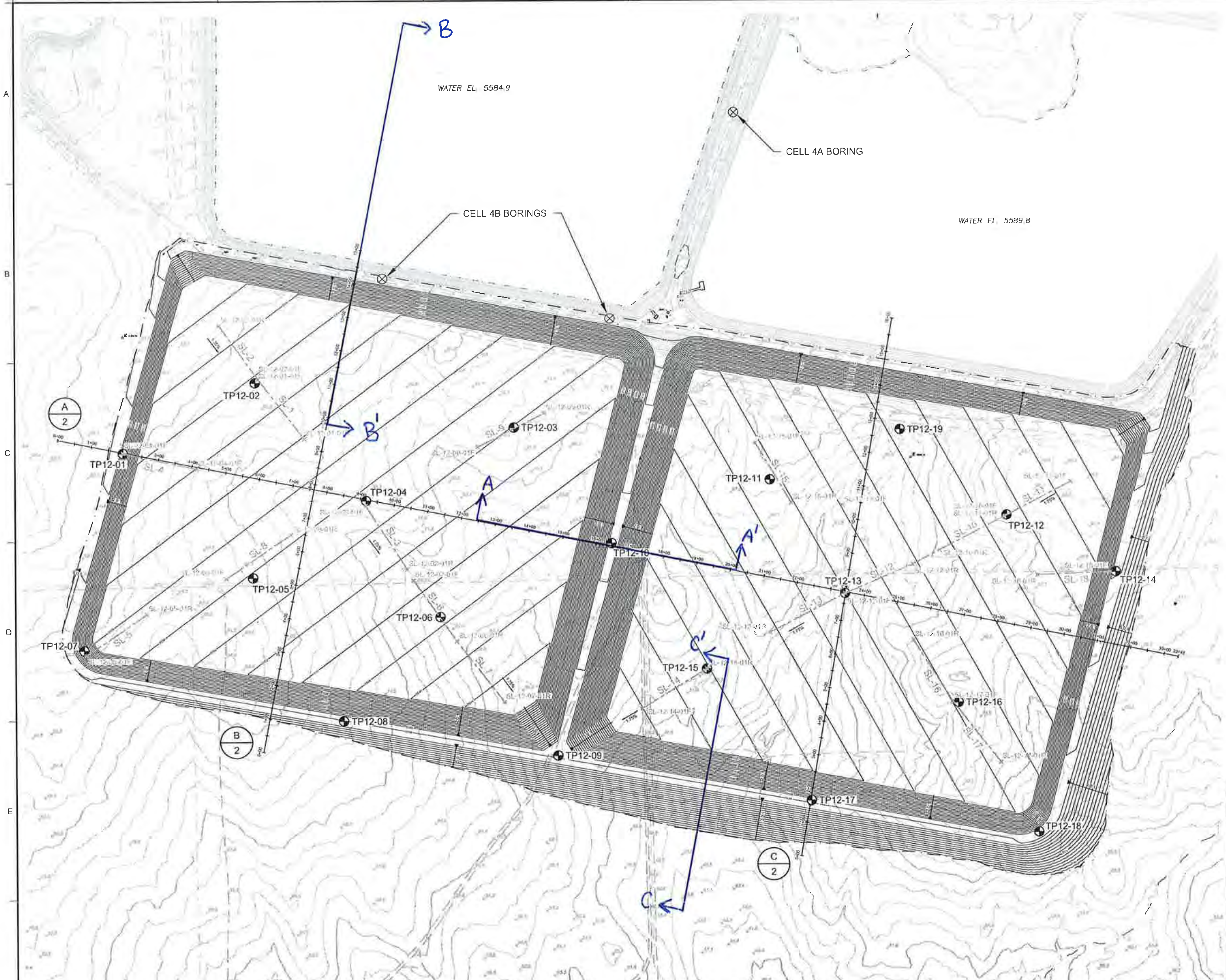
MFG, Inc. 2006. "Draft, Soil Property Verification and Slope Stability Analyses, Earthen Embankment between Cells 4A and 4B, IUC White Mesa Project, Blanding, Utah," dated 13 July 2006.

MFG, Inc. 2006. "White Mesa Uranium Facility, Cell 4 Seismic Study, Blanding, Utah," dated 27 November 2006.

TABLE 1
SUMMARY OF SLOPE STABILITY ANALYSES
Energy Fuels - White Mesa Mill, Cells 5A & 5B
Blanding, Utah

Cross Section	Loading Condition	Cell Condition	Yield Acceleration	Minimum Factor of Safety	Calculated Factor of Safety
A-A'	Static	Cell 5A filled with tailings; Cell 5B empty	--	1.5	3.2
	Seismic Loading (0.1g)		--	1.3	2.6
	Construction Loading		--	1.1	2.0
	Yield Acceleration		0.65	1.0	1.0
B-B'	Static	Cell 4B filled with tailings; Cell 5A empty	--	1.5	3.2
	Seismic Loading (0.1g)		--	1.3	2.6
	Construction Loading		--	1.1	2.1
	Yield Acceleration		0.66	1.0	1.0
C-C'	Static	Cell 5B filled with tailings	--	1.5	3.4
	Seismic Loading (0.1g)		--	1.3	2.5
	Construction Loading		--	1.1	2.8
	Yield Acceleration		0.51	1.0	1.0
Tailings Slope	Interim Tailings Slope	Cell 4B filled with tailings; Cell 5A partially full	--	1.3	1.3

Geosyntec consultants



LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- PROPOSED GRADING MAJOR CONTOUR (10')
- PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- AS-BUILT TRENCH LOCATION
- AS-BUILT SEISMIC LINES

PRELIMINARY VOLUME REPORT

JUNE 2011 EXISTING SURFACE VS. REVISED CELL 5A PROPOSED GRADING:

CUT = 1,228,929 CUBIC YARDS

FILL = 196,323 CUBIC YARDS

NET = 1,032,606 CUBIC YARDS <CUT>

JUNE 2011 EXISTING SURFACE VS. REVISED CELL 5B PROPOSED GRADING

CUT = 704,105 CUBIC YARDS

FILL = 240,573 CUBIC YARDS

NET = 463,532 CUBIC YARDS <CUT>

0 150' 300'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858.674.6559

ENERGY FUELS INC.
6425 S. HIGHWAY 191
P.O. BOX 809
BLANDING, UTAH 84511
PHONE: 858.674.6559

TITLE: CELL 5A AND 5B PROPOSED GRADING

PROJECT: CELL 5A AND 5B PRELIMINARY CELL DESIGN

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	GTC	DATE:	OCTOBER 2012
DRAWN BY:	MMC	PROJECT NO.:	SC0349
CHECKED BY:	GTC	FILE:	
REVIEWED BY:	GTC	FIGURE NO.:	
APPROVED BY:	GTC	1 OF 2	

FIGURE 1

PRELIMINARY DESIGN DRAWINGS
NOT FOR CONSTRUCTION

P:\PRJ\SDCadd\CADD\SC0349\SC0349-07-01\Working\10-2-12 CELL 5A & 5B REVISED GRADING.dwg

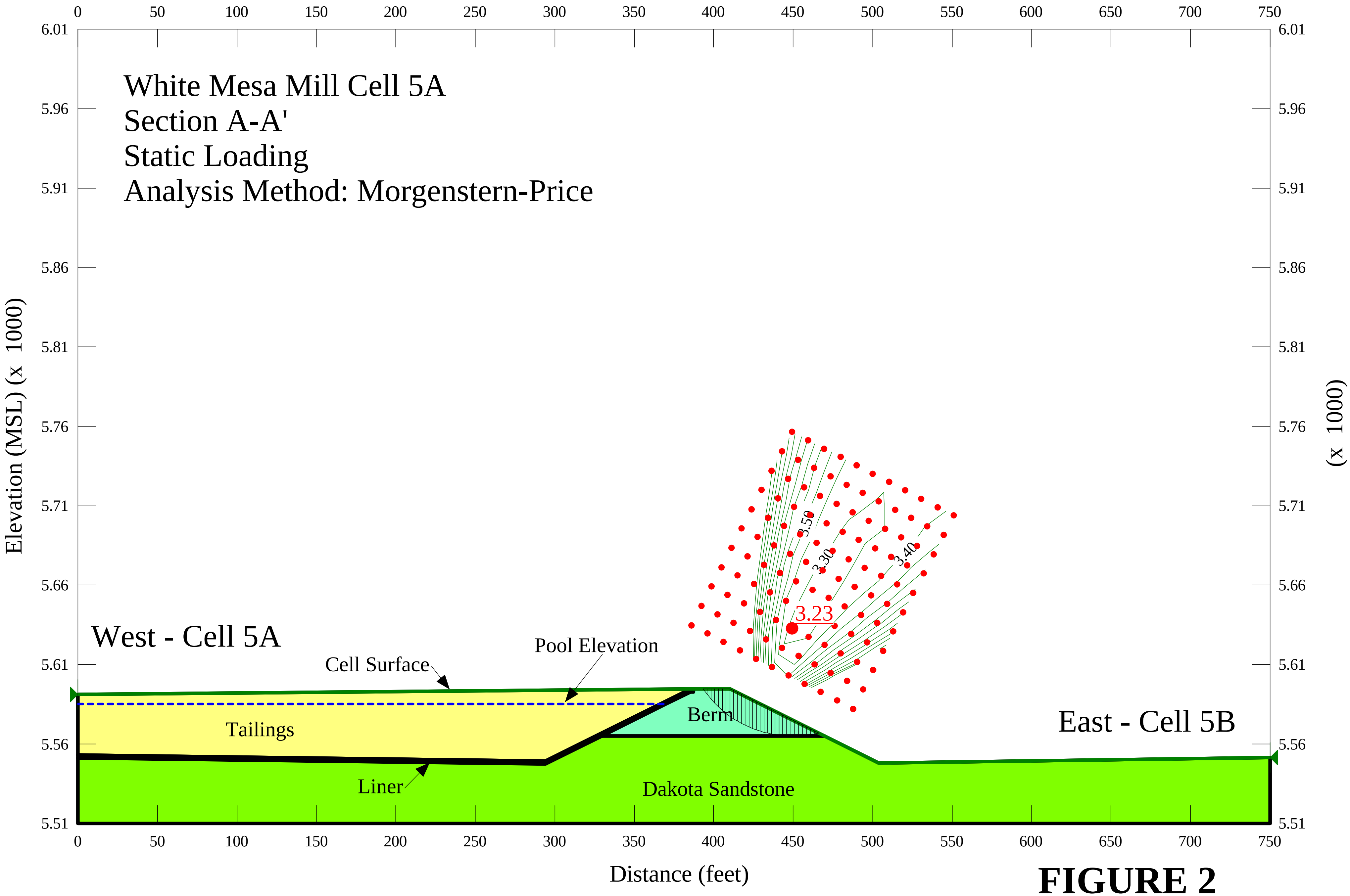
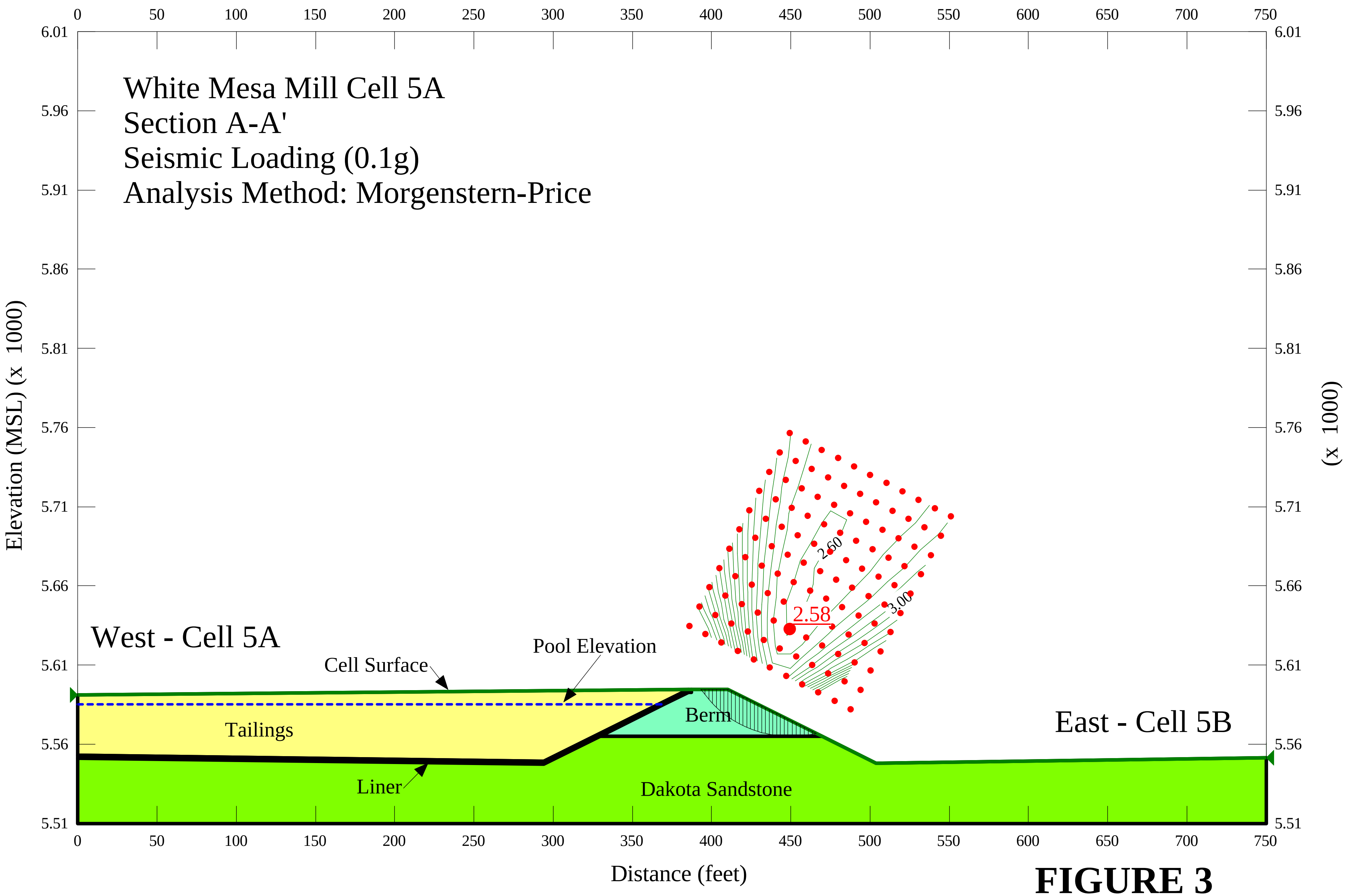
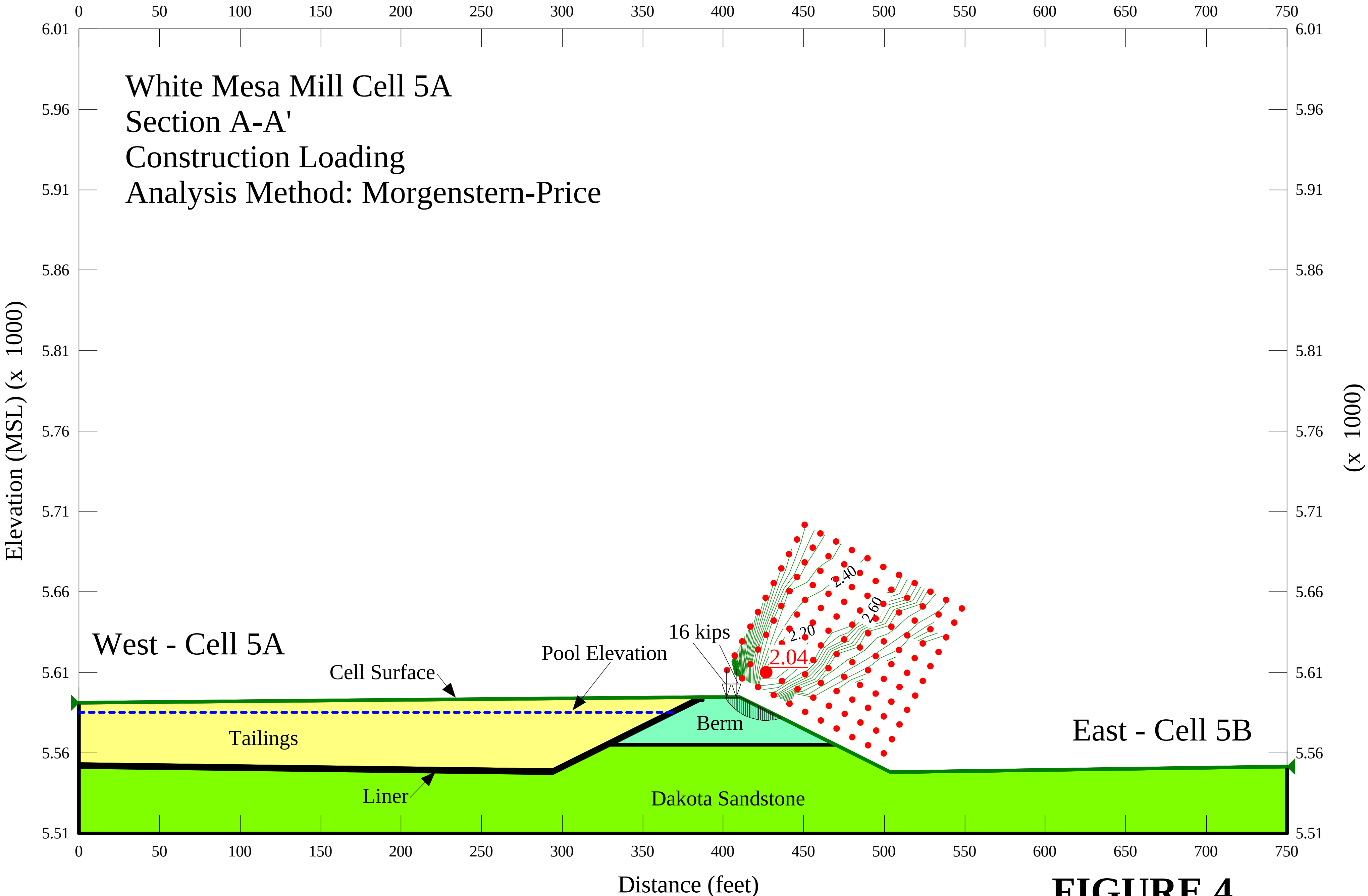

White Mesa Mill Cell 5A
Section A-A'
Static Loading
Analysis Method: Morgenstern-Price
West - Cell 5A
East - Cell 5B
Cell Surface
Pool Elevation
Tailings
Berm
Liner
Dakota Sandstone
3.23
3.50
3.30
3.40
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.01
5.96
5.91
5.86
5.81
5.76
5.71
5.66
5.61
5.56
5.51

FIGURE 2



White Mesa Mill Cell 5A
Section A-A'
Seismic Loading (0.1g)
Analysis Method: Morgenstern-Price
West - Cell 5A
East - Cell 5B
Cell Surface
Pool Elevation
Tailings
Berm
Liner
Dakota Sandstone
2.58
2.60
3.00
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.01
5.96
5.91
5.86
5.81
5.76
5.71
5.66
5.61
5.56
5.51

FIGURE 3



White Mesa Mill Cell 5A
Section A-A'
Construction Loading
Analysis Method: Morgenstern-Price
West - Cell 5A
East - Cell 5B
Cell Surface
Pool Elevation
16 kips
2.04
2.20
2.40
2.60
Berm
Tailings
Liner
Dakota Sandstone
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.01
5.96
5.91
5.86
5.81
5.76
5.71
5.66
5.61
5.56
5.51

FIGURE 4

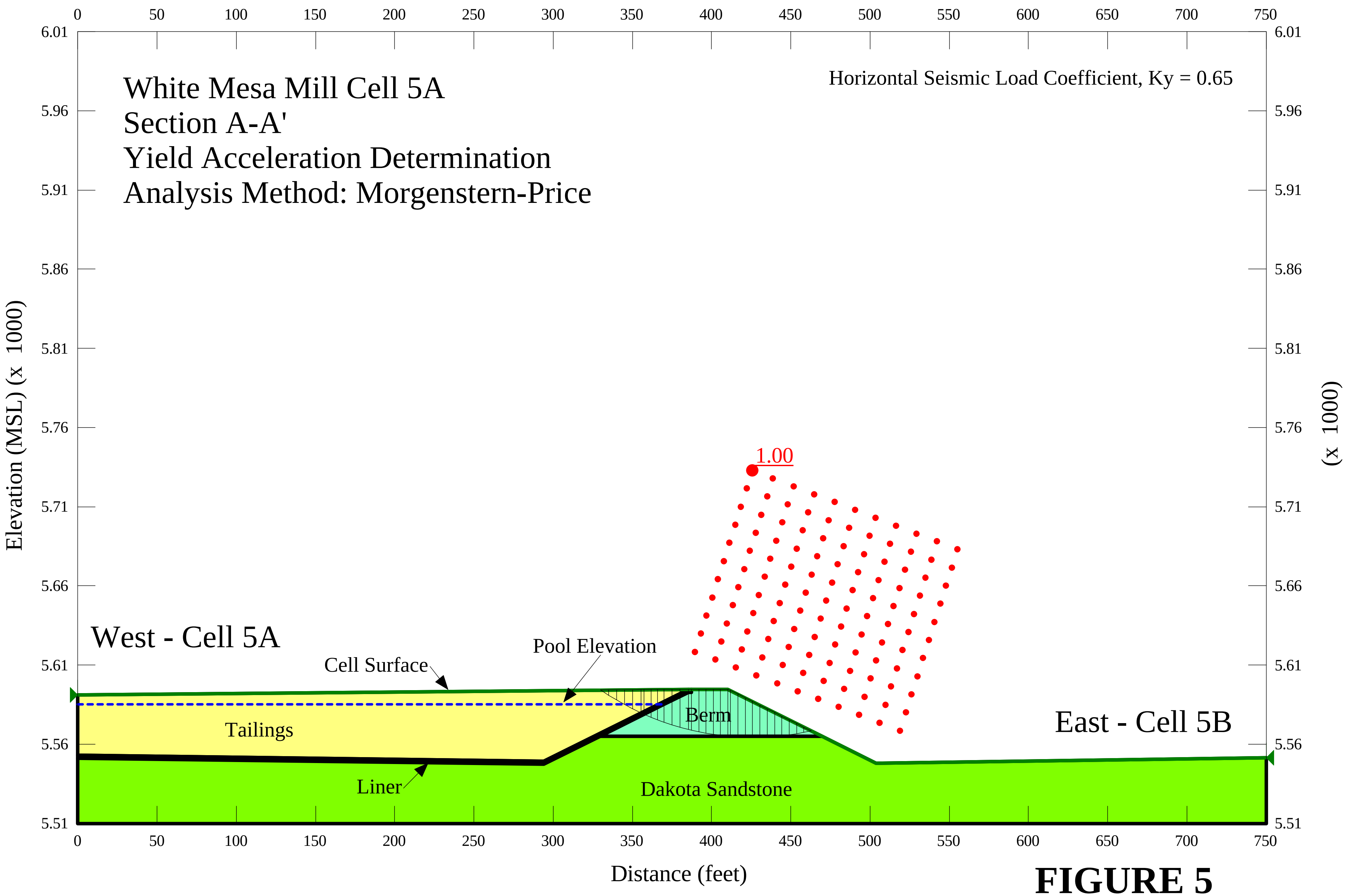
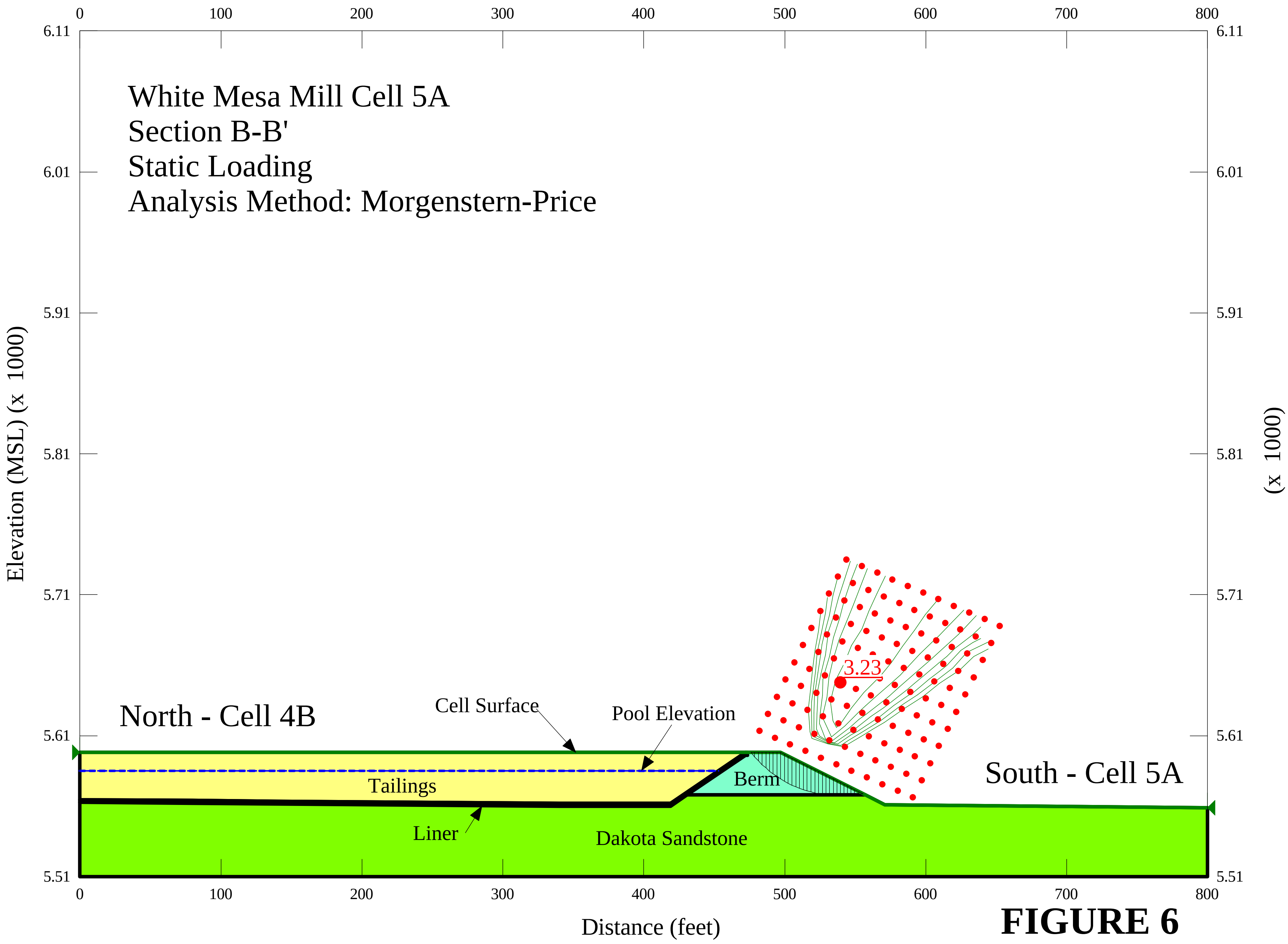

White Mesa Mill Cell 5A
Section A-A'
Yield Acceleration Determination
Analysis Method: Morgenstern-Price
Horizontal Seismic Load Coefficient, Ky = 0.65
1.00
West - Cell 5A
East - Cell 5B
Cell Surface
Pool Elevation
Tailings
Berm
Liner
Dakota Sandstone
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.01
5.96
5.91
5.86
5.81
5.76
5.71
5.66
5.61
5.56
5.51

FIGURE 5



White Mesa Mill Cell 5A
Section B-B'
Static Loading
Analysis Method: Morgenstern-Price
North - Cell 4B
South - Cell 5A
Cell Surface
Pool Elevation
Berm
Tailings
Liner
Dakota Sandstone
3.23
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
100
200
300
400
500
600
700
800
6.11
6.01
5.91
5.81
5.71
5.61
5.51

FIGURE 6

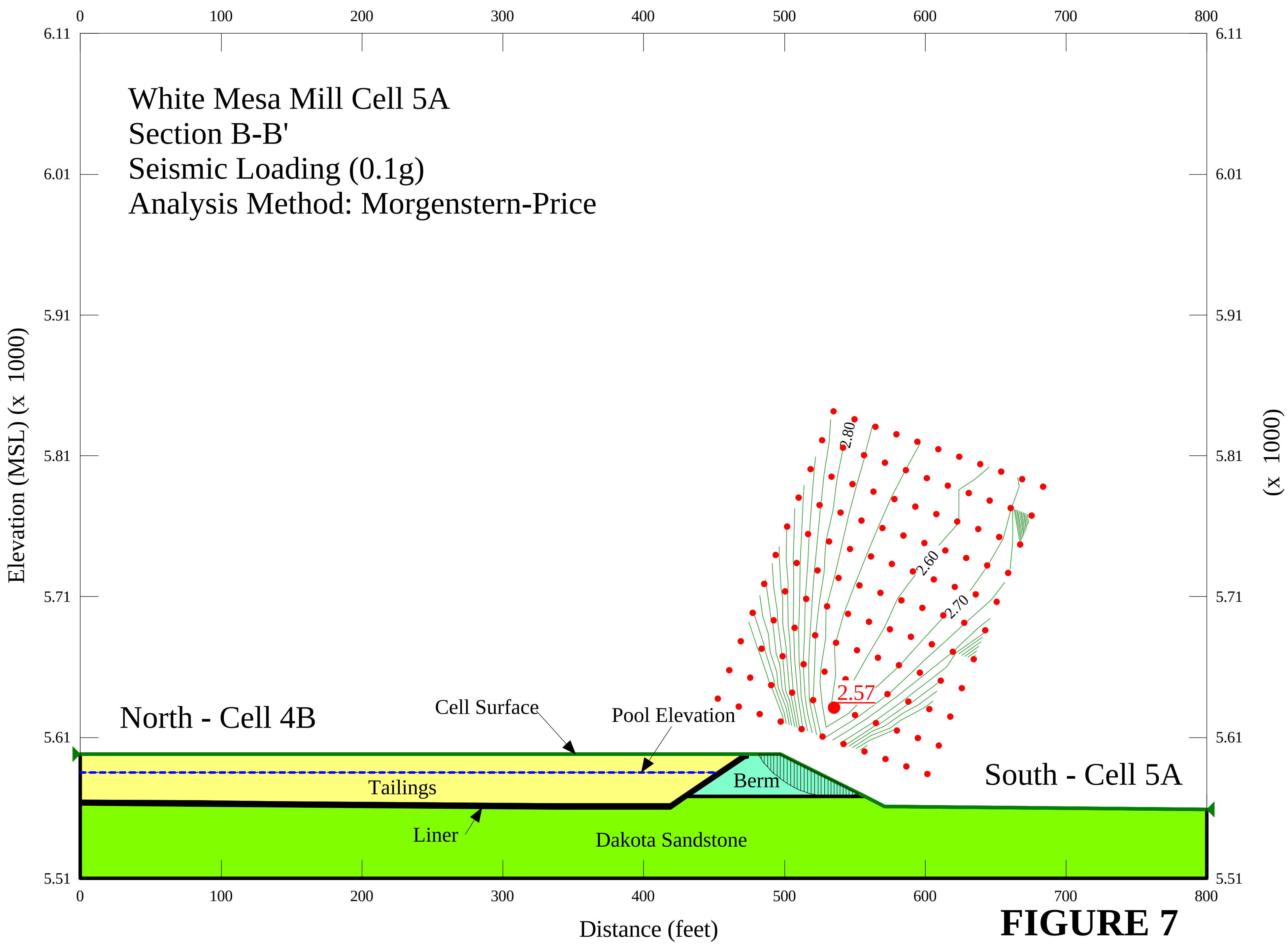
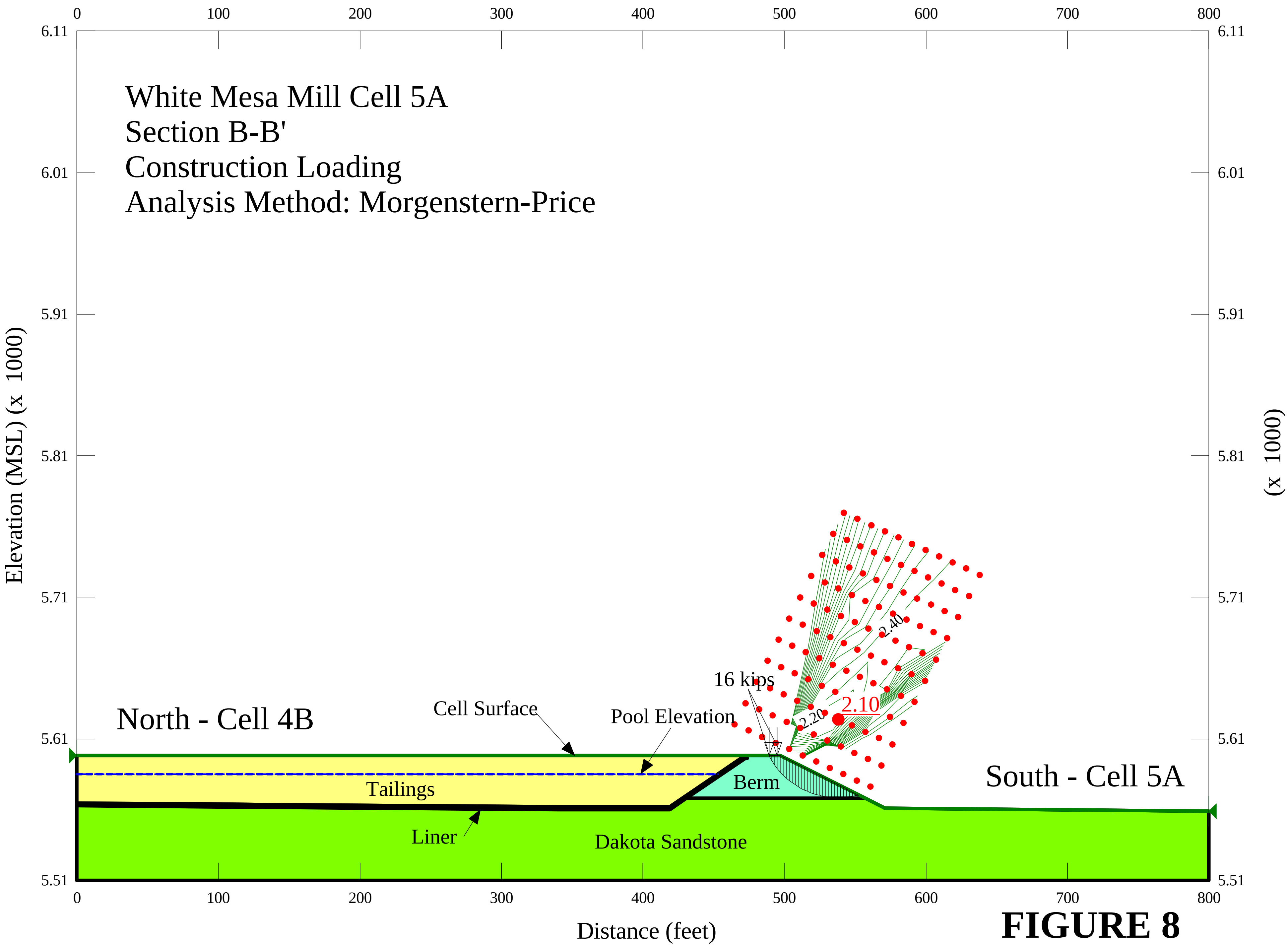
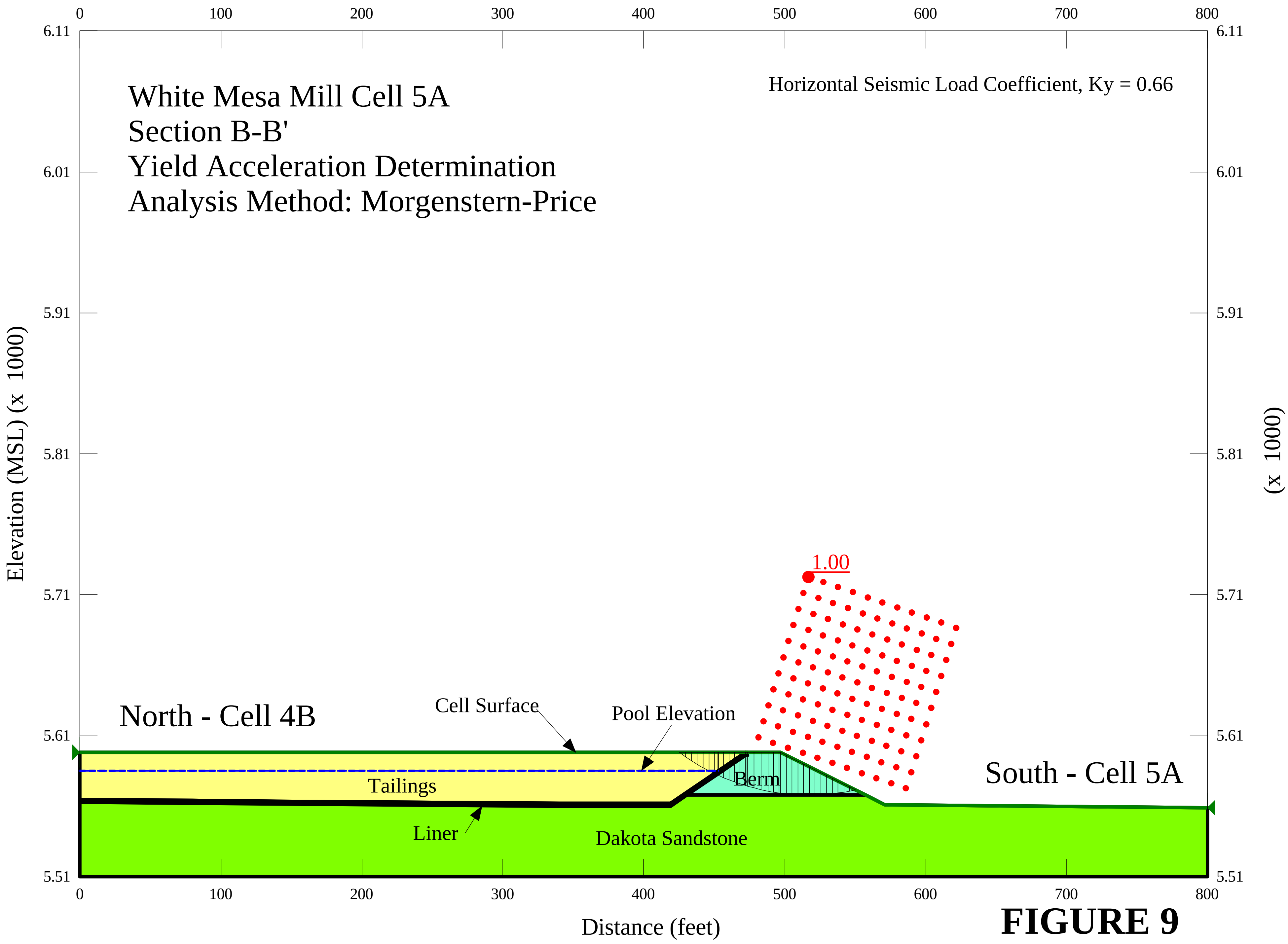

White Mesa Mill Cell 5A
Section B-B'
Seismic Loading (0.1g)
Analysis Method: Morgenstern-Price
North - Cell 4B
South - Cell 5A
Cell Surface
Pool Elevation
Tailings
Berm
Liner
Dakota Sandstone
2.57
2.60
2.70
2.80
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
100
200
300
400
500
600
700
800
6.11
6.01
5.91
5.81
5.71
5.61
5.51

FIGURE 7



White Mesa Mill Cell 5A
Section B-B'
Construction Loading
Analysis Method: Morgenstern-Price
North - Cell 4B
South - Cell 5A
Cell Surface
Pool Elevation
16 kips
2.10
2.20
2.40
Tailings
Berm
Liner
Dakota Sandstone
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
100
200
300
400
500
600
700
800
6.11
6.01
5.91
5.81
5.71
5.61
5.51

FIGURE 8



White Mesa Mill Cell 5A
Section B-B'
Yield Acceleration Determination
Analysis Method: Morgenstern-Price
Horizontal Seismic Load Coefficient, Ky = 0.66
1.00
North - Cell 4B
South - Cell 5A
Cell Surface
Pool Elevation
Berm
Tailings
Liner
Dakota Sandstone
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
100
200
300
400
500
600
700
800
6.11
6.01
5.91
5.81
5.71
5.61
5.51

FIGURE 9

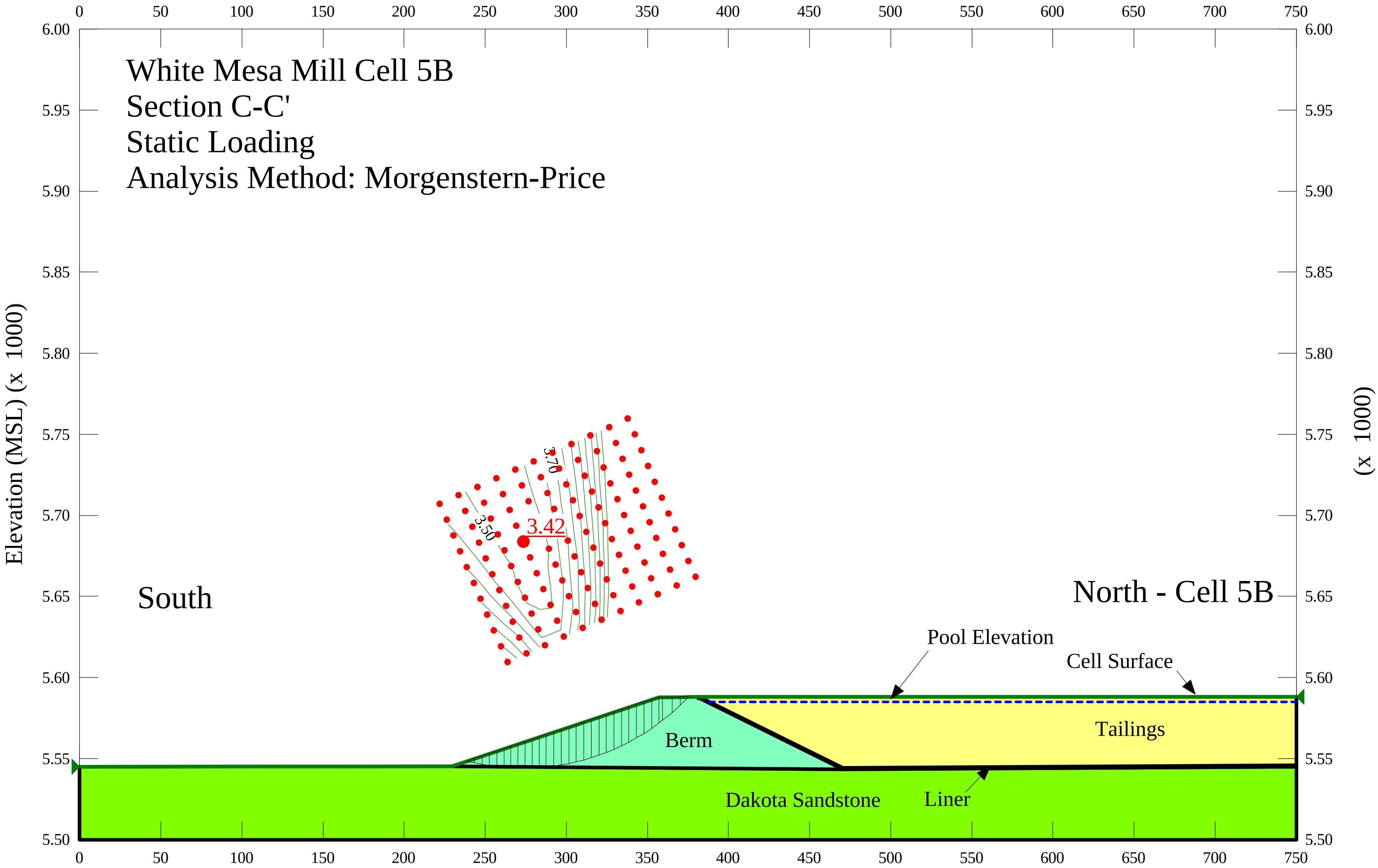

White Mesa Mill Cell 5B
Section C-C'
Static Loading
Analysis Method: Morgenstern-Price
South
North - Cell 5B
3.70
3.50
3.42
Pool Elevation
Cell Surface
Tailings
Berm
Dakota Sandstone
Liner
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.00
5.95
5.90
5.85
5.80
5.75
5.70
5.65
5.60
5.55
5.50

FIGURE 10

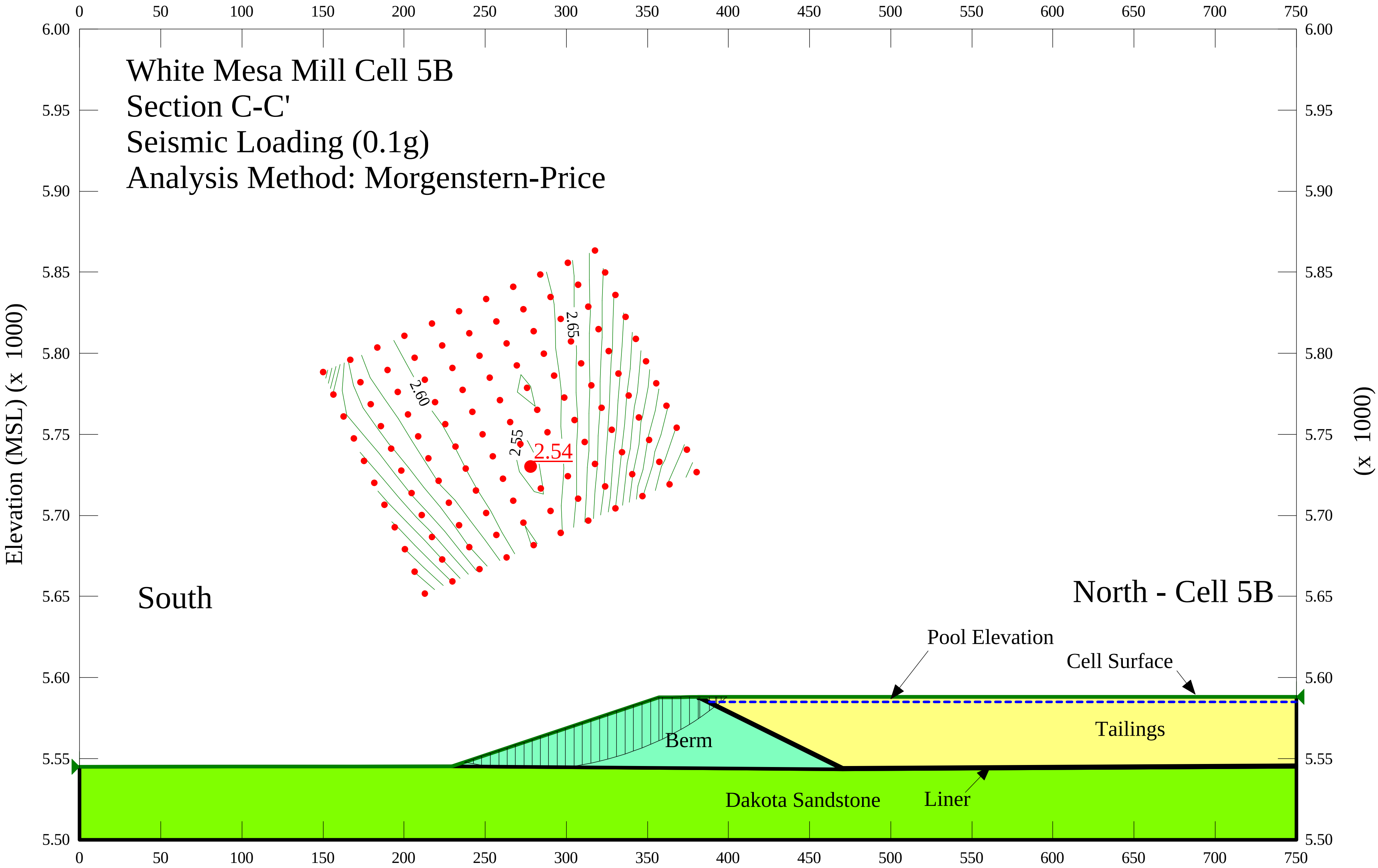

White Mesa Mill Cell 5B
Section C-C'
Seismic Loading (0.1g)
Analysis Method: Morgenstern-Price
2.65
2.60
2.55
2.54
South
North - Cell 5B
Pool Elevation
Cell Surface
Tailings
Berm
Dakota Sandstone
Liner
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.00
5.95
5.90
5.85
5.80
5.75
5.70
5.65
5.60
5.55
5.50

FIGURE 11

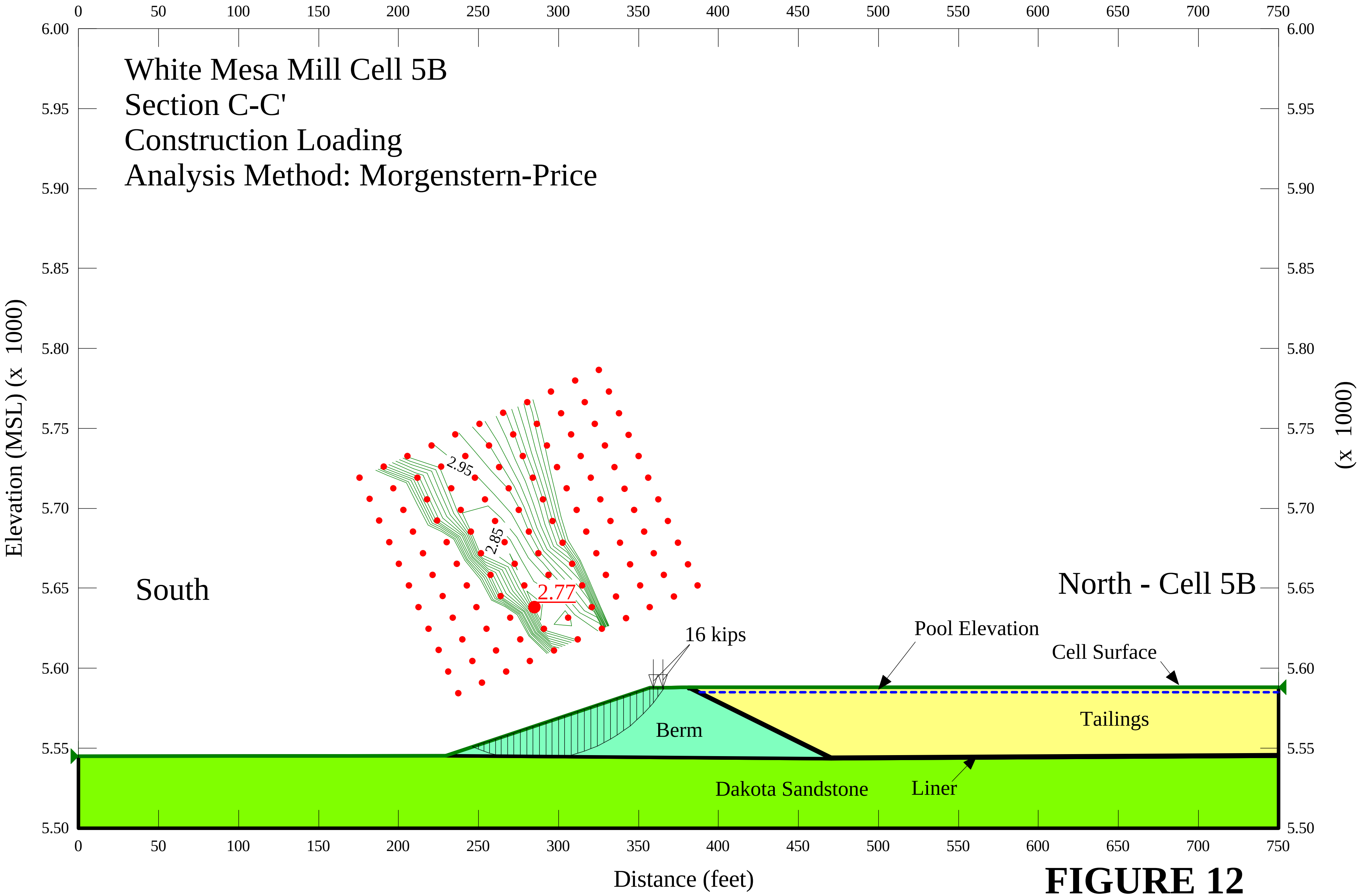

White Mesa Mill Cell 5B
Section C-C'
Construction Loading
Analysis Method: Morgenstern-Price
South
North - Cell 5B
2.95
2.85
2.77
16 kips
Pool Elevation
Cell Surface
Berm
Tailings
Dakota Sandstone
Liner
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.00
5.95
5.90
5.85
5.80
5.75
5.70
5.65
5.60
5.55
5.50

FIGURE 12

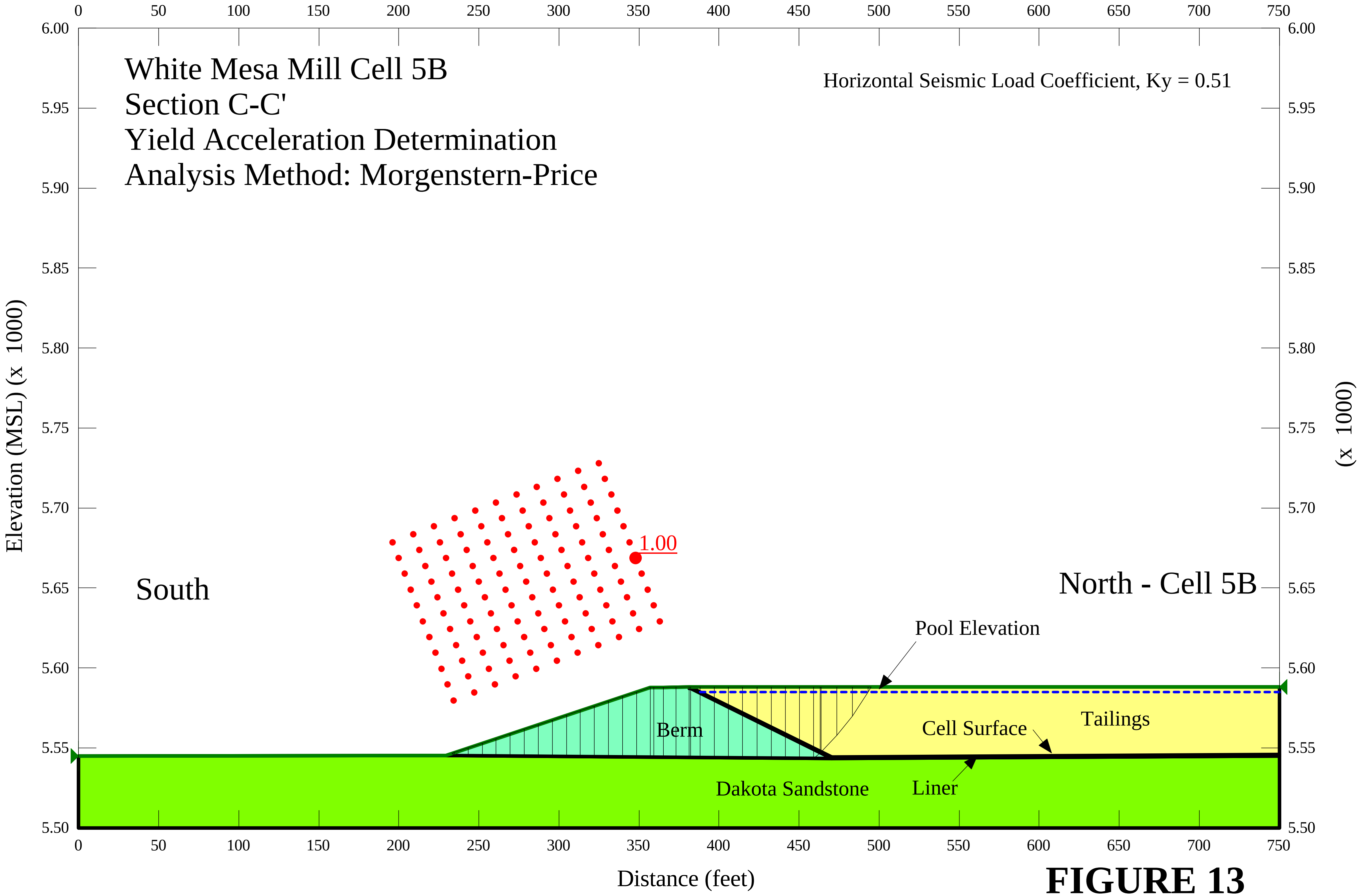
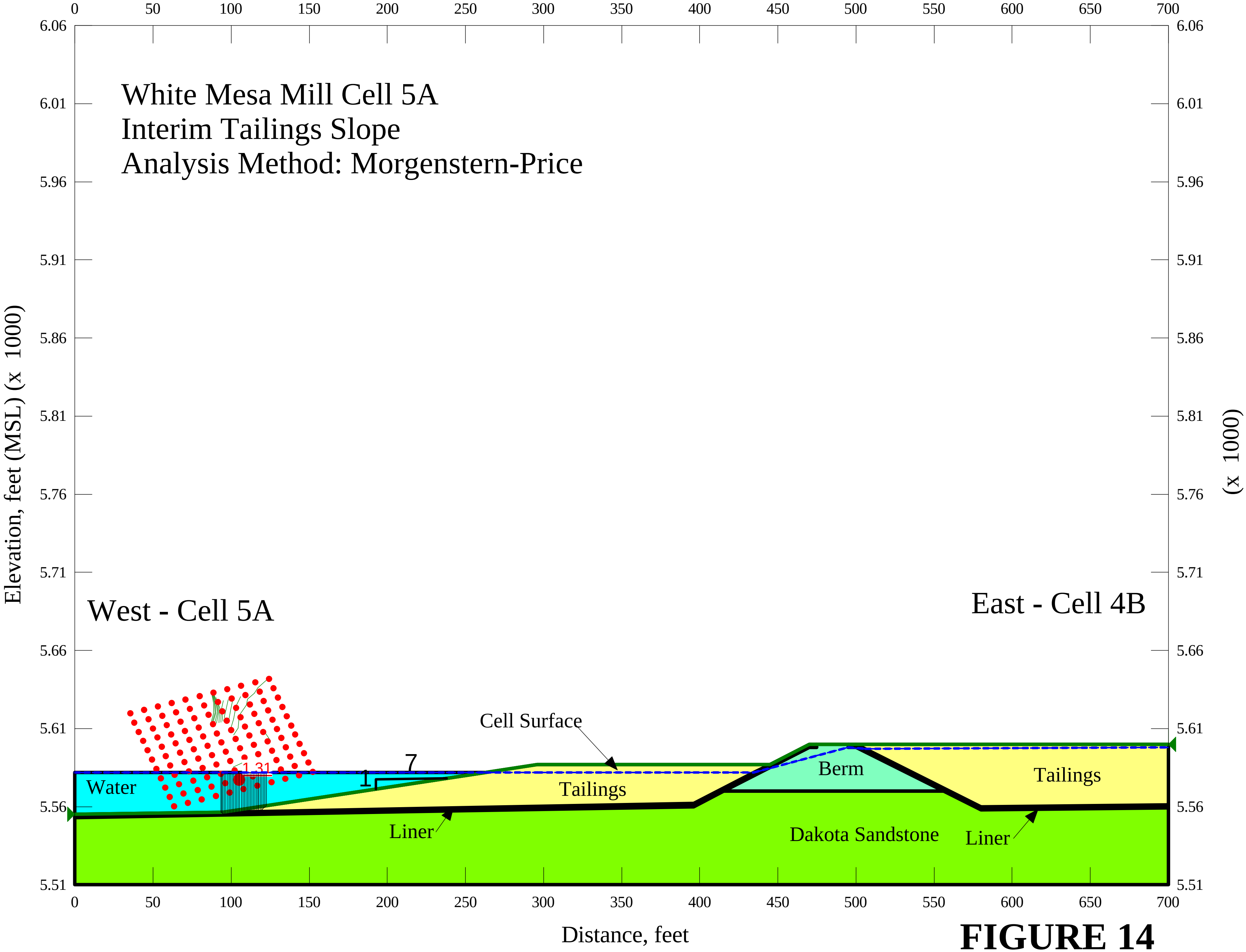

White Mesa Mill Cell 5B
Section C-C'
Yield Acceleration Determination
Analysis Method: Morgenstern-Price
Horizontal Seismic Load Coefficient, Ky = 0.51
1.00
South
North - Cell 5B
Pool Elevation
Berm
Cell Surface
Tailings
Dakota Sandstone
Liner
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.00
5.95
5.90
5.85
5.80
5.75
5.70
5.65
5.60
5.55
5.50

FIGURE 13



White Mesa Mill Cell 5A
Interim Tailings Slope
Analysis Method: Morgenstern-Price
West - Cell 5A
East - Cell 4B
Water
1.31
1
7
Cell Surface
Tailings
Berm
Tailings
Liner
Dakota Sandstone
Liner
Elevation, feet (MSL) (x 1000)
(x 1000)
Distance, feet
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
6.06
6.01
5.96
5.91
5.86
5.81
5.76
5.71
5.66
5.61
5.56
5.51

FIGURE 14

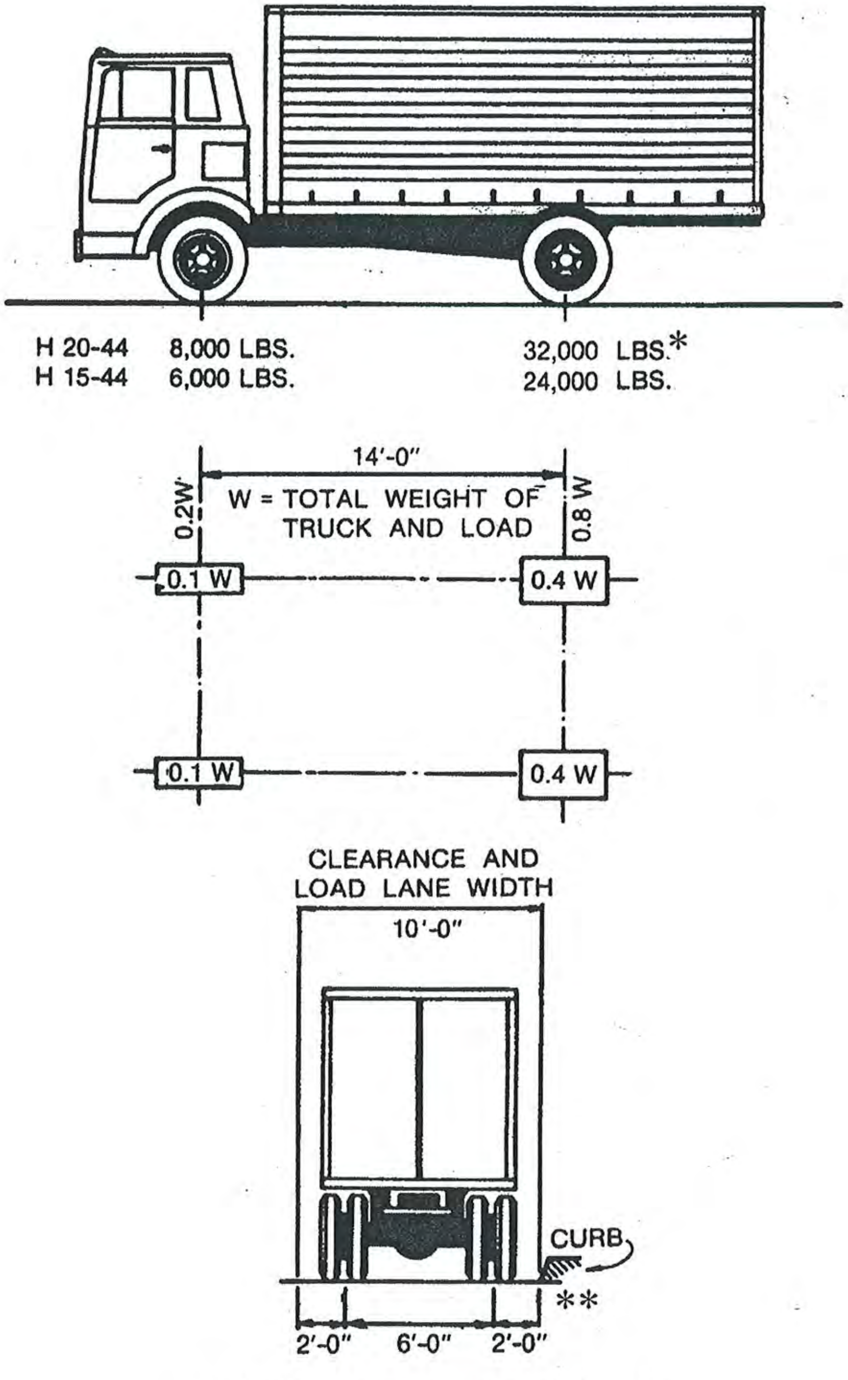


FIGURE 3.7.6A Standard H Trucks

* In the design of timber floors and orthotropic steel decks (excluding transverse beams) for H 20 loading, one axle load of 24,000 pounds or two axle loads of 16,000 pounds each spaced 4 feet apart may be used, whichever produces the greater stress, instead of the 32,000-pound axle shown.

** For slab design, the center line of wheels shall be assumed to be 1 foot from face of curb. (See Article 3.24.2)

Ta

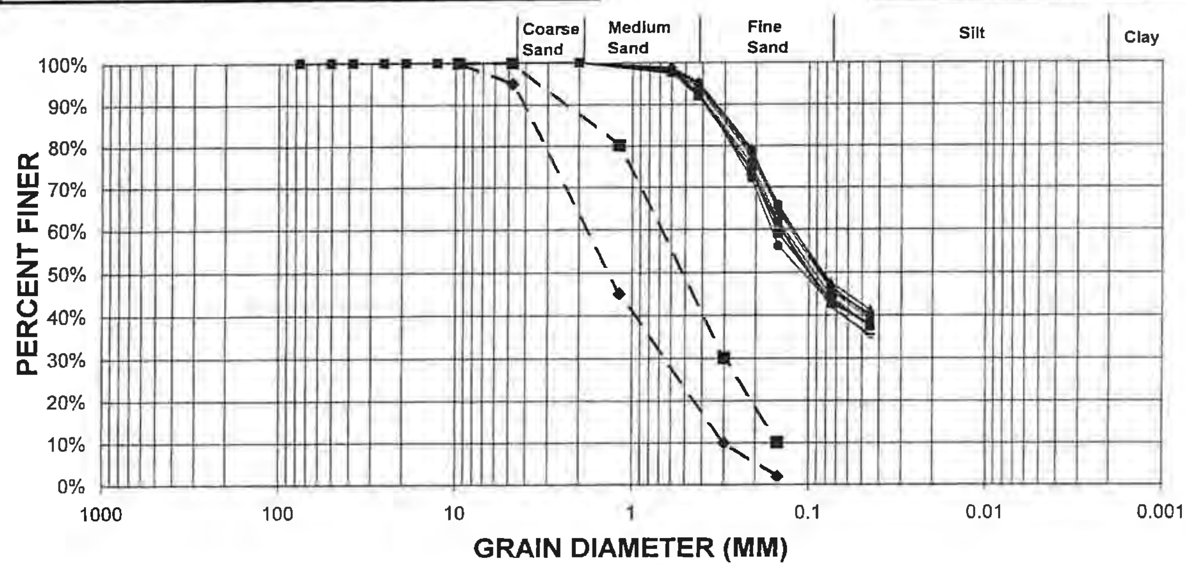
DSM Screen Undersize Gradation

SIEVE ANALYSIS

		Grinding Test 1			Grinding Test 2A			Grinding Test 2B			Grinding Test 3A			Grinding Test 3B		
Sieve No.	Diameter (mm)	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer
3 in.	76.2	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
2 in.	50.8	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 1/2 in.	38.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 in.	25.4	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/4 in.	19.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1/2 in.	12.7	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/8 in.	9.530	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 4	4.750	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 10	2.000	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 30	0.600	1.2	1.2%	98.8%	2.0	2.0%	98.0%	1.7	1.7%	98.3%	2.4	2.4%	97.6%	1.9	1.9%	98.1%
No. 40	0.425	4.6	4.6%	95.4%	7.3	7.3%	92.7%	6.0	6.0%	94.0%	8.1	8.1%	91.9%	6.9	6.9%	93.1%
No. 70	0.212	20.8	20.8%	79.2%	24.5	24.5%	75.5%	22.6	22.6%	77.4%	26.2	26.2%	73.8%	27.9	27.9%	72.1%
No. 100	0.150	34.8	34.8%	65.2%	38.1	38.1%	61.9%	35.5	35.5%	64.5%	41.0	41.0%	59.0%	43.9	43.9%	56.1%
No. 200	0.075	53.4	53.4%	46.6%	55.7	55.7%	44.3%	52.5	52.5%	47.5%	56.6	56.6%	43.4%	57.4	57.4%	42.6%
No. 325	0.045	60.5	60.5%	39.5%	62.7	62.7%	37.3%	58.8	58.8%	41.2%	62.5	62.5%	37.5%	61.9	61.9%	38.1%
Pan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		Grinding Test 6A			Grinding Test 6B			Grinding Test 4A			Grinding Test 4B		
Sieve No.	Diameter (mm)	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer
3 in.	76.2	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
2 in.	50.8	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 1/2 in.	38.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 in.	25.4	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/4 in.	19.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1/2 in.	12.7	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/8 in.	9.530	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 4	4.750	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 10	2.000	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 30	0.600	1.3	1.3%	98.7%	1.0	1.0%	99.0%	2.7	2.7%	97.3%	2.7	2.7%	97.3%
No. 40	0.425	5.2	5.2%	94.8%	4.7	4.7%	95.3%	7.6	7.6%	92.4%	7.3	7.3%	92.7%
No. 70	0.212	21.7	21.7%	78.3%	21.4	21.4%	78.6%	26.2	26.2%	73.8%	25.9	25.9%	74.1%
No. 100	0.150	34.1	34.1%	65.9%	35.9	35.9%	64.1%	38.7	38.7%	61.3%	39.2	39.2%	60.8%
No. 200	0.075	54.4	54.4%	45.6%	54.4	54.4%	45.6%	57.3	57.3%	42.7%	58.3	58.3%	41.7%
No. 325	0.045	59.7	59.7%	40.3%	61.1	61.1%	38.9%	65.4	65.4%	34.6%	64.6	64.6%	35.4%
Pan	-	-	-	-	-	-	-	-	-	-	-	-	-

3/8 in.



Average	
Med Sand	6.4%
Fine Sand	49.1%
Silt	44.4%

Colorado School of Mines
Research Institute
Grinding Reports
5 June 1978
OSM Screen Undersize"

%FINER = 100 - Σ%RETAINED

7/20/2007

Attachment B, 1/1

TABLE 6
Typical Values of Soil Index Properties

	Particle Size and Gradation				Voids[1]					Unit Weight[2] (lb./cu.ft.)						
	Approximate Size Range (mm)		Approx. D_{10} (mm)	Approx. Range Uniform Coefficient C_u	Void Ratio			Porosity (%)		Dry Weight			Wet Weight		Submerged Weight	
	D_{max}	D_{min}			e_{max} loose	e_{cr}	e_{min} dense	n_{max} loose	n_{min} dense	Min loose	100% Mod. AASHO	Max dense	Min loose	Max dense	Min loose	Max dense
GRANULAR MATERIALS																
Uniform Materials																
a. Equal spheres (theoretical values)	-	-	-	1.0	0.92	-	0.35	47.6	26	-	-	-	-	-	-	-
b. Standard Ottawa SAND	0.84	0.59	0.67	1.1	0.80	0.75	0.50	44	33	92	-	110	93	131	57	69
c. Clean, uniform SAND (fine or medium)	-	-	-	1.2 to 2.0	1.0	0.80	0.40	50	29	83	115	118	84	136	52	73
d. Uniform, inorganic SILT	0.05	0.005	0.012	1.2 to 2.0	1.1	-	0.40	52	29	80	-	118	81	136	51	73
Well-graded Materials																
a. Silty SAND	2.0	0.005	0.02	5 to 10	0.90	-	0.30	47	23	87	122	127	88	142	54	79
b. Clean, fine to coarse SAND	2.0	0.05	0.09	4 to 6	0.95	0.70	0.20	49	17	85	132	138	86	148	53	86
c. Micaceous SAND	-	-	-	-	1.2	-	0.40	55	29	76	-	120	77	138	48	76
d. Silty SAND & GRAVEL	100	0.005	0.02	15 to 300	0.85	-	0.14	46	12	89	-	146[3]	90	155[3]	56	92
MIXED SOILS																
Sandy or Silty CLAY	2.0	0.001	0.003	10 to 30	1.8	-	0.25	64	20	60	130	135	100	147	38	85
Skip-graded Silty CLAY with stones or rk fgmts	250	0.001	-	-	1.0	-	0.20	50	17	84	-	140	115	151	53	89
Well-graded GRAVEL, SAND, SILT & CLAY mixture	250	0.001	0.002	25 to 1000	0.70	-	0.13	41	11	100	140	148[4]	125	156[4]	62	94 *
CLAY SOILS																
CLAY (30%-50% clay sizes)	0.05	0.5μ	0.001	-	2.4	-	0.50	71	33	50	105	112	94	133	31	71
Colloidal CLAY (-0.002 mm: 50%)	0.01	10Å	-	-	12	-	0.60	92	37	13	90	106	71	128	8	66
ORGANIC SOILS																
Organic SILT	-	-	-	-	3.0	-	0.55	75	35	40	-	110	87	131	25	69
Organic CLAY (30% - 50% clay sizes)	-	-	-	-	4.4	-	0.70	81	41	30		100	81	125	18	62

Attachment C, NAVFAC DM7-01, 1986
(Navy Soil Design Manual)

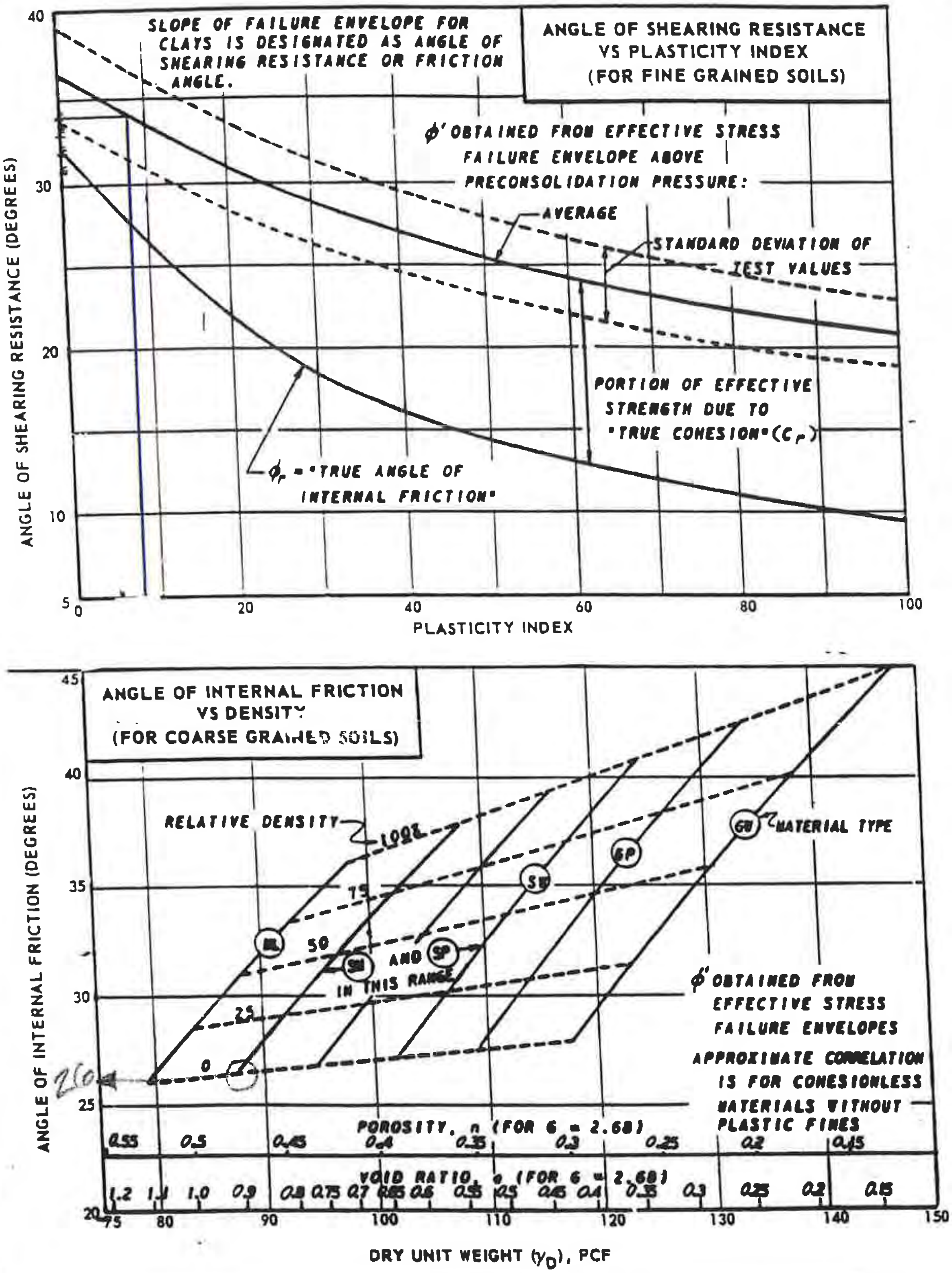


FIGURE 3-7
Correlations of Strength Characteristics

NAVFAC DM7-03, 1986

ATTACHMENT D

M
F
G
consulting scientists and engineers

TECHNICAL MEMORANDUM

TO: JoAnn Tischler, TetraTech EMI, Denver **MFG PROJECT: 181413X**

FROM: Tom Chapel

DATE: June 7, 2006

SUBJECT: White Mesa Stability Analysis

This memorandum presents details and results of slope stability analyses performed for an earthen embankment at the White Mesa Project near Blanding, Utah. The embankment was designed in approximately 1988 by Umetco Minerals Corporation, with details described in a report titled "*Cell 4 Design, Tailings Management System, White Mesa Project, Blanding, Utah*". The text of that report, excluding appendices was provided for our review, as were Sheet C4-1 and Sheet C4-2, plans prepared by Western Engineers, Inc. and dated January 17, 1989. Sheet C4-1 shows the location of Cell 4 and other facilities; and Sheet C4-2 shows cross sections at specified locations. The locations and configuration of the section used in our analyses are described later in this memorandum. In addition to the design report and plan sheets, we received a packet titled *Dike Construction, Soil Properties*, and one titled *Dike Construction, Compaction Test*. These documents are copies of laboratory and field tests characterizing the site soils from tests performed during design and construction of the embankment.

We understand the International Uranium (IUSA) Corporation is considering using Cell 4 to impound water and tailings. As part of the permitting process, IUSA has been requested to evaluate the stability of the 2h:1v embankment slope that was constructed on the Cell 4-A side of an embankment constructed between Cells 4-A and 4-B. Tetra Tech has evaluated the stability of the 2h:1v embankment slope. Our methodology, results, conclusions, and opinions are presented in the following paragraphs.

The design report indicates Cell 4-A and Cell 4-B are adjacent cells of a tailing impoundment, each approximately 1150 acre feet with final surface areas of 40 acres each. The tailings will be impounded on the upstream side of a homogenous earth dike. The embankment that is the subject of our investigation is a homogenous earthen embankment constructed between Cell 4-A and Cell 4-B. The general site layout and location are shown on Figure 1.

Several geotechnical investigations were conducted at the site between 1978 and 1981 and results are described in the design report. The embankment was constructed of on-site soils classified as CL and/or ML according to the Unified Soil Classification method (USCS). In the vicinity of Cell 4, bedrock is reported to be sandstone of the Dakota Formation that was encountered at depths of 3.5 to 13 feet. The bedrock is described as including discontinuous lenses of claystone and siltstone. Groundwater was found at depths of 70 and 110 feet below the ground surface in the vicinity of Cell 4.

According to the design report, the embankment base was prepared by removing topsoil, then compacting and proof-rolling the base to identify soft areas, which were removed and replaced with suitable soils.

ATTACHMENT E (1/8)

The embankment was constructed using 12 inch loose layers compacted and tested. Test results provided to us support the methods described in the design report.

The design report included a slope stability analysis performed on the Cell 4-B side of the separating embankment using a STABR computer model, the Ordinary Method of slices, and Bishops modified Method of analysis. That analysis indicated a minimum factor of safety of 1.5 for a 25 foot high embankment and a 3h:1v slope, assuming a saturated, steady state condition in which water was impounded to a level 2 feet below the crest of the embankment. The section was also analyzed using a 0.1g lateral load and a minimum factor of safety of 1.1 was calculated.

Tetra Tech modeled the slope using Cell 4 cross section D-D' shown on Sheet C4-2. We assumed a maximum crest elevation of 5608 feet, a crest width of 18 feet, a side slope of 2h:1v on the Cell 4-A side of the embankment, and a side slope of 3h:1v on the Cell 4-B side of the embankment. This resulted in a maximum embankment height of 46 feet, including 28 feet of man-placed, fine, silty sand fill over seven feet of natural silty sand, over sandstone bedrock. Where the excavation penetrated the bedrock we assumed a one foot thick layer was processed to a sand soil condition and recompacted in place. IUSA indicated a minimum 3 foot freeboard will be maintained. The soil parameters used in our analysis were taken from Figure 3.4-1 of the design report, and are shown in Table 1 below:

Table 1. Soil Properties

Unit	Description	Phi (degrees)	Cohesion, c (psf)	Total unit weight (pcf)
1	water	0	0	62.4
2	Compacted fine, silty sand	30	0	123
3	Natural silty sand	28	0	120
4	bedrock	-	-	-

We evaluated the embankment stability with Slope/W software by Geoslope International, using Spencers method, Bishops modified method, and the Ordinary method of slices. We evaluated a steady state condition under static conditions and using a 0.1g seismic loading. IUSA requested we model the slope in a submerged condition assuming a no-strength fluid (water) as one alternative; and in a submerged condition with an impermeable synthetic liner/barrier as a second alternative. We understand that rapid draw down conditions are not applicable for this application. Figures 2 and 3 show the slope conditions and minimum factors of safety for the static and seismic conditions and the steady state, saturated condition. Figures 4 and 5 show the slope conditions and minimum factors of safety for static and seismic conditions assuming an impenetrable barrier between the water and the soil. Minimum safety factors are summarized in Table 2, below:

Table 2. Minimum Factors of Safety

Figure	Condition	Calculated Minimum Factor of Safety
2	Unlined alternative, static, steady state	1.42
3	Unlined Alternative, 0.1g seismic	0.93
4	Lined Alternative, static	1.88
5	Lined Alternative, 0.1g seismic	1.37

The Slope/W software includes a feature called "safety mapping" which plots variable numbers of slip surfaces in addition to the critical failure surface. These radii can be seen in Figures 2 and 3 and show primary failure planes are generally more deep seated, but the slope has a much higher factor of safety against the larger failure planes. A similar plot is included in Figures 4 and 5, however the slip surfaces (including the critical radius) are very small and occur near the crest of the embankment.

The results of our analysis indicate the minimum factors of safety for the unlined alternative are lower than recommended standards. A factor of safety of 1.0 indicates an unstable condition. However, these scenarios assumed an unlined saturated, condition and are therefore not representative of the planned construction. We understand the planned construction is with double synthetic liners with a drain medium and solution recovery system between the liners. The unlined alternative is not a valid analysis if the Cell is completed according to the reported plans. The lined alternative had minimum safety factors greater than commonly accepted standards for both the static and seismic conditions. The impoundment should not be used in an unlined condition unless additional analyses are performed that indicate acceptable performance, but if the construction is completed as described then the dike between Cell 4-A and 4-B with the side slope of 2h:1v meets or exceeds recommended standards for stability and safety factors.

We assumed that as-constructed soil conditions are as indicated in the design report and according to data from tests performed during the actual construction, and significant changes have not occurred since the time of construction. These analyses and results should be considered valid only for the conditions described herein.

We understand the soil/liner stability issues will be addressed by others. If you have any questions regarding our analysis or this memorandum, please contact the undersigned.

Thomas A. Chapel, CPG, PE

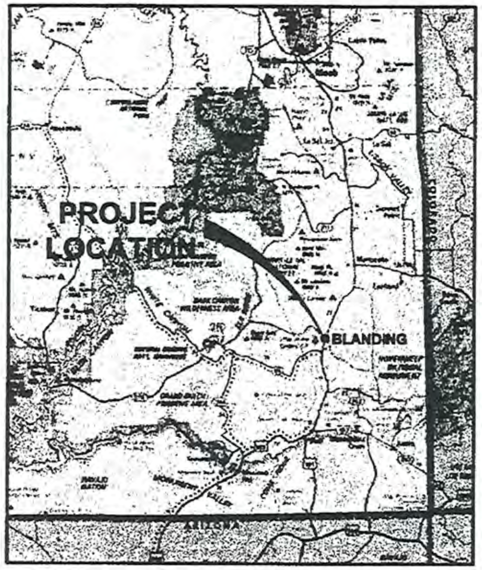
Senior Geotechnical Engineer

Reviewed by:

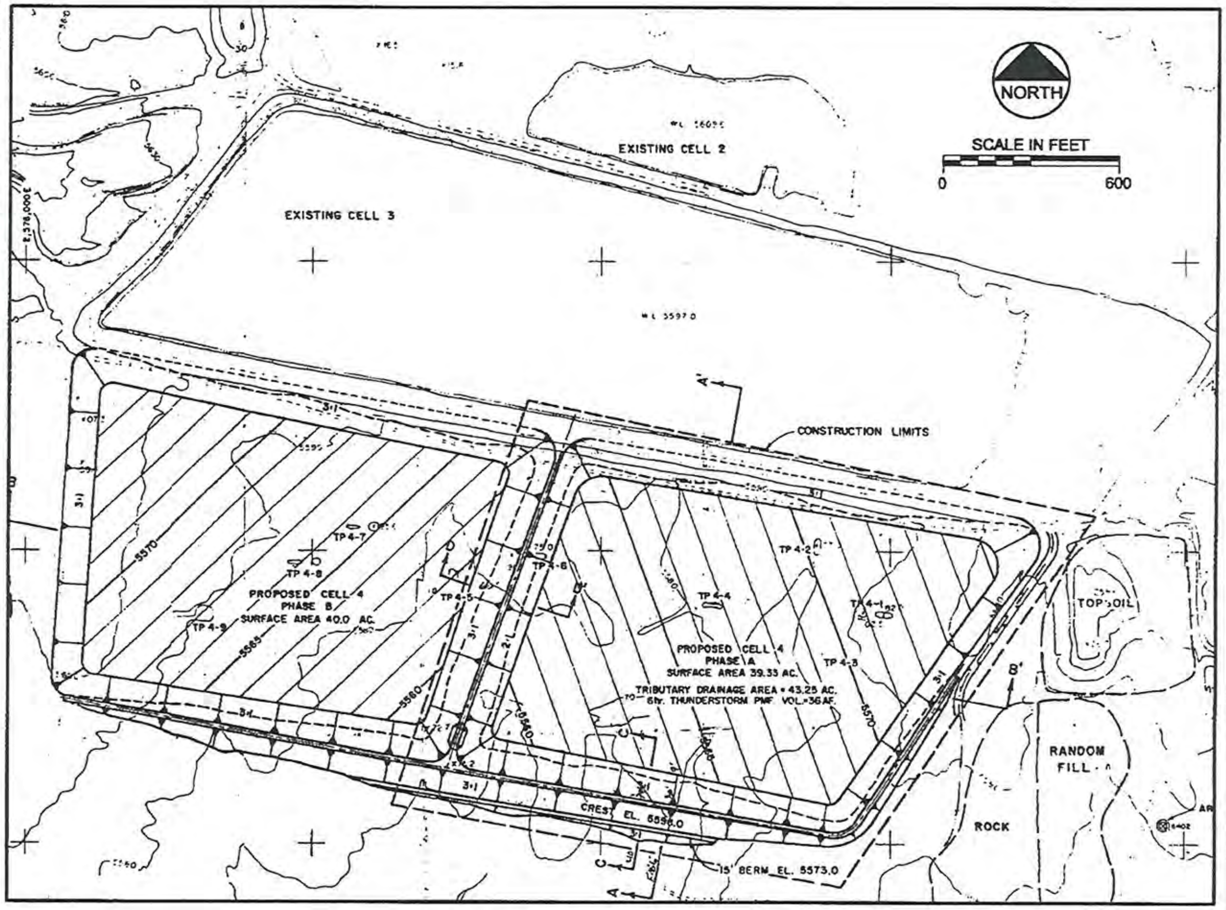
Daniel D. Overton, PE

Senior Geotechnical Engineer

PROFESSIONAL ENGINEER No. 262... DANIEL D. OVERTON STATE OF UTAH 12/21/06



VICINITY MAP



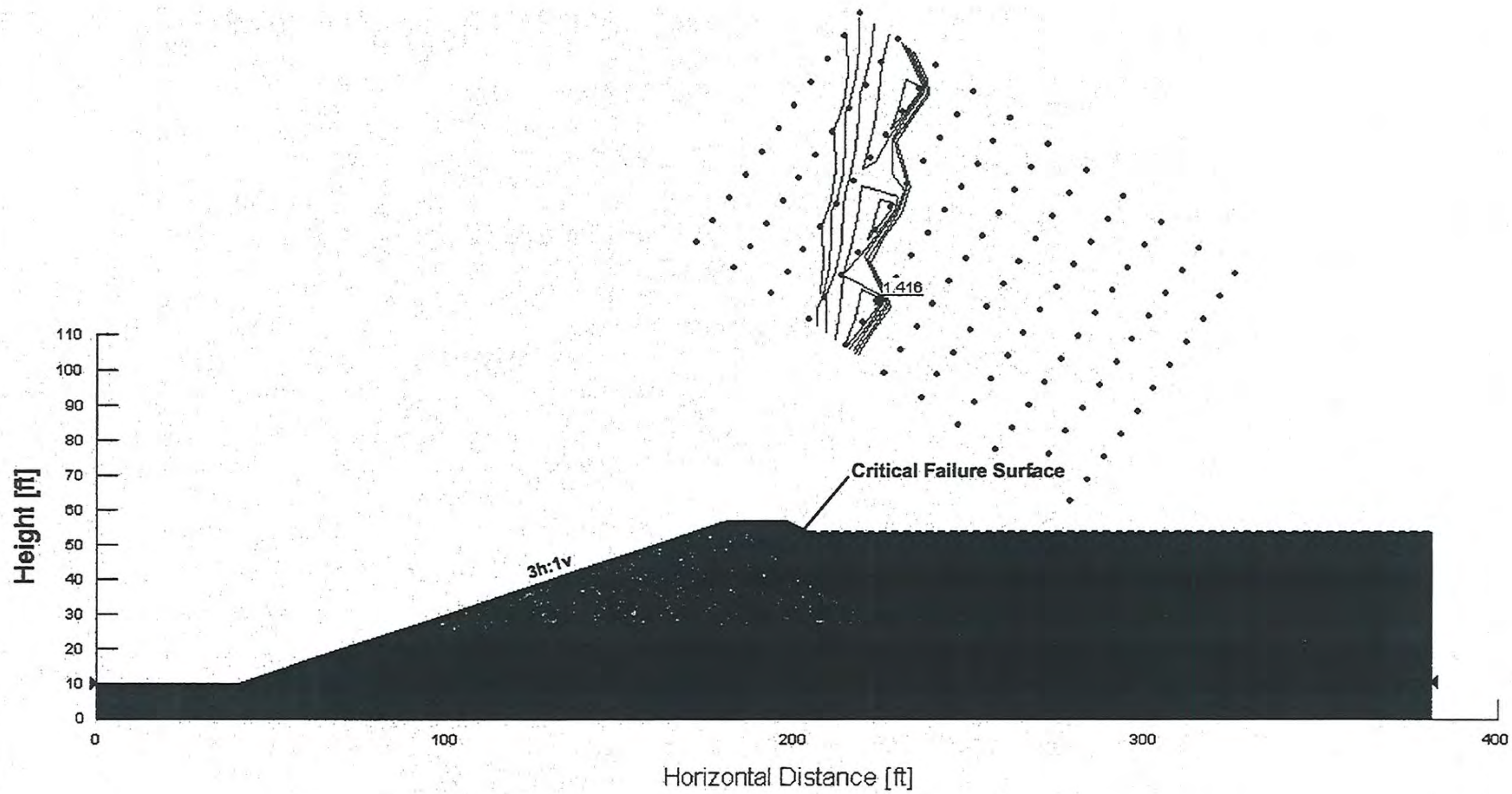
PROJECT AREA

TETRA TECH, INC.

FIGURE 1
SITE LOCATION MAP

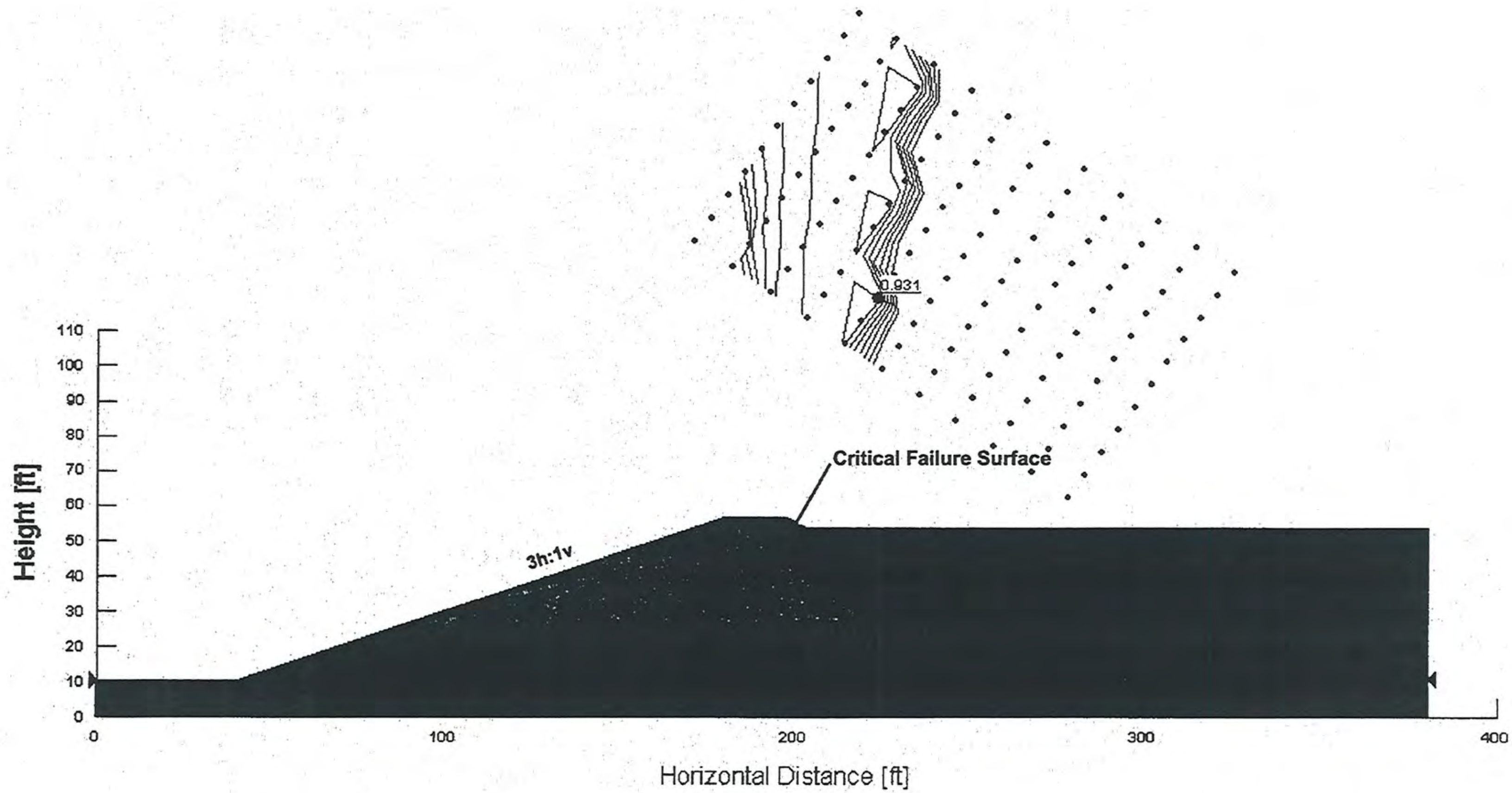
Date:	JUNE 2006
Project:	181413X
File:	LOCATION.DWG

E (4/8)



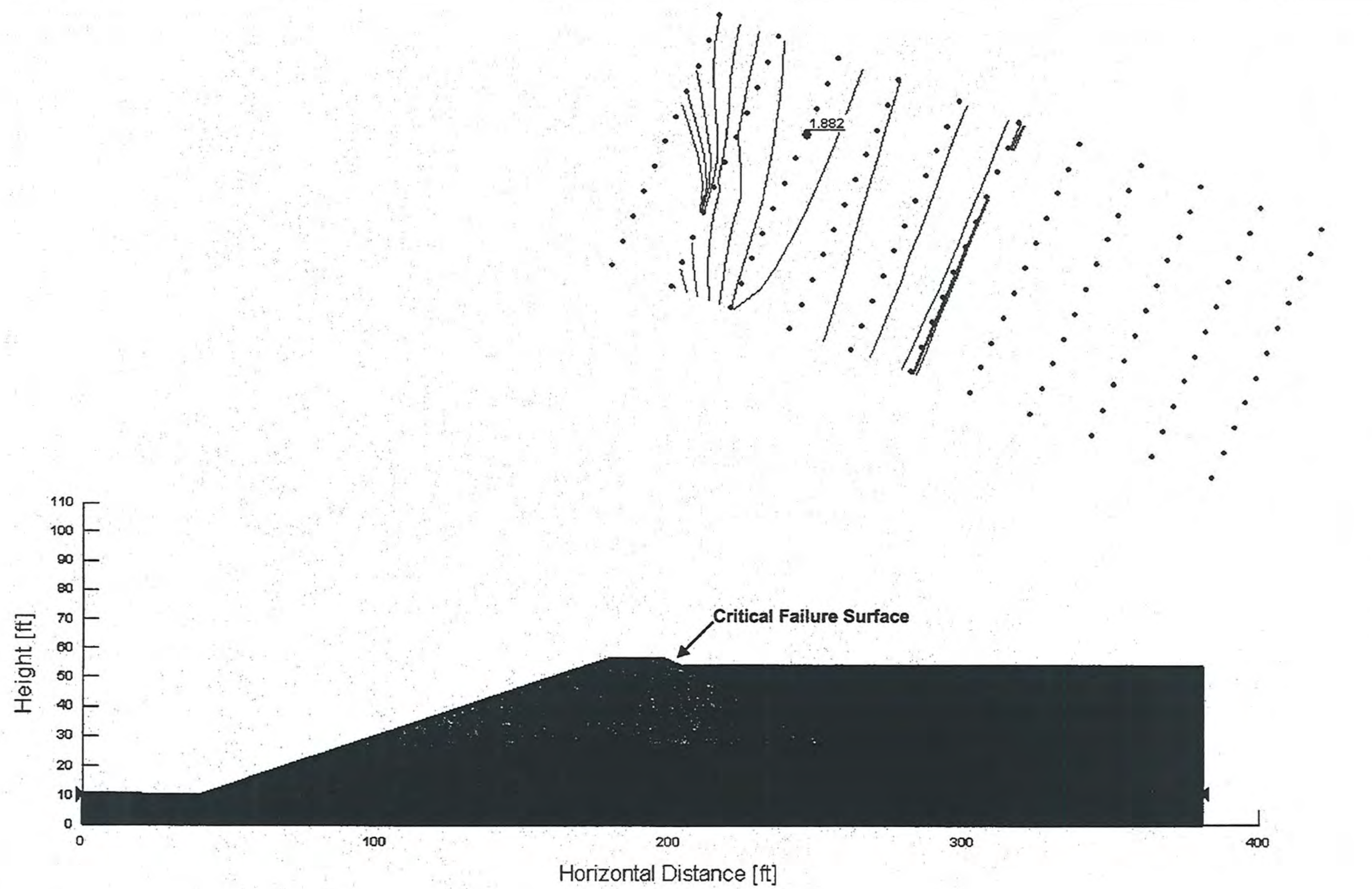
TetraTech, Inc.	FIGURE 2 Unlined Alternative Static Condition	International Uranium Corp. Project: White Mesa (181413x) 06/01/06

E (5/8)



TetraTech, Inc.	FIGURE 3 Unlined Alternative Seismic Condition	International Uranium Corp. Project: White Mesa (181413x) 06/01/06

E(6/8)

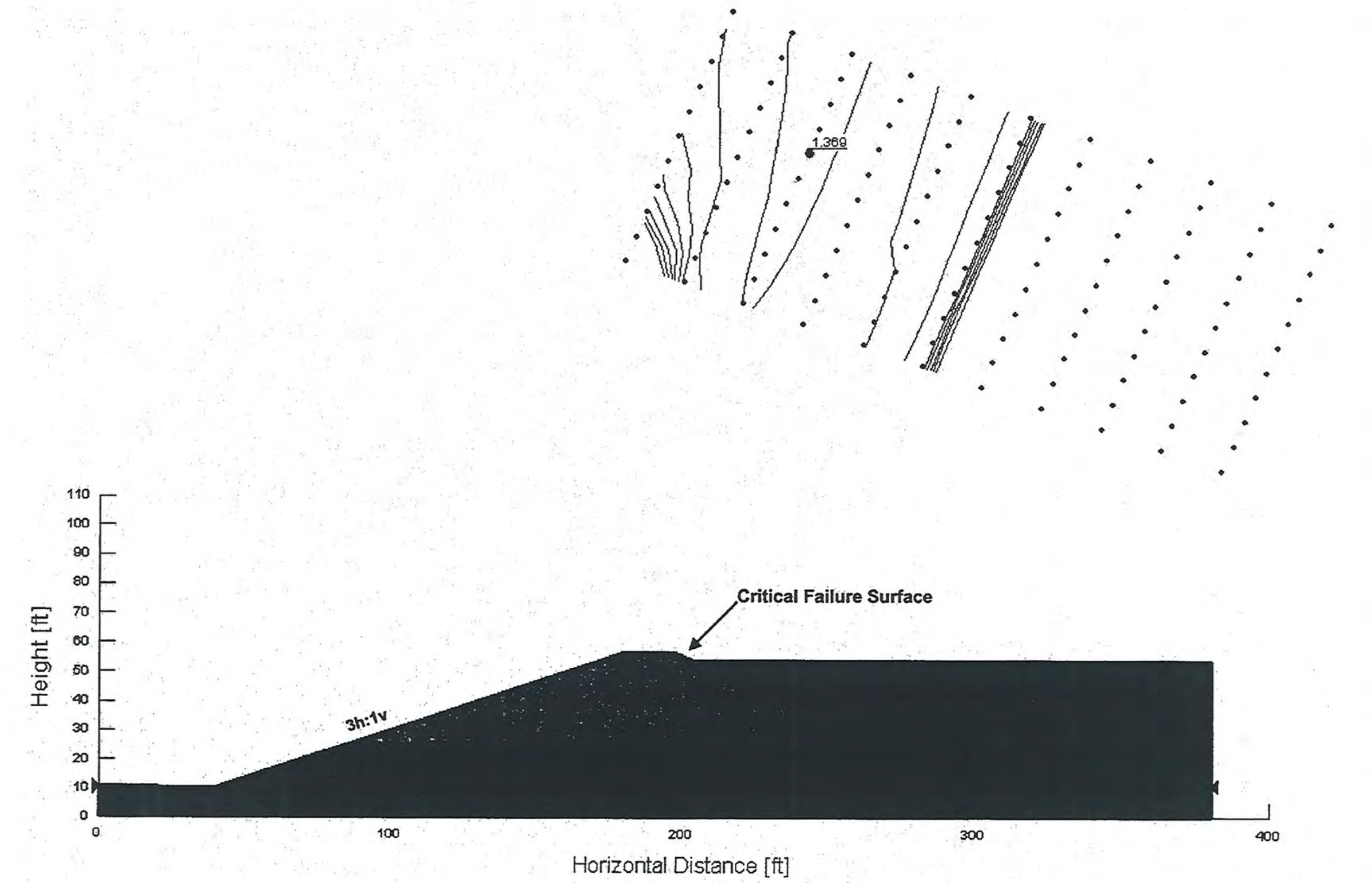


TetraTech, Inc.

FIGURE 4
Lined Alternative
Static Condition

International Uranium Corp.
Project: White Mesa (181413x)
06/01/06

E(7/8)



TetraTech, Inc.	FIGURE 5 Lined Alternative Seismic Condition	International Uranium Corp. Project: White Mesa (181413x) 06/01/06

E (8/8)

M
F
G
consulting
scientists and
engineers

MFG, Inc.
A TETRA TECH COMPANY
Fort Collins Office
3801 Automation Way, Suite 100
Fort Collins, CO 80525
970.223.9600
Fax: 970.223.7171

July 13, 2006

Tetra Tech EM, Inc.
950 17th Street, 22nd Floor
Denver, Colorado 80202

MFG Project No. 181413x

Attn: Ms. JoAnn Tischler

Subject: Draft
Soil Property Verification and
Slope Stability Analyses
Earthen Embankment between Cells 4A and 4B,
IUC White Mesa Project
Blanding, Utah

Tetra Tech MFG prepared a technical memorandum dated June 7, 2006, and a letter dated June 9, 2006 describing slope stability analyses, assumptions, and recommendations for verification of soil properties for an earthen embankment at the International Uranium (USA) Corporation, White Mesa Project near Blanding, Utah.

On June 15, 2006, Tetra Tech drilled an exploratory boring in the embankment between Cell 4A and Cell 4B at the approximate location shown on Figure 1 (attached). Descriptions of soils encountered in the boring are shown on the Borehole log (also attached). The boring was drilled to a depth of 30 feet and sampled at 5 foot intervals using a 2 inch diameter California sampler driven into the soil by a 140 pound weight dropped 30 inches (a Standard Penetration Test, SPT). Samples were examined by a geotechnical engineer in our soils laboratory. Samples were selected and tested for moisture and density and Atterberg Limits to determine their classification and similarity to properties identified in previous geotechnical reports for the project. A triaxial test was performed to compare the angle of internal friction and cohesion of the in-place soil with the values determined by the original designers in 1981.

The moisture and density of the samples tested are shown in Table 1 below:

ATTACHMENT F (1/7)

Table 1. Soil Properties

Depth	Description	Wet Density (pcf)	Dry Density (pcf)	Moisture content (%)
10	Silty sand	136.5	125.0	9.2
20	Silty sand	140.5	126.3	11.3
25	Silty sand	134.7	122.6	9.9
-	Average	137.2	124.6	10.1

Atterberg limits tests indicate a liquid limit of 25, and a Plasticity Index of 13, with 50 percent silt and clay sized particles (passing the number 200 sieve). Triaxial testing indicated an effective angle of internal friction of 26.5 degrees and a drained cohesion of 957.5 psf.

These test results indicate although the samples were visually classified as silty sand, laboratory tests indicate the embankment soils tested are a very sandy clay rather than sand and silty sand as reported by others and assumed in our initial analysis.

We performed additional slope stability analyses using the following soil properties: an average moist unit weight of 137 pcf, an angle of internal friction of 26 degrees, and an effective cohesion of 900 psf. We calculated the minimum factors of safety shown in Table 2.

Table 2. Revised Minimum Factors of Safety

Condition	Calculated Minimum Factor of Safety
Unlined alternative, static, steady state	2.45
Unlined Alternative, 0.1g seismic	1.67
Lined Alternative, static	4.61
Lined Alternative, 0.1g seismic	3.21

Therefore the factors of safety calculated and presented in our June 2 Technical Memorandum are conservative. In fact, analyses using the measured soil properties indicate that the embankment exceeds typical minimum acceptable safety factors even in the event leakage were to occur from the liner and produce a saturated condition as shown in Figure 3 of our previous memorandum.

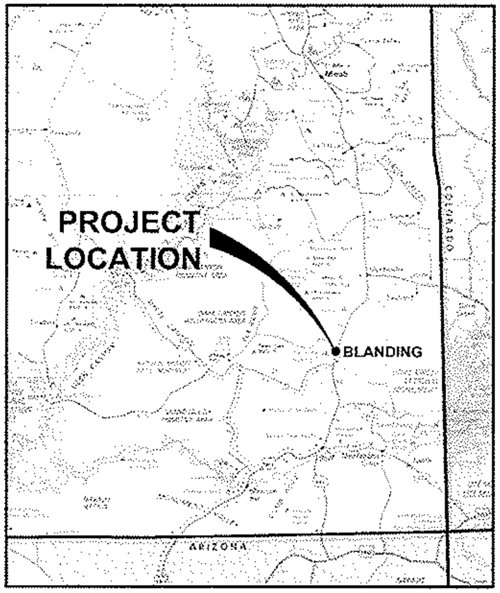
If you have any questions regarding our analysis, our previous correspondence, or this letter, please contact the undersigned.

Respectfully submitted,

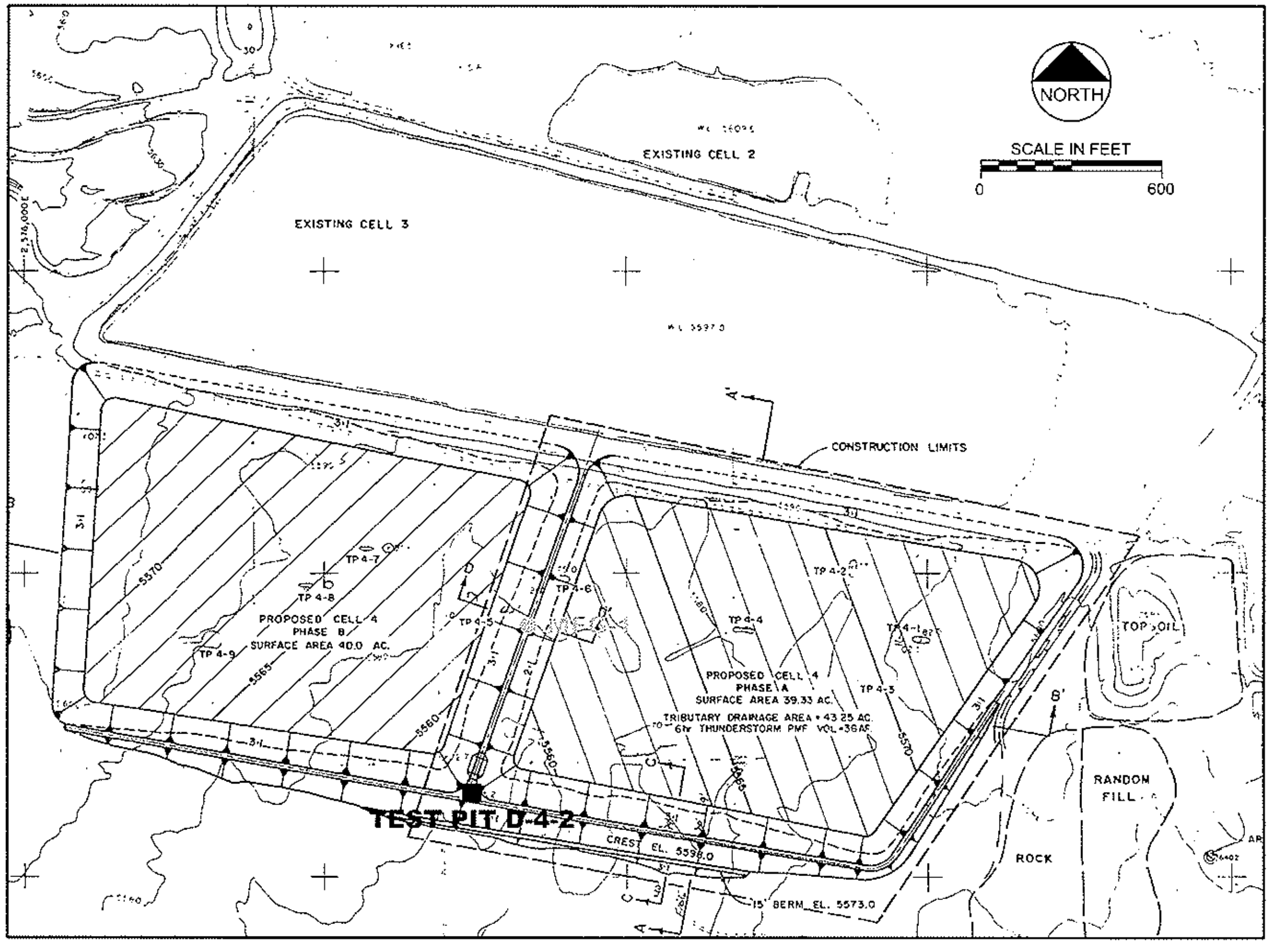
Tetratech MFG, Inc.

Thomas A. Chapel, CPG, PE
Senior Geotechnical Engineer

2 copies sent



VICINITY MAP



PROJECT AREA

4-INCH SOLID AUGER TO 30 FT.
SAMPLE AT 5 FT. INTERVALS
BACKFILL WITH BENTONITE

TETRA TECH, INC.

FIGURE 1
SITE LOCATION MAP

Date: JUNE 2006
Project: 181413X
File: LOCATION.DWG

F (4/7)

MFG, Inc.
consulting scientists and engineers

BOREHOLE LOG

DATE: 6/15/06

BOREHOLE NO.: **MFG-1**

PROJECT INFORMATION

PROJECT: WHITE MESA

PROJECT NO.: 181413X

CLIENT: TETRA TECH EMI

OWNER: INTERNATIONAL URANIUM (IUSA) CORPORATION

LOCATION: BLANDING, UTAH

BOREHOLE LOCATION

SEE FIGURE 1

FIELD INFORMATION

DATE & TIME ARRIVED: 6/15/06 9:00AM

BOREHOLE LOGGED BY: NMT

VISITORS: NONE

WEATHER: PARTLY CLOUDY, SLIGHT BREEZE, APPROX. 80°

DRILLING INFORMATION

DRILLING COMPANY: DA SMITH DRILLING

START TIME: 11:10AM

BORING DEPTH: APPROX. 31' BORING DIA.: 6"

DRILLING METHOD: CME 75 SOLID STEM AUGER

SAMPLING METHOD: 2-IN CA SAMPLES

TIME DRILLING COMPLETE: 12:50PM

BOREHOLE COMPLETION / ABANDONMENT INFORMATION

START TIME: 12:50PM COMPLETE TIME: 1:10PM

INSTRUMENTATION: NONE BACKFILL: BENTONITE

GROUNDWATER CONDITIONS

GROUNDWATER WAS NOT ENCOUNTERED DURING DRILLING

FOLLOWING FIELD WORK

TIME OF CLEAN-UP COMPLETE: 1:10PM TIME LEFT SITE: 1:50PM

NOTES:

F(5/7)

MFG, Inc.
consulting scientists and engineers

BOREHOLE LOG

PROJECT: *WHITE MESA* PAGE: *2 OF 3*

PROJECT NO.: *181413X* DATE: *6/15/06*

BOREHOLE NO.: **MFG-1**

DEPTH (FT)	CORE RECOV.	DRIVE SAMPLES: SAMPLE TYPE	DRIVE SAMPLES: BLOWS (PER 6")	DRIVE SAMPLES: RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
0							**COAL COVER AT SURFACE (APPROX. 0.25')**
0 – 5.5							**SILTY CLAY (0 TO APPROX. 5.5')** SLIGHTLY MOIST, LIGHT OLIVE BROWN (2.5Y 5/3), VERY STIFF SILTY CLAY FILL, TRACE SAND, TRACE PEBBLES, WHITE PRECIPITATE, ZONES OF COLOR CHANGE TO RED (2.5YR 4/6). APPROX. 0.5' - MOIST.
5 – 6.5		CA B A	11 19 33	17"			**SILTY SAND (APPROX. 5.5' TO APPROX. 30')** SLIGHTLY MOIST, RED (2.5YR 5/6), VERY DENSE SILTY SAND, FINE TO MEDIUM GRAIN, TRACE TO SOME CLAY, WHITE PRECIPITATE. APPROX. 6.5' - SANDSTONE FRAGMENTS, DRY, PINK (5YR 8/3), VERY DENSE, MEDIUM CEMENTATION, FINE GRAIN.
10 – 11.5		CA B A	15 32 43	13"			
15 – 16.5		CA B A	13 18 36	18"			APPROX. 15' - ZONES OF SANDY CLAY VARIOUS COLORS, MOIST.
20							

F(6/7)

MFG, Inc. *consulting scientists and engineers*	**BOREHOLE LOG** **PROJECT:** *WHITE MESA* **PAGE:** *3 OF 3* **PROJECT NO.:** *181413X* **DATE:** *6/15/06*	**BOREHOLE NO.:** **MFG-1**

DEPTH (FT)	CORE RECOV.	DRIVE SAMPLES: SAMPLE TYPE	DRIVE SAMPLES: BLOWS (PER 6")	DRIVE SAMPLES: RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
20							**SILTY SAND (APPROX. 5.5' TO APPROX. 30')** SEE DESCRIPTION ON PREVIOUS PAGE.
20–21.5		CA B A	15 29 50/6"	18"			
24							APPROX. 24' - SLIGHTLY MOIST.
25–26.5		CA B A	12 13 20	13"			
30							**SANDSTONE (APPROX. 30' TO E.O.B.)** SLIGHTLY MOIST, PINK (2.5YR 8/3), VERY DENSE SANDSTONE, FINE TO MEDIUM CEMENTATION, FINE GRAIN.
30–31		CA B A	38 50/5"	13"			
31							E.O.B. = 31.0'

Depth scale: 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

F(7/7)

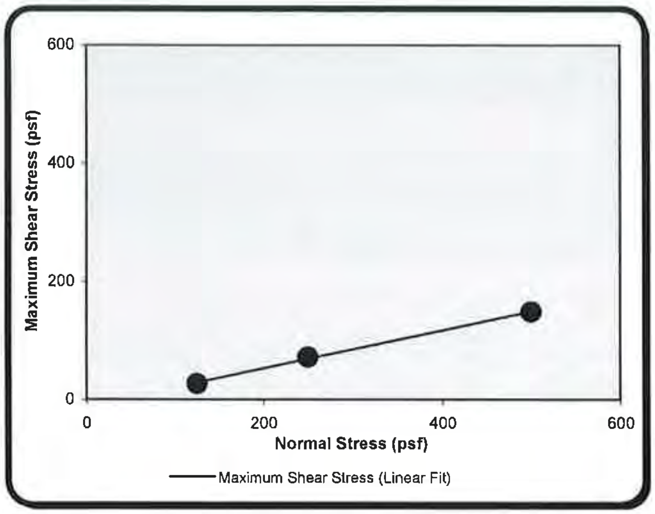
TRI/ENVIRONMENTAL, INC.

A Texas Research International Company

INTERFACE FRICTION TEST REPORT

Client:	**Agru**	TRI Log#:	E2201-75-03
Project:	Anne Steacy	Test Method:	ASTM D 5321
Test Date:	7/5-7/5/05		

Tested Interface: Agru 60 mil Studliner vs. Agru 60 mil Smooth Geomembrane



Upper Box: Agru 60 mil smooth Geomembrane

Lower Box: Agru 60 mil Studliner

Interface Conditioning: Interface soaked and loading applied for a minimum of 3 hours prior to shear

Box Dimension: 12"x12"x4"

Test Condition: Wet

Shearing Rate: 0.2 inches/minute

Trial Number	1	2	3
Bearing Slide Resistance (lbs)	9	10	13
Normal Stress (psf)	125	250	500
Maximum Shear Stress (psf)	36	82	161
Corrected Shear Stre	27	72	148
Secant Angle (degrees)	12.1	16.0	16.5

RESULTS: Maximum Friction Angle and Y-intercept

Regression Friction Angle (degrees):		**16.2**		
Y-intercept or Regression Adhesion (psf):		**0**		
Regression Line:	Y=	0.290	* X +	0
Regression Coefficient (r squared):		0.986		

Note: The regression line includes the origin.

John M. Allen, E.I.T., 07/11/2005
Quality Review/Date

9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

ATTACHMENT G (1/4)

TRI/ENVIRONMENTAL, INC.

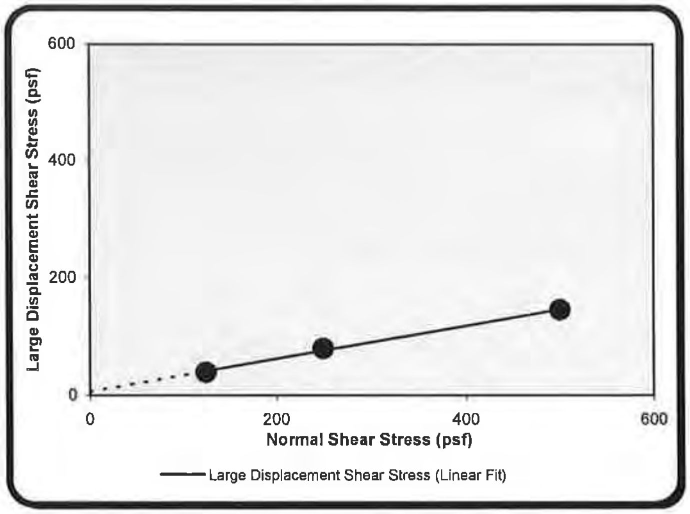
A Texas Research International Company

INTERFACE FRICTION TEST REPORT

Client: **Agru**
Project: Anne Steacy
Test Date: 7/5-7/5/05

TRI Log#: E2201-75-03
Test Method: ASTM D 5321

Tested Interface: Agru 60 mil Studliner vs. Agru 60 mil Smooth Geomembrane



Upper Box: Agru 60 mil smooth Geomembrane

Lower Box: Agru 60 mil Studliner

Interface Conditioning: Interface soaked and loading applied for a minimum of 3 hours prior to shear

Box Dimension: 12"x12"x4"

Test Condition: Wet

Shearing Rate: 0.2 inches/minute

Trial Number	1	2	3
Bearing Slide Resistance (lbs)	9	10	13
Normal Stress (psf)	125	250	500
Large Displacment Shear Stress (psf)	48	90	158
Corrected Shear Stress (psf)	39	80	145
Secant Angle (degrees)	17.2	17.7	16.2

RESULTS: Large Displacement Friction Angle and Y-intercept at 3.5-in. of Displacement

Regression Friction Angle (degrees):		**15.7**		
Y-intercept or Regression Adhesion (psf):		**6**		
Regression Line:	Y=	0.281	* X +	6
Regression Coefficient (r squared):		0.997		

John M. Allen, E.I.T., 07/11/2005
Quality Review/Date

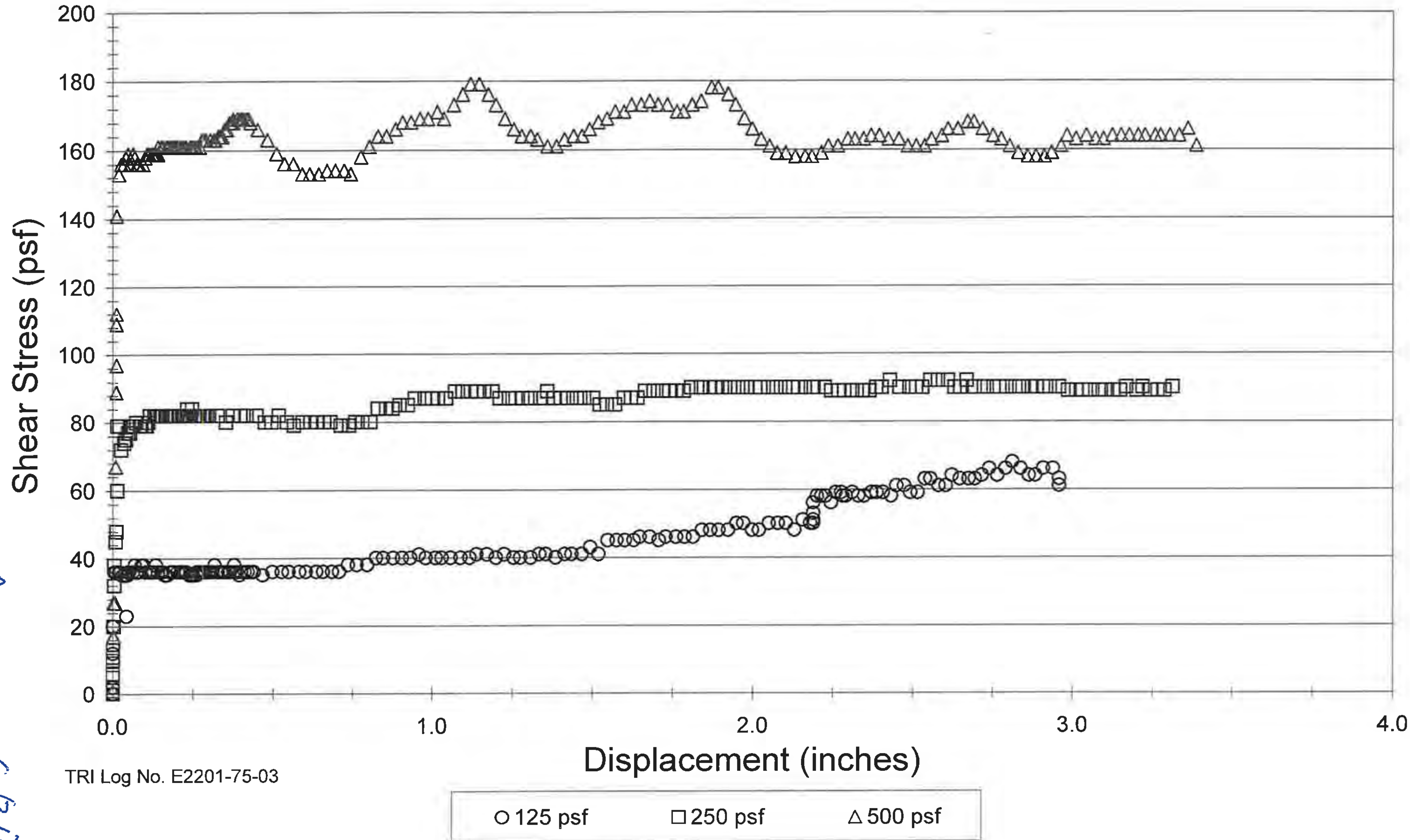
Large displacement shear stresses interperted at 2 inches of diplacement due to strain hardening effects.

9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

ATTACHMENT G (2/4)

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

AGRU INTERFACE FRICTION TEST
Agru 60 mil Smooth Geomembrane vs. Agru 60 mil Studliner

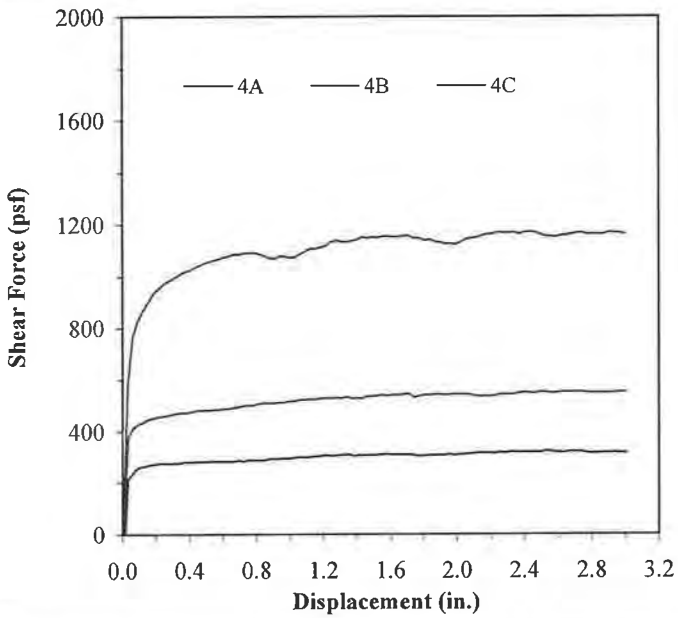


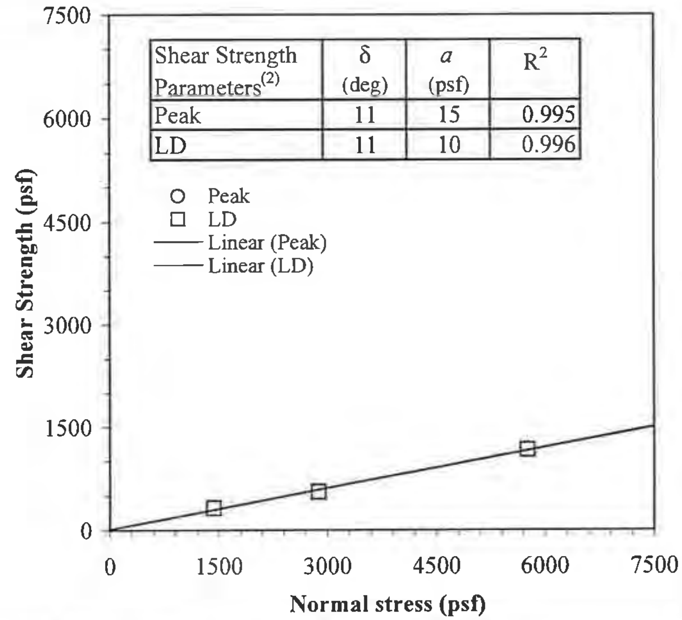
TRI Log No. E2201-75-03

ATTACHMENT G (3/4)

GEOSYNTEC CONSULTANTS - DENISON MINES
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Steel plate with textured surafce
GSE GNS-300E geonet #131340947/
GSE 60-mil B/W smooth HDPE geomembrane #104152973 with white side up/
Lower Shear Box: Concrete sand





Shear Strength Parameters[2]	δ (deg)	a (psf)	R^2
Peak	11	15	0.995
LD	11	10	0.996

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	GCL Soaking Stress (psf)	GCL Soaking Time (hour)	Consolidation[1] Stress (psf)	Consolidation[1] Time (hour)	Subgrade Soil γ_d (pcf)	Subgrade Soil ω_i (%)	Subgrade Soil ω_f (%)	Cover Soil γ_d (pcf)	Cover Soil ω_i (%)	Cover Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_P (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
4A	12 x 12	1440	0.20	-	-	-	-	-	-	-	-	-	-	-	-	324	316	(1)
4B	12 x 12	2880	0.20	-	-	-	-	-	-	-	-	-	-	-	-	553	552	(1)
4C	12 x 12	5760	0.20	-	-	-	-	-	-	-	-	-	-	-	-	1172	1162	(1)

NOTES:
(1) Shear failure occurred at the interface between the geonet and white side of geomembrane.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

SGI TESTING SERVICES, LLC

DATE OF REPORT:	5/15/2010
FIGURE NO.	C-4
PROJECT NO.	SGI10027
DOCUMENT NO.	
FILE NO.	

APPENDIX G (4/4)

S10027-04.ds.xls

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF** Project: **White Mesa Mill – Cell 5A & 5B** Project/ Proposal No.: **SC0634** Task No.

Title of Computations **Spillway Capacity Calculations**

Computations by:	Signature		12/18/12 Date
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		12/20/12 Date
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations Checked by:	Signature		12/20/12 Date
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations backchecked by: (originator)	Signature		12/18/12 Date
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature		12/18/12 Date
	Printed Name	Gregory T. Corcoran, P.E.	
	Title	Principal	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	Energy Fuels	Project:	White Mesa Mill-Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

SPILLWAY CAPACITY CALCULATIONS

OBJECTIVE

The purpose of this calculation is to estimate the capacity of the spillway designed for Cells 5A and 5B. Cells 5A and 5B will be used for process liquids evaporation and disposal of tailings and by-products of the ore processing operations at the site. Initially, Cell 5A will contain excess runoff from the upstream Cells 2, 3, 4A, and 4B during the Probable Maximum Precipitation (PMP); 6 hour storm event. Following construction of Cell 5B, excessive runoff from the upstream Cells 2 through 5A will be contained in Cell 5B. The spillway between Cells 4B and 5A is located at the northeast corner of Cell 5A and is designed to pass excess runoff not retained in Cells 2 through 4B during the PMP event. The spillway between Cells 5A and 5B will be located in the southeast and southwest corners of Cells 5A and 5B, respectively, and is designed to pass excess runoff not retained in Cells 2 through 5A during the PMP event.

ASSUMPTIONS

The following assumptions were used for completion of this calculation:

- The watershed areas of the Cells are:

	Watershed Area
Cell 2	87 acre
Cell 3	83 acre
Cell 4A	42 acre
Cell 4B	44.5 acre
Cell 5A	42 acre
Cell 5B	42 acre

- The spillway conveying flows were designed with the following discharges:

Spillway	Flow
Cell2 to Cell 3	1283 cfs
Cell 3 to Cell 4A	1224 cfs
Cell 4A to Cell 4B	2507 cfs
Cell 4B to Cell 5A	*To Be Determined
Cell 5A to Cell 5B	*To Be Determined

- Runoff from the Cells were calculated using a weighted average of the prior Cell's runoff:
  - The area weighted discharge (Q) for Cell 3 is: 2507 cfs/170ac = 14.75 cfs. Therefore, the design Q for Cell 4A is 14.75 cfs/ac * 42 acres = 620 cfs.
  - The area weighted Q for Cell 4B is: 14.75 cfs/acre*44.5 acres = 656 cfs
  - The area weighted Q for Cell 5A is: 14.75 cfs/acre*42 = 620 cfs

- During the PMP event after Cell 5A construction, Cells 2 through 4B are at capacity and the discharge passing through the 4B spillway is the sum of the four design flows: $Q_{Cell\ 2} + Q_{Cell\ 3} + Q_{cell\ 4A} + Q_{cell\ 4B}$ = 1283 cfs + 1224 cfs + 620 cfs + 649 cfs = **3,783 cfs.**
- During the PMP event after Cell 5B construction, Cells 2 through 5A are at capacity and the discharge passing through the 5A spillway is the sum of the five design flows: $Q_{Cell\ 2} + Q_{Cell\ 3} + Q_{cell\ 4A} + Q_{cell\ 4B} + Q_{cell\ 5A}$ = 1283 cfs + 1224 cfs + 620 cfs + 656 cfs + 620 cfs = **4,403 cfs.**
- The 5A spillway is designed with a bottom width of 40 feet, 10:1 (horizontal: vertical) side slopes, a channel slope of 2 percent, total depth of 5.5 feet (flow depth of 2.7 feet), and finished with smooth concrete (Manning's n of 0.015). (Attachment B)
- The 5B spillway is designed with a bottom width of 35 feet, 10:1 (horizontal: vertical) side slopes, a channel slope of 1.5 percent, total depth of 4 feet (flow depth of 3.2 feet), and finished with smooth concrete (Manning's n of 0.015). (Attachment B)

SPILLWAY CAPACITY CALCULATIONS

The spillway capacity is estimated using the Manning's equation:

$Q = (1.49/n)*R^{2/3}*S^{1/2}*A$

Where:

Q – Discharge (cfs),

n – Roughness Coefficient,

R – Hydraulic Radius (ft),

Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
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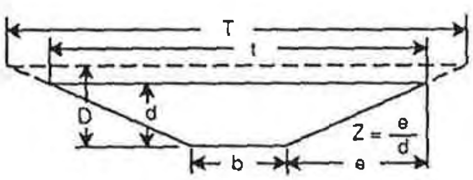
S – Channel Slope (ft/ft),
A – Flow Area (ft^2)

<u>Cell 4B into Cell 5A</u>

The top hinge of the spillway from Cell 4B to Cell 5A is at an elevation of 5598 ft msl. The lowest elevation around the crest of Cell 4B is 5596 ft msl and the wave run up factor is 0.77 ft (from the 10 January 1990 Drainage Report); therefore, a minimum of 2.77 ft of spillway freeboard (i.e. the top of liquid flow through the 4B to 5A spillway is 5595.23 ft msl) is necessary to prevent overtopping Cell 4B at the lowest point along the crest while allowing discharge of the runoff into Cell 5A. A discharge depth of 2.7 (i.e. the bottom of the spillway is at elevation 5592.53 ft msl) is calculated to verify that the design Q could pass the spillway with freeboard.

Figure 1 – Channel Dimensions for Trapezoidal Channels

Note: Freeboard = D–d for all selection



Cross-sectional area a	Wetted perimeter, p
$bd + Zd^2$	$b + 2d\sqrt{Z^2 + 1}$

Trapezoidal cross section

Discharge with Freeboard

n = 0.015
b = 40 ft
Z = 10
d = 2.7 ft (assumed depth of flow)
$A = (40 \times 2.7) + 10 \times 2.7^2 = 181\ ft^2$
$R = A/P; R = ((40 \times 2.7)+(10 \times 2.7^2))/(40+(2 \times 2.7)x(10^2+1)^{0.5}) = 1.92$ ft
S = 0.02
$Qall = (1.49/0.015) \times 1.92^{2/3} x 0.02^{1/2} \times 181 =$ **3,924 cfs**

In summary, the Cell 4B into Cell 5A spillway will have a total depth of 5.5 ft (from elevation 5598 ft msl), a total top width of 150 ft, a bottom width of 40 ft, and a cross slope of 2 percent.

Written by:	**R. Flynn**	Date:	12/18/12	Reviewed by:	**G. Corcoran**	Date:	12/18/12
Client:	**Energy Fuels**	Project:	**White Mesa Mill-Cells 5A and 5B**	Project/ Proposal No.:	**SC0634**	Task No.:	**02**

Cell 5A into Cell 5B

The top hinge of the Cell 5A spillway is at an elevation between The capacity calculation for the spillway used the channel dimensions presented above and assumed a 0.77 ft freeboard corresponding to the wave run-up factor (from the 10 January 1990 Drainage Report). Therefore, a discharge depth of 3.23 ft is calculated to verify that the design Q could pass with spillway freeboard

Discharge with Freeboard
n = 0.015
b = 35 ft
Z = 10
d = 3.23 ft (assumed depth of flow)
$A = (35 \times 3.23) + 10 \times 3.23^2 = 217 \text{ ft}^2$
$R = A/P; R = ((35 \times 3.23)+(10 \times 3.23^2))/(35+(2 \times 3.23)x(10^2+1)^{0.5}) = 2.18 \text{ ft}$
S = 0.015
$Qall = (1.49/0.015) \times 2.18^{2/3} x0.015^{1/2} \times 217 =$ **4,440 cfs**

In summary, the Cell 5A into Cell 5B spillway will have a total depth of 4 ft, a total top width of 115 ft, a bottom width of 35 ft, and a cross slope of 1.5 percent.

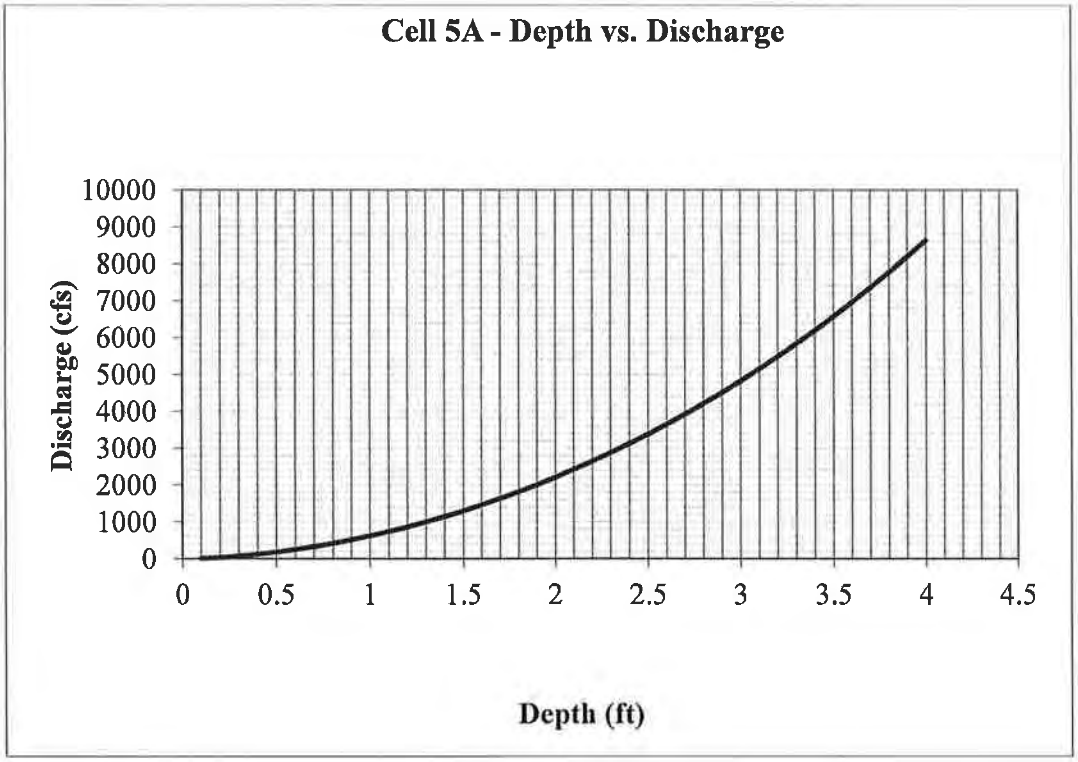
CONCLUSION

The allowable flows for the spillways, as designed, are estimated to be 3,924 cfs and 4,440 cfs (Cells 5A and 5B, respectively) which are greater than the flow rates for the PMP events, 3,783 cfs and 4,403 cfs for Cells 5A and 5B, respectively. Iterating on the discharge depth, the rating curve (Depth vs. Q) for the spillway is presented as Figures 2 and 3.

The spillway shown on Sheets 3B and 10 of the Construction Drawings show the Cell 5A to Cell 5B spillway with a top hinge elevation of 5585 ft msl. The lowest elevation around the crest of Cell 5A is 5588 ft msl. Accounting for the wave run up factor of 0.77 ft the top of liquid flow over the Cell 5A to Cell 5B spillway is at elevation 5587.23 ft msl. These elevations do not necessarily correspond to the capacity calculations presented herein. However; the spillway dimensions corresponding to the elevations on the Construction Drawings result in a spillway with greater capacity than the spillway designed in this calculation package.

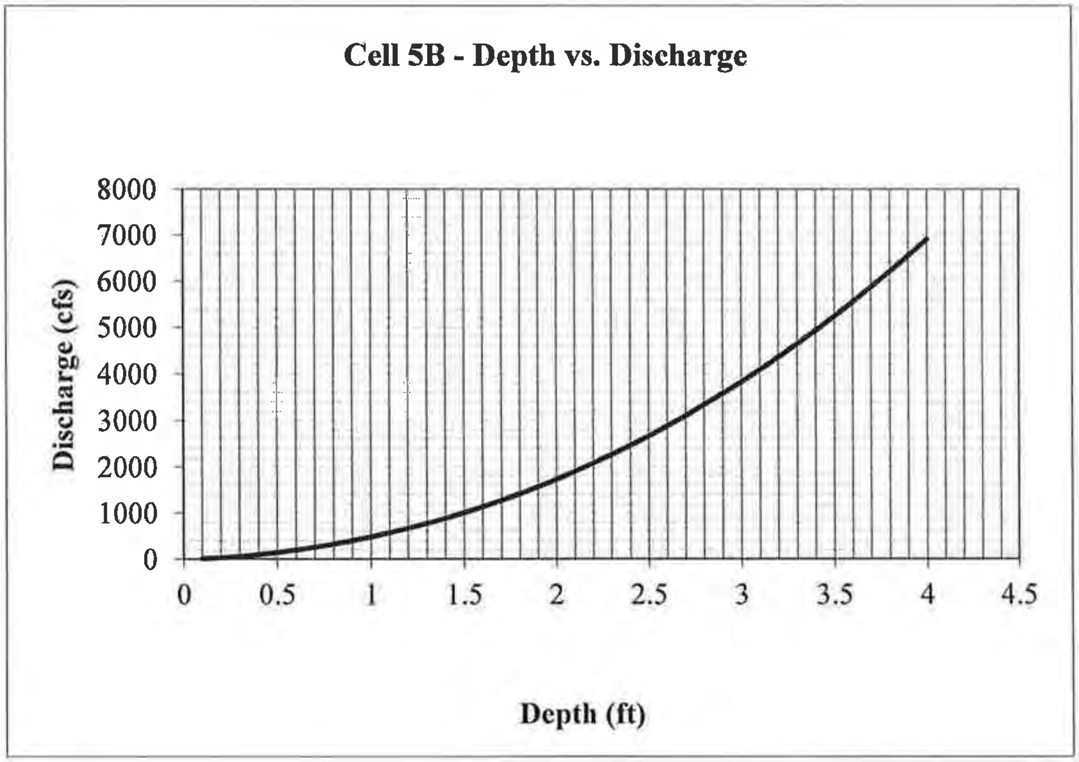
Written by:	**R. Flynn**	Date:	12/18/12	Reviewed by:	**G. Corcoran**	Date:	12/18/12
Client:	**Energy Fuels**	Project:	**White Mesa Mill-Cells 5A and 5B**	Project/ Proposal No.:	**SC0634**	Task No.:	**02**

Figure 2 – Rating Curve for Spillway 5A.



Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	Energy Fuels	Project:	White Mesa Mill-Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

Figure 3 – Rating Curve for Spillway 5B



References

Mays, Larry W., "Water Resources Engineering, 2005 Edition," John Wiley & Sons, Inc, 2005.

Mays, Larry W., "Water Resources Engineering, 2005 Edition," John Wiley & Sons, Inc, 2005.

Table 5.1.1 Values of the Roughness Coefficient *n* *(continued)*
(Boldface figures are values generally recommended in design)

Type of channel and description	Minimum	Normal	Maximum
c. Concrete			
1. Trowel finish	0.011	**0.013**	0.015
2. Float finish	0.013	0.015	0.016
3. Finished, with gravel on bottom	0.015	0.017	0.020
4. Unfinished	0.014	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	—
8. On irregular excavated rock	0.022	0.027	—
d. Concrete bottom float finished with sides of			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry, plastered	0.016	0.020	0.024
4. Cement rubble masonry	0.020	0.025	0.030
5. Dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. Glazed	0.011	**0.013**	0.015
2. In cement mortar	0.012	**0.015**	0.018
g. Masonry			
1. Cemented rubble	0.017	0.025	0.030
2. Dry rubble	0.023	0.032	0.035
h. Dressed ashlar	0.013	0.015	0.017
i. Asphalt			
1. Smooth	0.013	0.013	—
2. Rough	0.016	0.016	—
j. Vegetal lining	0.030	—	0.500
C. Excavated or dredged			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	**0.022**	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
c. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140

AHC

Geosyntec
consultants

COMPUTATION COVER SHEET

Client: **EF** Project: **White Mesa Mill – Cells 5A and 5B** Project/ Proposal No.: **SC0634** Task No. **02**

Title of Computations **Side Slope Riser Trench Stability Evaluation- Veneer Stability**

Computations by:	Signature		Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		Date 12/20/12
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations Checked by:	Signature		Date 12/18/12
	Printed Name	Jay Griffin	
	Title	Senior Staff Engineer	
Computations backchecked by: (originator)	Signature		Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature		Date 12/18/12
	Printed Name	Gregory T Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	11/14/12	Reviewed by:	G. Corcoran	Date:	12/10/12
Client:	EF	Project:	WMM- Cells 5A & 5B	Project/ Proposal No.:	SC0634	Task No.:	02

SIDE SLOPE RISER TRENCH STABILITY EVALUATION VENEER STABILITY OF GEOSYNTHETIC-SOIL LINED SLOPES

OBJECTIVE

To evaluate the tension developed within the geosynthetic-soil layered side slope riser trench liner system of the tailings pond liner system of the White Mesa Mill Cells 5A and 5B in Blanding, Utah.

SUMMARY OF RESULTS

The calculations suggest that the minimum peak geosynthetic interface friction angle of 23 degrees and no peak adhesion meets the requirement to prevent the development of tension in the geosynthetic components of the side slope riser trench liner system.

METHOD OF ANALYSIS

The stability analysis of the geosynthetic-soil layered systems was carried out using the approach outlined by Koerner and Soong [1998] (Attachment A). This approach calculates the driving force of an active soil wedge along a geosynthetic-soil layered side slope and compares it to the resisting force of the complementary passive soil wedge to evaluate the overall factor of safety against failure. The method presented by Koerner and Soong [1998] allows for the consideration of a uniform depth soil layer and the influence of dynamic equipment loading.

SIDE SLOPE RISER TRENCH LINER SYSTEM

The side slope liner system consists of, from top to bottom (Figure 1):

- 2 ft gravel;
- Cushion Geotextile;
- 60-mil HDPE Geomembrane, textured (primary);
- Cushion Geotextile;
- 60-mil HDPE Geomembrane, textured (secondary);
- Cushion Geotextile;

Written by:	**R. Flynn**	Date:	**11/14/12**	Reviewed by:	**G. Corcoran**	Date:	12/18/12
Client:	**EF**	Project:	**WMM- Cells 5A & 5B**	Project/ Proposal No.:	**SC0634**	Task No.:	**02**

- 60-mil HDPE Geomembrane, textured (tertiary); and
- Prepared subgrade.

The critical side slope inclination is a maximum of 3.0H:1.0V. The maximum height of the side slope riser trench is 46 vertical feet in the southeast corner of Cell 5B and 46 feet in the southwest corner of Cell 5A.

MATERIAL PARAMETERS

Based on a review of potential liner interfaces, the likely critical interface has been identified as the textured HDPE geomembrane and non-woven geotextile. Based on laboratory test data of material similar to that intended for the site, this interface is assumed to have ashear strength of approximately 28 degrees and no adhesion (Attachment B).

Geosynthetic Interface:

The geosynthetic interface friction angle was varied to evaluate the minimum allowable value to obtain no tension at a minimum factor of safety value of 1.3. A literature review was performed to evaluate if the calculated minimum allowable interface friction value is achievable in addition to laboratory testing performed on the material anticipated for this project.

REVIEW OF REPORTED INTERFACE STRENGTHS

The following values for the interface friction between the geosynthetic and soil components of the liner system represent values reported in the literature and as reported with laboratory test results:

Gravel (GP)	38	NAVFAC(1), 0 psf cohesion (Attachment C)
NW geotextile to Textured HDPE	28	Cell 4B CQA Report (Attachment B)
Textured HDPE to Sand Subgrade	33	4th GRI Seminar (Attachment D)

1. NAVFAC (1986) lists typical shear strength values for various compacted soils. To be conservative, a value of phi = 32 degree was used.

DESIGN CRITERION

For the geosynthetic-soil lined slopes of the Cell 5A and 5B liner systems, it was desired to evaluate inclination which would introduce no geosynthetic tension. Subsequently, zero geosynthetic tension was established as the design criterion for veneer stability of the geosynthetic-soil lined side slopes.

In consideration of the significance of no tension in the geosynthetic liner system and consistent with current practice, Geosyntec will adopt a factor of safety (FS) equal to or greater than 1.3 for veneer stability.

ANALYSIS

According to the Koerner and Soong approach, a soil veneer on a side slope is stable when the resultant driving force on the passive wedge (E_P) is equal to or less than the resultant resistant force on the active wedge (E_A). The following equations represent the resultant resistance and active forces, respectively:

$$E_A = \frac{FS(W_A - N_A \cos\beta) - (N_A \tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$ (Attachment A, 2 of 6)

$$E_P = \frac{C + W_P \tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$ (Attachment A, 2 of 6)

The variables will be defined in a subsequent section.

By setting E_A=E_P, the resulting equation may be arranged in the form of the quadratic equation $ax^2+bx+c=0$. Considering FS as the variable of interest, the resulting equation is as follows:

$$a(FS)^2 + b(FS) + c = 0$$ (Attachment A, 2 of 6)

Written by:	R. Flynn	Date:	11/14/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	WMM- Cells 5A & 5B	Project/ Proposal No.:	SC0634	Task No.:	02

The factor of safety may be obtained from the solution of the following equation:

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$ (Attachment A, 2 of 6)

Where the constants are defined, as in Attachment A, 6 of 6:

$$a = (W_A - N_A \cos\beta)\cos\beta \quad (1)$$

$$b = -[(W_A - N_A \cos\beta)\sin\beta\tan\phi + (N_A \tan\delta + C_a)\sin\beta\cos\beta + \sin\beta(C + W_P \tan\phi)] \quad (2)$$

$$c = (N_A \tan\delta + C_a)\sin^2\beta\tan\phi \quad (3)$$

In which the variables are indicated on Figure 1 and defined as follows:

$$C = \frac{c \cdot h}{\sin\beta} \quad (4)$$ (Attachment A, 2 of 6)

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right) \quad (5)$$ (Attachment A, 2 of 6)

$$W_A = \gamma \cdot h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right) \quad (6)$$ (Attachment A, 2 of 6)

$$N_A = W_A \cos\beta \quad (7)$$ (Attachment A, 2 of 6)

$$W_P = \frac{\gamma \cdot h^2}{\sin 2\beta} \quad (8)$$ (Attachment A, 2 of 6)

β = soil slope angle beneath the geomembrane, **18.4°** for 3H:1V slope
δ = minimum interface friction angle of side slope liner system, **23°**
ϕ = friction angle of gravel, **32°**
γ = unit weight of the gravel, **135 pcf**
C = cohesive force along the failure plane of the passive wedge
c = cohesion of the gravel, **0 psf**

Written by:	R. Flynn	Date:	11/14/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	WMM- Cells 5A & 5B	Project/ Proposal No.:	SC0634	Task No.:	02

C_a = adhesive force
c_a = adhesion between the sand and the geomembrane, **0 psf**
h = thickness of the gravel, **2 feet**
L = length of slope measured along the geomembrane beneath gravel, **145.5 feet**
N_A = effective force normal to the failure plane of the active wedge
W_A = total weight of the active wedge
W_P = total weight of the passive wedge

Substituting the variables and solving equations (4)-(8), above:

$$C = \frac{c \cdot h}{\sin\beta} = \frac{0 \cdot 2}{\sin(26.6)} = \mathbf{0\ lbs/ft} \quad (4)$$

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right) = 0\left(126.5 - \frac{2}{\sin 18.4}\right) = \mathbf{0\ lbs/ft} \quad (5)$$

$$W_A = \gamma \cdot h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right) = 135 \cdot 2^2\left(\frac{145.5}{2} - \frac{1}{\sin 18.4} - \frac{\tan 18.4}{2}\right) = \mathbf{37{,}481\ \ lbs/ft} \quad (6)$$

$$N_A = W_A \cos\beta = 37{,}481 \cdot \cos 18.4 = \mathbf{35{,}565\ lbs/ft} \quad (7)$$

$$W_P = \frac{\gamma \cdot h^2}{\sin 2\beta} = \mathbf{901\ lbs/ft} \quad (8)$$

Next, substituting the solutions to equations (4)-(8) into equations (1)-(3):

$$a = (37{,}481 - 35{,}565 \cdot \cos 18.4) \cos(18.4) = \mathbf{3{,}543\ lbs/ft} \quad (1)$$

$$\begin{aligned} b = -[&(37{,}481 - 35{,}565 \cdot \cos 18.4) \sin 18.4 \tan 32 \\ &+ (35{,}565 \tan 23 + 0) \sin 18.4 \cos 18.4 \\ &+ \sin 18.4 (0 + 901 \tan 32)] = \mathbf{-5{,}435\ lbs/ft} \end{aligned} \quad (2)$$

$$c = (35{,}565 \tan 23 + 0) \sin^2 18.4 \tan 32 = \mathbf{940\ lbs/ft} \quad (3)$$

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Finally, inserting the solutions to (1), (2) and (3) and solving the following equation:

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a} = \frac{-(-5435) + \sqrt{(-5435)^2 - 4 \cdot 3543 \cdot 940}}{2 \cdot 3543} = \mathbf{1.33}$$

Therefore, the factor of safety for the veneer stability of the drainage aggregate layer on a sideslope composite liner system is 1.33. This factor of safety satisfies the stability criterion of 1.3, as previously described.

RESULTS AND CONCLUSIONS

The results suggest that the proposed side slope riser trench liner system satisfies the design criteria of no geosynthetic tension development:

Soil Cover Layer Inclination (H:V)	Equipment Loading	Tension FS
3.0H:1V	NONE	1.33

Results of veneer stability analyses presented herein indicate that the interface friction angle (residual) of 28 degrees with no apparent peak cohesion textured geomembrane to sand subgrade interface meets the static factor of safety that satisfies that design criteria of no tension in the geosynthetic liner system.

REFERENCES

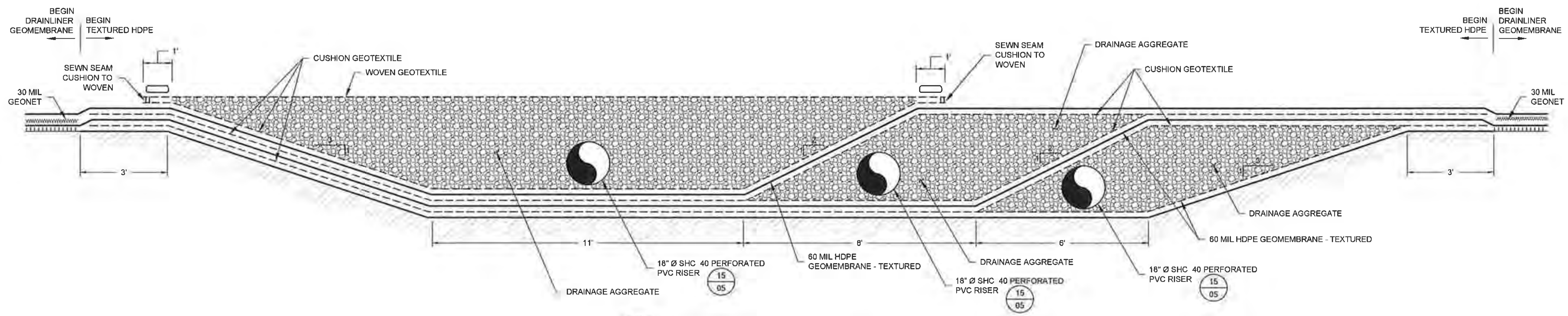
Abramson, Lee, Lee, Thomas, Sharma, Sunil, Boyce, Glenn (2002), "Slope Stability and Stabilization Methods." (*Attachment B*)

Koerner, R. K. and Soong, T.Y., [1998], "Analysis and Design of Veneer Cover Soils", Proceedings of the Sixth International Conference on Geosynthetics, Atlanta, Georgia, Vol. I, 1998. *(Attachment A)*

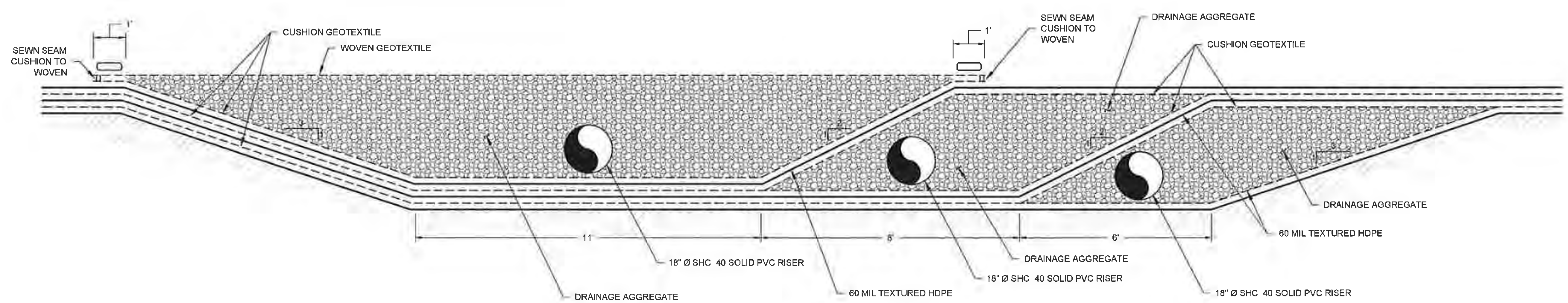
Written by:	**R. Flynn**	Date:	**11/14/12**	Reviewed by:	**G. Corcoran**	Date:	12/18/12
Client:	**EF**	Project:	**WMM- Cells 5A & 5B**	Project/ Proposal No.:	**SC0634**	Task No.:	**02**

NAVFAC (1982), "Foundations and Earth Structures, Design Manual - 7.2," Department of Navy, Naval Facilities Engineering Command, May 1982 *(Attachment C)*

Proceedings of the 4th GRI Seminar on the Topic of Landfill Closures. GRI – Dec 14, 1990. (*Attachment D*)



E
07
SECTION
SUMP SECTION (FLOOR)
SCALE: 1" = 2'



F
07
SECTION
SUMP SECTION (SLOPE)
SCALE: 1" = 2'

FIGURE 1

NOTES:

1. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF COMPACTED FILL OVERLYING SANDSTONE AS PER SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. SOIL THICKNESSES ARE MINIMUMS.
3. WOVEN GEOTEXTILE SHALL BE PROPEX 200 ST, SKAPS W 200, OR APPROVED EQUAL (WOVEN SLIT FILM, AOS = 40, FLOW RATE = 4 GPM/SF, GRAB STRENGTH = 200 LBS, PUNCTURE = 100 LBS.)

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858 674 6559

Energy Fuels Resources (USA) Inc

TITLE: DETAILS & SECTIONS IV

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL, BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED

SIGNATURE

DATE

DESIGN BY	GTC	DATE	JANUARY 2013
DRAWN BY	MMC	PROJECT NO	SC0634
CHECKED BY	RBF	FILE	SC0634-05-07
REVIEWED BY	GTC	DRAWING NO	08 OF 12
APPROVED BY	GTC		

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

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- The issue of appropriate normal stress is greatly complicated if gas pressures are generated in the underlying waste. These gas pressures will counteract some (or all) of the gravitational stress of the cover soil. The resulting shear strength, and subsequent stability, can be significantly decreased. See Liu et al (1997) for insight into this possibility.
- Shear rates necessary to attain drained conditions (if this is the desired situation) are extremely slow, requiring long testing times.
- Deformations necessary to attain residual strengths require large relative movement of the two respective halves of the shear box. So as not to travel over the edges of the opposing shear box sections, devices should have the lower shear box significantly longer than 300 mm. However, with a lower shear box longer than the upper traveling section, new surface is constantly being added to the shearing plane. This influence is not clear in the material's response or in the subsequent behavior.
- The attainment of a true residual strength is difficult to achieve. ASTM D5321 states that one should "run the test until the applied shear force remains constant with increasing displacement". Many commercially available shear boxes have insufficient travel to reach this condition.
- The ring torsion shearing apparatus is an alternative device to determine true residual strength values, but is not without its own problems. Some outstanding issues are the small specimen size, nonuniform shear rates along the width of the specimen, anisotropic shearing with some geosynthetics and no standardized testing protocol. See Stark and Poeppel (1994) for information and data using this alternative test method.

2.3 Various Types of Loadings

There are a large variety of slope stability problems that may be encountered in analyzing and/or designing final covers of engineered landfills, abandoned dumps and remediation sites as well as leachate collection soils covering geomembranes beneath the waste. Perhaps the most common situation is a uniformly thick cover soil on a geomembrane placed over the soil subgrade at a given and constant slope angle. This "standard" problem will be analyzed in the next section. A variation of this problem will include equipment loads used during placement of cover soil on the geomembrane. This problem will be solved with equipment moving up the slope and then moving down the slope.

Unfortunately, cover soil slides have occurred and it is felt that the majority of the slides have been associated with seepage forces. Indeed, drainage above a geomembrane (or other barrier material) in the cover soil cross section must be accommodated to avoid the possibility of seepage forces. A section will be devoted to this class of slope stability problems.

Lastly, the possibility of seismic forces exists in earthquake prone locations. If an earthquake occurs in the vicinity of an engineered landfill, abandoned dump or remediation site, the seismic wave travels through the solid waste mass reaching the upper surface of the cover. It then decouples from the cover soil materials, producing a horizontal force which must be appropriately analyzed. A section will be devoted to the seismic aspects of cover soil slope analysis as well.

All of the above actions are destabilizing forces tending to cause slope instability. Fortunately, there are a number of actions that can be taken to increase the stability of slopes.

Other than geometrically redesigning the slope with a flatter slope angle or shorter slope length, a designer can add soil mass at the toe of the slope thereby enhancing stability. Both toe berms and tapered soil covers are available options and will be analyzed accordingly. Alternatively, the designer can always use geogrids or high strength geotextiles within the cover soil acting as reinforcement materials. This technique is usually referred to as veneer reinforcement. Cases of both intentional and nonintentional veneer reinforcement will be presented.

Thus it is seen that a number of strategies influence slope stability. Each will be described in the sections to follow. First, the basic gravitational problem will be presented followed by those additional loading situations which tend to decrease slope stability. Second, various actions that can be taken by the designer to increase slope stability will be presented. The summary will contrast the FS-values obtained in the similarly crafted numeric examples.

3 SITUATIONS CAUSING DESTABILIZATION OF SLOPES

This section treats the standard veneer slope stability problem and then superimposes upon it a number of situations, all of which tend to destabilize slopes. Included are gravitational, construction equipment, seepage and seismic forces. Each will be illustrated by a design graph and a numeric example.

3.1 Cover Soil (Gravitational) Forces

Figure 3 illustrates the common situation of a *finite* length, uniformly thick cover soil placed over a liner material at a slope angle "β". It includes a passive wedge at the toe and has a tension crack of the crest. The analysis that follows is after Koerner and Hwu (1991), but comparable analyses are available from Giroud and Beech (1989), McKelvey and Deutsch (1991), Ling and Leshchinsky (1997) and others.

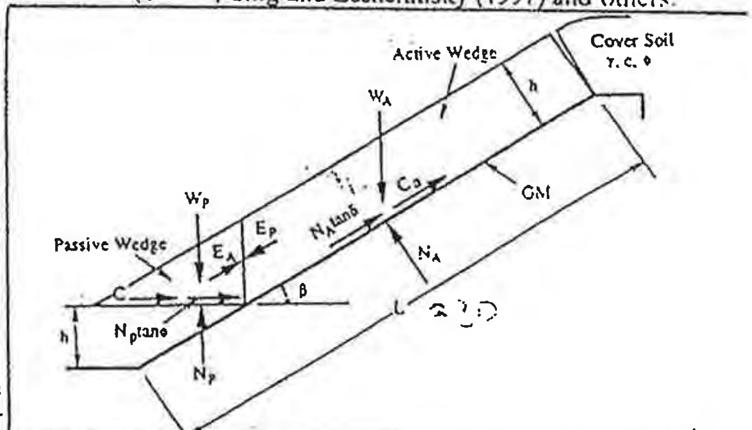

Figure 3. Limit equilibrium forces involved in a finite length slope analysis for a uniformly thick cover soil.

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The symbols used in Figure 3 are defined below.

- W_A = total weight of the active wedge
- W_P = total weight of the passive wedge
- N_A = effective force normal to the failure plane of the active wedge
- N_P = effective force normal to the failure plane of the passive wedge
- γ = unit weight of the cover soil
- h = thickness of the cover soil
- L = length of slope measured along the geomembrane
- β = soil slope angle beneath the geomembrane
- ϕ = friction angle of the cover soil
- δ = interface friction angle between cover soil and geomembrane
- C_a = adhesive force between cover soil of the active wedge and the geomembrane
- c_a = adhesion between cover soil of the active wedge and the geomembrane
- C = cohesive force along the failure plane of the passive wedge
- c = cohesion of the cover soil
- E_A = interwedge force acting on the active wedge from the passive wedge
- E_P = interwedge force acting on the passive wedge from the active wedge
- FS = factor of safety against cover soil sliding on the geomembrane

The expression for determining the factor of safety can be derived as follows:

Considering the active wedge,

$$W_A = \gamma h^2 \left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2} \right) \quad (3)$$

$$N_A = W_A \cos\beta \quad (4)$$

$$C_a = c_a \left(L - \frac{h}{\sin\beta} \right) \quad (5)$$

By balancing the forces in the vertical direction, the following formulation results:

$$E_A \sin\beta = W_A - N_A \cos\beta - \frac{N_A \tan\delta + C_a}{FS} \sin\beta \quad (6)$$

Hence the interwedge force acting on the active wedge is:

$$E_A = \frac{(FS)(W_A - N_A \cos\beta) - (N_A \tan\delta + C_a)\sin\beta}{\sin\beta(FS)} \quad (7)$$

The passive wedge can be considered in a similar manner:

$$W_P = \frac{\gamma h^2}{\sin 2\beta} \quad (8)$$

$$N_P = W_P + E_P \sin\beta \quad (9)$$

$$C = \frac{(c)(h)}{\sin\beta} \quad (10)$$

By balancing the forces in the horizontal direction, the following formulation results:

$$E_P \cos\beta = \frac{C + N_P \tan\phi}{FS} \quad (11)$$

Hence the interwedge force acting on the passive wedge is:

$$E_P = \frac{C + W_P \tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi} \quad (12)$$

By setting $E_A = E_P$, the resulting equation can be arranged in the form of the quadratic equation $ax^2 + bx + c = 0$ which in our case, using FS-values, is:

$$a(FS)^2 + b(FS) + c = 0 \quad (13)$$

where

$$a = (W_A - N_A \cos\beta)\cos\beta$$
$$b = -[(W_A - N_A \cos\beta)\sin\beta\tan\phi + (N_A \tan\delta + C_a)\sin\beta\cos\beta + \sin\beta(C + W_P \tan\phi)]$$
$$c = (N_A \tan\delta + C_a)\sin^2\beta\tan\phi \quad (14)$$

The resulting FS-value is then obtained from the solution of the quadratic equation:

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a} \quad (15)$$

When the calculated FS-value falls below 1.0, sliding of the cover soil on the geomembrane is to be anticipated. Thus a value of greater than 1.0 must be targeted as being the minimum factor of safety. How much greater than 1.0 the FS-value should be, is a design and/or regulatory issue. The issue of minimum allowable FS-values under different conditions will be assessed at the end of the paper. In order to better illustrate the implications of Eqs. 13, 14 and 15, typical design curves for various FS-values as a function of slope angle and interface friction angle are given in Figure 4. Note that the curves are developed specifically for the variables stated in the legend of the figure. Example 1 illustrates the use of the curves in what will be the standard example to which other examples will be compared.

Example 1:
Given a 30 m long slope with a uniformly thick 300 mm cover soil at a unit weight of 18 kN/m³. The soil has a friction angle of 30 deg. and zero cohesion, i.e., it is a sand. The cover soil is placed directly on a geomembrane as shown in Figure 3. Direct shear testing has resulted in a interface friction angle between the cover soil and geomembrane of 22 deg. with zero adhesion. What is the FS-value at a slope angle of 3(H)-to-1(V), i.e., 18.4 deg?

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Solution:

Substituting Eq. 14 into Eq. 15 and solving for the FS-value results in the following which is seen to be in agreement with the curves of Figure 4.

$$\left.\begin{aligned} a &= 14.7\,kN/m \\ b &= -21.3\,kN/m \\ c &= 3.5\,kN/m \end{aligned}\right\}\ FS = 1.25$$

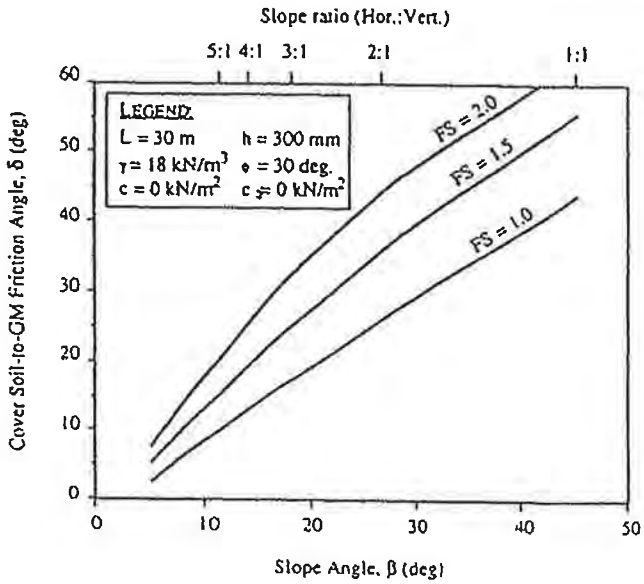


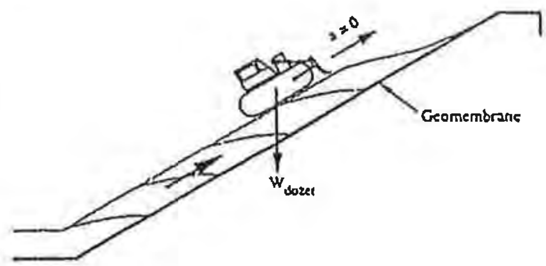
Figure 4. Design curves for stability of uniform thickness cohesionless cover soils on linear failure planes for various global factors-of-safety.

Comment:
In general, this is too low of a value for a final cover soil factor-of-safety and a redesign is necessary. While there are many possible options of changing the geometry of the situation, the example will be revisited later in this section using toe berms, tapered cover soil thickness and veneer reinforcement. Furthermore, this general problem will be used throughout the main body of this paper for comparison purposes to other cover soil slope stability situations.

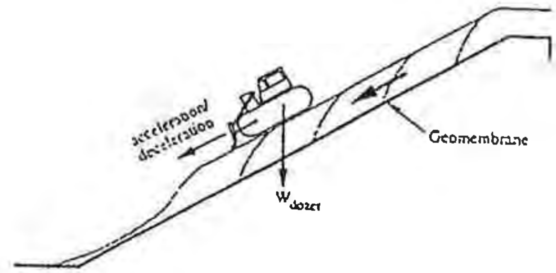
3.2 Tracked Construction Equipment Forces

The placement of cover soil on a slope with a relatively low shear strength inclusion (like a geomembrane) should always be from the toe upward to the crest. Figure 5a shows the recommended method. In so doing, the gravitational forces of the cover soil and live load of the construction equipment are compacting previously placed soil and working with an ever present passive wedge and stable lower-portion beneath the active wedge. While it is necessary to specify low ground pressure equipment to place the soil, the reduction of the FS-value for this situation of equipment working up the slope will be seen to be relatively small.

For soil placement down the slope, however, a stability analysis cannot rely on toe buttressing and also a dynamic stress should be included in the calculation. These conditions decrease the FS-value and in some cases to a great extent. Figure 5b shows this procedure. Unless absolutely necessary, it is not recommended to place cover soil on a slope in this manner. If it is necessary, the design must consider the unsupported soil mass and the dynamic force of the specific type of construction equipment and its manner of operation.



(a) Equipment backfilling up slope
(the recommended method)



(b) Equipment backfilling down slope
(method is not recommended)

Figure 5. Construction equipment placing cover soil on slopes containing geosynthetics.

For the first case of a bulldozer pushing cover soil up from the toe of the slope to the crest, the analysis uses the free body diagram of Figure 6a. The analysis uses a specific piece of tracked construction equipment (like a bulldozer characterized by its ground contact pressure) and dissipates this force or stress through the cover soil thickness to the surface of the geomembrane. A Boussinesq analysis is used, see Poulos and Davis (1974). This results in an equipment force per unit width as follows:

$$W_e = q\,w\,I \qquad (16)$$ *

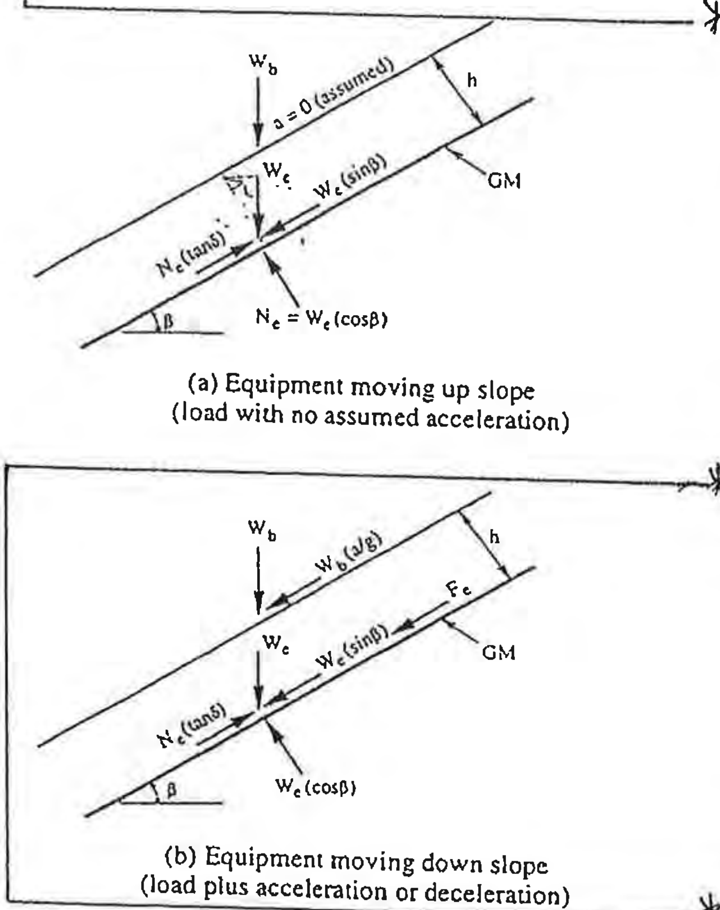
where

W_e = equivalent equipment force per unit width at the geomembrane interface

q = $W_b / (2 \times w \times b)$ *

Attachment A 3/L

W_b = actual weight of equipment (e.g., a bulldozer)
w = length of equipment track
b = width of equipment track
I = influence factor at the geomembrane interface see Figure 7



(a) Equipment moving up slope
(load with no assumed acceleration)

(b) Equipment moving down slope
(load plus acceleration or deceleration)

Figure 6. Additional (to gravitational forces) limit equilibrium forces due to construction equipment moving on cover soil (see Figure 3 for the gravitational soil force to which the above forces are added).

Upon determining the additional equipment force at the cover soil-to-geomembrane interface, the analysis proceeds as described in Section 3.1 for gravitational forces only. In essence, the equipment moving up the slope adds an additional term, W_e, to the W_A-force in Eq. 3. Note, however, that this involves the generation of a resisting force as well. Thus, the net effect of increasing the driving force as well as the resisting force is somewhat neutralized insofar as the resulting FS-value is concerned. It should also be noted that no acceleration/deceleration forces are included in this analysis which is somewhat optimistic. Using these concepts (the same equations used in Section 3.1 are used here), typical design curves for various FS-values as a function of equivalent ground contact equipment pressures and cover soil thicknesses are given in Figure 8. Note that the curves are developed specifically for the variables stated in the legend. Example 2a illustrates the use of the formulation.

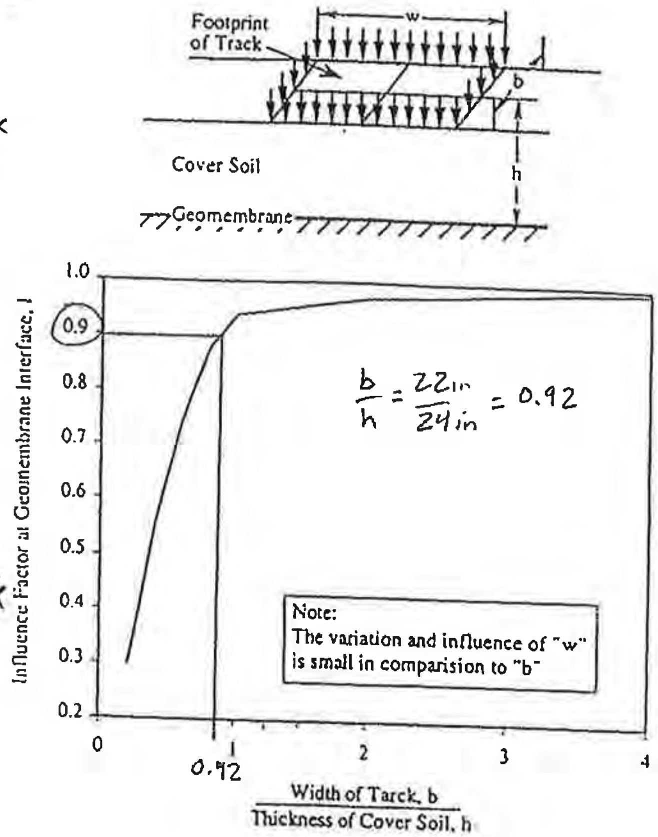


Figure 7. Values of influence factor, "I", for use in Eq. 16 to dissipate surface force of tracked equipment through the cover soil to the geomembrane interface, after Poulos and Davis (1974).

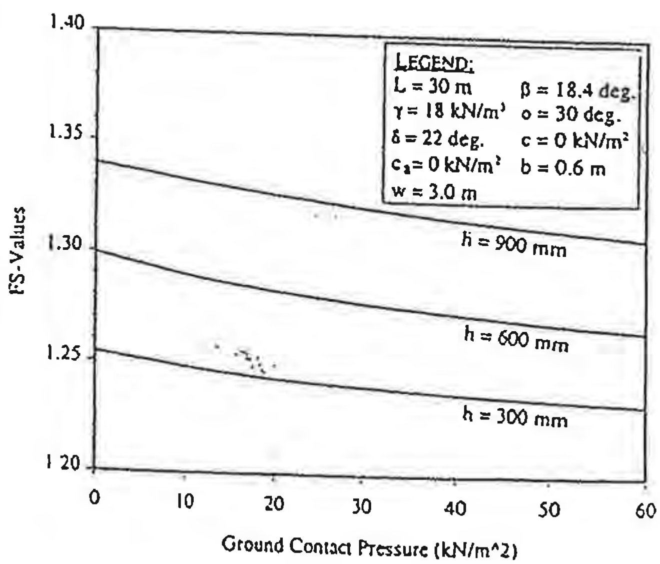


Figure 8. Design curves for stability of different thickness of cover soil for various values of tracked ground contact pressure construction equipment.

Example 2a:

Given 30 m long slope with uniform cover soil of 300 mm thickness at a unit weight of 18 kN/m^3. The soil has a friction angle of 30 deg. and zero cohesion, i.e., it is a sand. It is placed on the slope using a bulldozer moving from the toe of the slope up to the crest. The bulldozer has a ground pressure of 30 kN/m^2 and tracks that are 3.0 m long and 0.6 m wide. The cover soil to geomembrane friction angle is 22 deg. with zero adhesion. What is the FS-value at a slope angle of 3(H)-to-1(V), i.e., 18.4 deg.

Solution:
This problem follows Example 1 exactly except for the addition of the bulldozer moving up the slope. Using the additional equipment load Eq. 16, substituted into Eqs. 14 and 15 results in the following.

$$\left.\begin{aligned} a &= 73.1\ kN/m \\ b &= -104.3\ kN/m \\ c &= 17.0\ kN/m \end{aligned}\right\} FS = 1.24$$

Comment:
While the resulting FS-value is low, the result is best assessed by comparing it to Example 1, i.e., the same problem except without the bulldozer. It is seen that the FS-value has only decreased from 1.25 to 1.24. Thus, in general, a low ground contact pressure bulldozer placing cover soil up the slope with negligible acceleration/deceleration forces does not significantly decrease the factor-of-safety.

For the second case of a bulldozer pushing cover soil down from the crest of the slope to the toe as shown in Figure 5b, the analysis uses the force diagram of Figure 6b. While the weight of the equipment is treated as just described, the lack of a passive wedge along with an additional force due to acceleration (or deceleration) of the equipment significantly changes the resulting FS-values. This analysis again uses a specific piece of construction equipment operated in a specific manner. It produces a force parallel to the slope equivalent to W_b (a/g), where W_b = the weight of the bulldozer, a = acceleration of the bulldozer and g = acceleration due to gravity. Its magnitude is equipment operator dependent and related to both the equipment speed and time to reach such a speed, see Figure 9. A similar behavior will be seen for deceleration.

The acceleration of the bulldozer, coupled with an influence factor "I" from Figure 7, results in the dynamic force per unit width at the cover soil to geomembrane interface, "F_e". The relationship is as follows:

$$F_e = W_e\left(\frac{a}{g}\right) \qquad (17)$$

where

F_e = dynamic force per unit width parallel to the slope at the geomembrane interface,

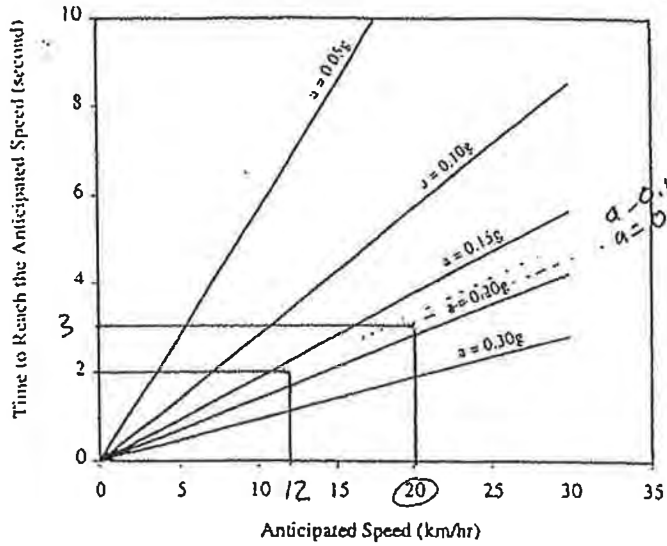


Figure 9. Graphic relationship of construction equipment speed and rise time to obtain equipment acceleration.

W_e = equivalent equipment (bulldozer) force per unit width at geomembrane interface, recall Eq. 16.
β = soil slope angle beneath geomembrane
a = acceleration of the bulldozer
g = acceleration due to gravity

Using these concepts, the new force parallel to the cover soil surface is dissipated through the thickness of the cover soil to the interface of the geomembrane. Again, a Boussinesq analysis is used, see Poulos and Davis (1974) The expression for determining the FS-value can now be derived as follows:

Considering the active wedge, and balancing the forces in the direction parallel to the slope, the following formulation results:

$$E_A + \frac{(N_e + N_A)\tan\delta + C_a}{FS} = (W_A + W_e)\sin\beta + F_e \qquad (18)$$

where

N_e = effective equipment force normal to the failure plane of the active wedge
= $W_e \cos\beta$ (19)

Note that all the other symbols have been previously defined.

The interwedge force acting on the active wedge can down be expressed as:

$$E_A = \frac{(FS)\left[(W_A + W_e)\sin\beta + F_e\right]}{FS} - \frac{\left[(N_e + N_A)\tan\delta + C_a\right]}{FS} \qquad (20)$$

The passive wedge can be treated in a similar manner. The following formulation of the interwedge force acting on the passive wedge results:

Attachment A 5/6

$$E_P = \frac{C + W_P \tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi} \tag{21}$$

By setting $E_A = E_P$, the following equation can be arranged in the form of Eq. 13 in which the "a", "b" and "c" terms are as follows:

$$a = \left[(W_A + W_e)\sin\beta + F_e\right]\cos\beta$$

$$b = -\left\{\left[(N_e + N_A)\tan\delta + C_a\right]\cos\beta + \left[(W_A + W_e)\sin\beta + F_e\right]\sin\beta\tan\phi + (C + W_P\tan\phi)\right\}$$

$$c = \left[(N_e + N_A)\tan\delta + C_a\right]\sin\beta\tan\phi \tag{22}$$

Finally, the resulting FS-value can be obtained using Eq. 15. Using these concepts, typical design curves for various FS-values as a function of equipment ground contact pressure and equipment acceleration can be developed, see Figure 10. Note that the curves are developed specifically for the variables stated in the legend. Example 2b illustrates the use of the formulation.

Example 2b:

Given a 30 m long slope with uniform cover soil of 300 mm thickness at a unit weight of 18 kN/m^3. The soil has a friction angle of 30 deg. and zero cohesion, i.e., it is a sand. It is placed on the slope using a bulldozer moving from the crest of the slope down to the toe. The bulldozer has a ground contact pressure of 30 kN/m^2 and tracks that are 3.0 m long and 0.6 m wide. The estimated equipment speed is 20 km/hr and the time to reach this speed is 3.0 sec. The cover soil to geomembrane friction angle is 22 deg. with zero adhesion. What is the FS-value at a slope angle of 3(H)-to-1(V), i.e., 18.4 deg.

Solution:

Using the design curves of Figure 10 along with Eqs. 22 substituted into Eq. 15 the solution can be obtained:

- From Figure 9 at 20 km/hr and 3.0 sec. the bulldozer's acceleration is 0.19g.
- From Eq. 22 substituted into Eq. 15 we obtain

$$\left.\begin{aligned} a &= 88.8\,\text{kN/m} \\ b &= -107.3\,\text{kN/m} \\ c &= 17.0\,\text{kN/m} \end{aligned}\right\} \quad FS = 1.03$$

Comment:

This problem solution can now be compared to the previous two examples:

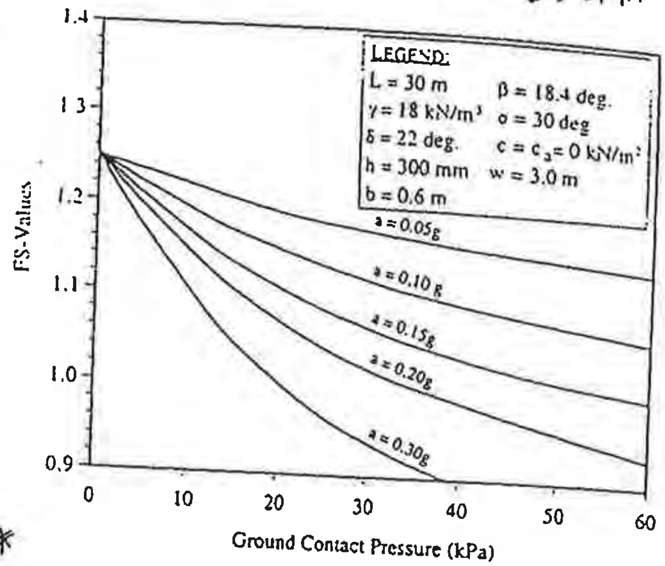


Figure 10. Design curves for stability of different construction equipment ground contact pressure for various equipment accelerations.

Ex. 1:	cover soil alone with no bulldozer loading	FS = 1.25
Ex. 2a:	cover soil plus bulldozer moving up slope	FS = 1.24
Ex. 2b:	cover soil plus bulldozer moving down slope	FS = 1.03

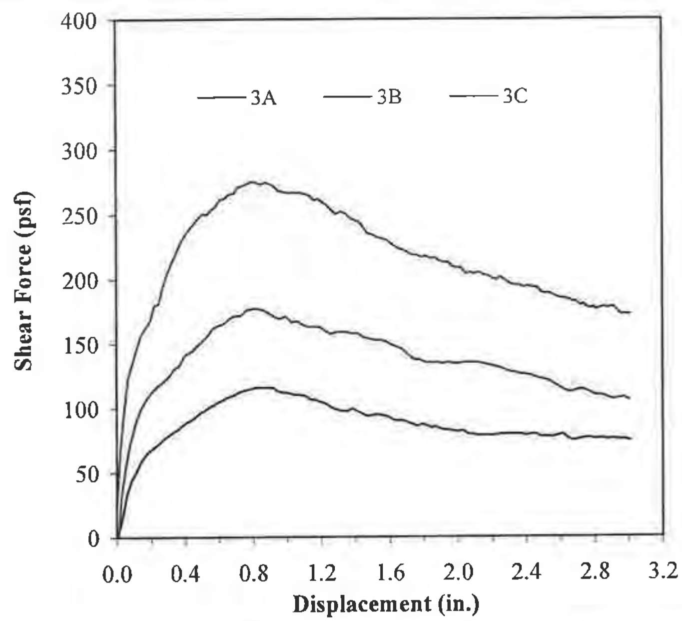
The inherent danger of a bulldozer moving down the slope is readily apparent. Note, that the same result comes about by the bulldozer decelerating instead of accelerating. The sharp breaking action of the bulldozer is arguable the more severe condition due to the extremely short times involved when stopping forward motion. Clearly, only in unavoidable situations should the cover soil placement equipment be allowed to work down the slope. If it is unavoidable, an analysis should be made of the specific stability situation and the construction specifications should reflect the exact conditions made in the design. The maximum allowable weight and ground contact pressure of the equipment should be stated along with suggested operator movement of the cover soil placement operations. Truck traffic on the slopes can also give as high, or even higher, stresses and should be avoided unless adequately designed. Additional detail is given in McKelvey (1994). The issue of access ramps is a unique subset of this example and one which deserves focused attention due to the high loads and decelerations that often occur.

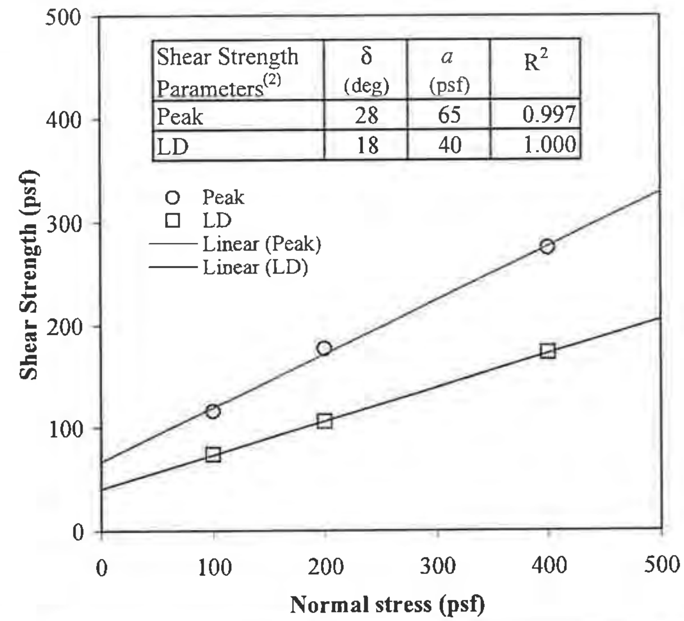
3.3 Consideration of Seepage Forces

The previous sections presented the general problem of slope stability analysis of cover soils placed on slopes under different conditions. The tacit assumption throughout was that either permeable soil or a drainage layer was placed above the barrier layer with adequate flow capacity to efficiently remove permeating water safely way from the cross section. The amount of water to be removed is obviously a site specific situation. Note that in extremely

GEOSYNTEC CONSULTANTS - DENISON MINES – Cell 4B
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
SKAPS GE116 nonwoven geotextile with non heat-treated side down/
GSE 60-mil B/W textured HDPE geomembrane #104152824 with white side up/
Lower Shear Box: Concrete sand





Shear Strength Parameters[2]	δ (deg)	a (psf)	R^2
Peak	28	65	0.997
LD	18	40	1.000

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	GCL Soaking Stress (psf)	GCL Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Subgrade Soil γ_d (pcf)	Subgrade Soil ω_i (%)	Subgrade Soil ω_f (%)	Cover Soil γ_d (pcf)	Cover Soil ω_i (%)	Cover Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_P (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
3A	12 x 12	100	0.2	-	-	-	-	-	-	-	-	-	-	-	-	116	74	(1)
3B	12 x 12	200	0.2	-	-	-	-	-	-	-	-	-	-	-	-	177	106	(1)
3C	12 x 12	400	0.2	-	-	-	-	-	-	-	-	-	-	-	-	275	173	(1)

NOTES:
(1) Shear failure occurred at the interface between the non heat-treated side of geotextile and white side of geomembrane.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

SGI TESTING SERVICES, LLC

DATE OF REPORT:	5/24/2010
FIGURE NO.	C-3
PROJECT NO.	SGI10027
DOCUMENT NO.	
FILE NO.	

ATTACHMENT B(1/1)

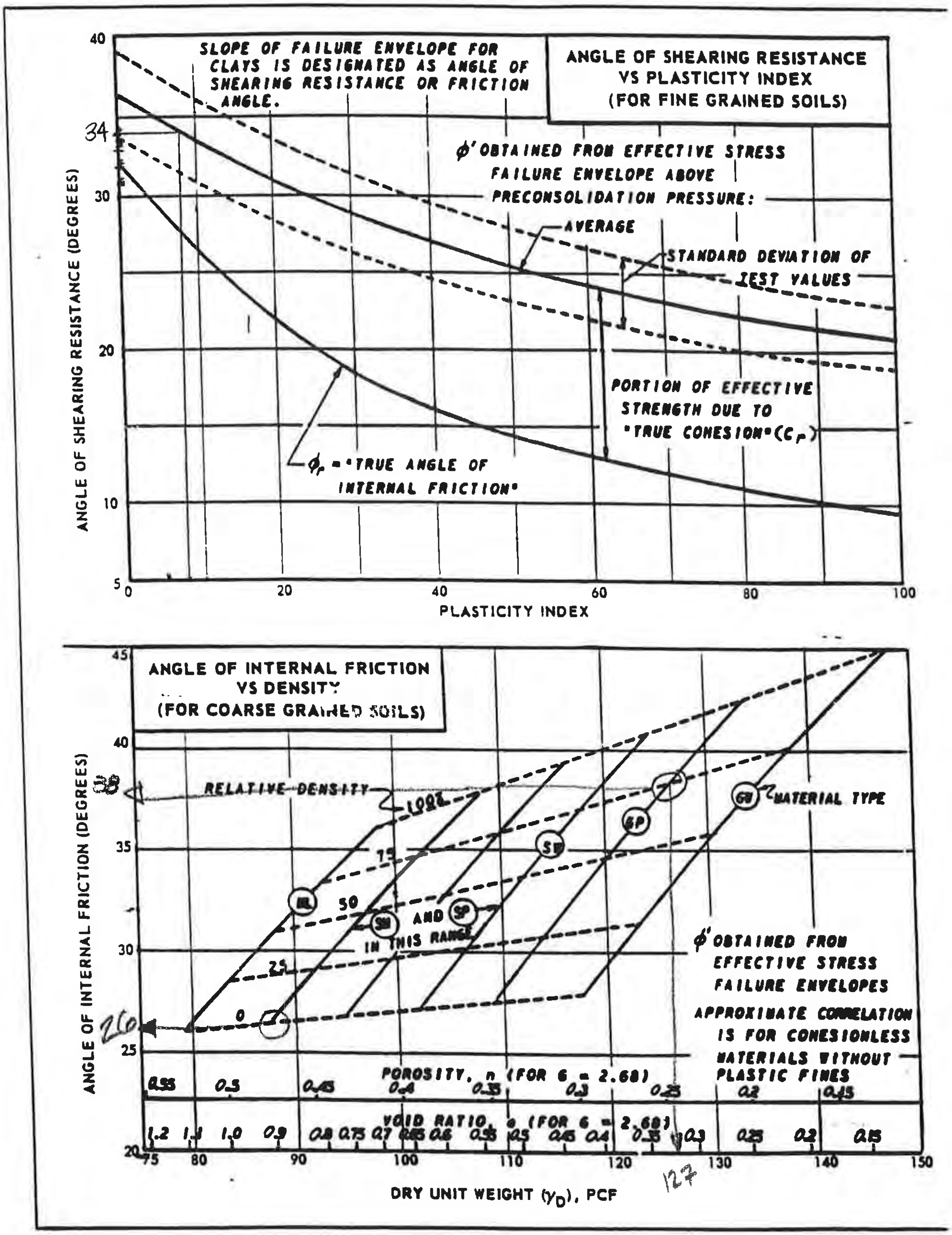


FIGURE 3-7
Correlations of Strength Characteristics

NAVFAC DM7-03, 1986

ATTACHMENT C
(1/1)

FROM - PROCEEDINGS OF THE 4th GRI SEMINAR ON THE TOPIC OF LANDFILL CLOSURES
GRI - DEC. 14, 1990

TABLE 6
TMI COEFFICIENT OF FRICTION TEST RESULTS

GEONET VS. GEOSYNTHETICS INTERFACE FRICTION

NONWOVEN, NEEDLEPUNCHED	20°
NONWOVEN, HEATBONDED	17°
MONOFILAMENT	14°
MULTIFILAMENT	20°
SLIT FILM	14°
HDPE - SMOOTH	16°
HDPE - ROUGH	18°
CSPE	24°
VLDPE	20°
PVC	17°

GEOTEXTILE VS. GEOMEMBRANE INTERFACE FRICTION

GEOTEXTILE INTERFACE	HDPE	HDPE (ROUGH)	PVC	CSPE	VLDPE
WOVEN, SLIT FILM	18°	17°	23°	25°	22°
WOVEN, MONOFILAMENT	21°	14°	22°	23°	22°
WOVEN, MULTIFILAMENT	21°	25°	29°	27°	22°
NONWOVEN, HEATBONDED	23°	23°	19°	23°	19°
NONWOVEN, NEEDLEPUNCHED	19°	34°	22°	21°	20°

Attachment D 1/1

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF** Project: **White Mesa Mill – Cells 5A and 5B** Project/ Proposal No.: **SC0634** Task No. **02**

Title of Computations **ANALYSIS OF SLIMES DRAIN**

Computations by:	Signature		Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		Date 12/13/12
	Printed Name	Gregory T. Corcoran, P.E.	
	Title	Principal	
Computations Checked by:	Signature		Date 12/10/12
	Printed Name	Jay Griffin	
	Title	Senior Staff Engineer	
Computations backchecked by: (originator)	Signature		Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature		Date 12/13/12
	Printed Name	Gregory T. Corcoran, P.E.	
	Title	Principal	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	11/11/12	Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	White Mesa Mill – Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

PURPOSE AND METHOD OF ANALYSIS

The purpose of this calculation package is to demonstrate that the proposed "slimes drain system" will dewater the tailings at the site within a reasonable time.

Fluid flow rate in porous media will be evaluated using Darcy's law.

ASSUMPTIONS

- This project involves the construction of two 42 acre triple lined tailings cells (Cells 5A and 5B) that are approximately 46 feet deep at their deepest point (Cell 5B) and 28 feet deep at the shallowest point with an average depth of 37 feet. The liquids level in the cell will be kept a minimum of 3 feet below the top of the berm (free-board). Therefore, the maximum depth of liquid in the cell will be 43 feet at the start of dewatering with an average and minimum depth of liquid of 34 and 25 feet, respectively.
- The cell will be filled with -28 mesh (US No. 30 sieve) tailings, largely consisting of fine sands and silts, with some clay. Results of grinding test sieve analyses, which are reported based on Tyler Mesh sieve sizes, are presented in Table 1. The grinding test data report is presented in Attachment A. Sieve to Tyler Mesh conversions are presented in Attachment B.
- The tailings will be placed within the cell in a slurry form under the surface of the free liquid contained within the cell. This placement methodology is anticipated to result in a low density (no compaction) soil structure. Therefore, saturated hydraulic conductivity and total porosity are anticipated to be higher than similar soils that are compacted.
- Based on the grinding report (Attachment A), tailings are comprised of approximately 6% medium sand, 49% fine sand, and 45% silt and clay size particles (Table 1).
- Based on the gradation of the tailings (Table 1) from the grinding report (Attachment A), the tailings would be classified as silty sand (SM) by the unified soil classification system (USCS). According to the Hydrologic Evaluation of Landfill Performance (HELP) Model Engineering Documentation (Attachment C), **low density** SM soils would exhibit saturated hydraulic

conductivities of between 1.7×10^{-3} cm/sec and 5.2×10^{-4} cm/sec and **low density** silt (ML) and sandy clay (SC) would exhibit saturated hydraulic conductivities of between 3.7×10^{-4} cm/sec and 1.2×10^{-4} cm/sec. The geomean of these two groups of soils, which are gradationally similar to the tailings, is 4.74×10^{-4} cm/sec (Table 2). According to Cedergren (Attachment D), under a normal stress of 2 tons per square foot (approximate normal stress on deeper tailings in the cell), medium sand, fine sand, silt, and silty clay would exhibit a saturated hydraulic conductivities of approximately 2×10^{-2} cm/sec, 1×10^{-2} cm/sec, 1×10^{-4} cm/sec 5×10^{-7} cm/sec, respectively. The geomean of these three soil types, which are gradationally similar to the tailings, is 3.31×10^{-4} cm/sec. The more conservative, lower hydraulic conductivity of 3.31×10^{-4} cm/sec, will be used in this analysis.

- Based on the gradation of the tailings from the grinding report, the tailings would be classified as silty sand (SM) by the unified soil classification system (USCS). According to the HELP Model Engineering Documentation (Attachment C), **low density** SM soils would exhibit drainable porosity of between 0.251 and 0.332 and **low density** silt (ML) and sandy clay (SC) would exhibit drainable porosity of between 0.154 and 0.231. The average of these two groups of soils, which are gradationally similar to the tailings, is 0.253 (Table 2). According to the HELP Model Engineering Documentation, medium sand, fine sand, silt, and silty clay would exhibit drainable porosity values of 0.35, 0.29, 0.14, and 0.11, respectively. The average of these three soil types, where are gradationally similar to the tailings, is 0.22. Since the average drainable porosity of 0.22 corresponds to the lower hydraulic conductivity (higher density, lower permeability, lower porosity) selected above, this value will be used in this analysis.

- The permeability of the tailings is isotropic.

- Darcy's law will be used to compute water flow velocities.

- The proposed slimes drain system will consist of a series of strip drains (geotextile wrapped HDPE core, 1" thick, 12" wide, with a transmissivity of 29 (gal/min/ft), which connect to a perforated 4" diameter PVC header pipe that is bedded in drainage aggregate and wrapped in a woven geotextile. The PVC pipe will convey the liquid to the sump for removal.

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- The slimes drain spacing will be 50' and will be continuous across the base of the cell (Figure 1).

CALCULATIONS

The flow geometry for the maximum depth of liquid within the cell is illustrated on Figure 2 and used to compute the emptying time for the proposed slimes drain system.

Calculate the flow into a unit length of strip drain for the various hydraulic gradient conditions.

At the start of cell dewatering, the maximum depth of liquid will vary between 25 feet at the shallow end and 43 feet at the deep end, with an average depth of approximately 34 feet. As the water level drops within the cell, the length of the longest flow path and the associated hydraulic gradient will continually change with time.

The total volume to be drained by a unit length of strip, Q, can be calculated using Darcy's law as follows:

$Q = kiA$

where:

k = hydraulic conductivity of tailings = $3.31\text{x}10^{-4}$ cm/sec = $6.51\text{x}10^{-4}$ ft/min

i = gradient along flowpath = $\frac{dh}{dl} = \frac{43}{49.7} = 0.87$ (see Figure 2)

A = area of strip drain where flow will pass =1.17 ft^2/ft (see Figure 3)

$$Q = (6.57 \times 10^{-4} \frac{ft}{\text{min}})(0.87)(1.17\ ft^2)$$

$$Q = 6.69x10^{-4} \frac{ft^3}{\text{min}} \times 7.48 \frac{gal}{ft^3} = 5.0x10^{-3} \frac{gal}{\text{min}}$$

For each one foot incremental drop in fluid elevation within the cell, the total volume to be drained by a unit length of strip drain is as follows:

V = 1 ft unit length x 1ft depth x 50 ft width x 0.22 (drainable porosity) = 11 ft^3 of free liquid

Therefore, the time to drain the first one foot of liquid within the cell can be estimated as follows:

$t = V/Q = 11\ ft^3 / 6.69x10^{-4}\ ft^3/min = 16{,}731$ minutes = 11.62 days

Tables 3, 4, and 5 depict the calculations for the maximum (43 feet), average (34 feet), and minimum (25 feet) cell liquid depth, respectively. The results of the maximum depth calculations indicate that the proposed slimes drain system will allow the tailings contained in Cell 5B to drain within approximately 5.63 years.

Calculate the design flow rate of the strip drains.

For this calculation we will assume that the strip drains have a flow rate of 29 gallon per minute per foot (Attachment E, GDE Multi-Flow, 2006), a width of 12" and that flow is occurring under a gradient of 0.01. The assumed gradient of 0.01 is less than the actual gradient, which is between 0.011 and 0.014; therefore, this estimate is conservative.

Design Flow rate of strip drains:

$$q = \Theta i$$

where:

q = flowrate per unit width

$$i = \frac{dh}{dl} = 0.01$$

Θ = transmissivity = 29 gpm/ft

To account for detrimental effects on the geonet such as chemical clogging, biological clogging, installation defects, and creep, partial factors of safety were used to reduce the strip drain transmissivity. Using recommended partial factor of safety values from Koerner (1999) (Attachment F, 2/4), the reduced transmissivity is calculated as follows:

$$\Theta_{allow} = \Theta_{ult}\left[\frac{1}{FS_{IN} \times FS_{CR} \times FS_{CC} \times FS_{BC}}\right]$$

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where:

Θ_{allow} = allowable flow

$\Theta_{ultimate}$ = calculated value of flow

FS_{IN} = factor of safety for installation, 1.5 (CQA performed during installation)

FS_{CR} = factor of safety for creep, 2.0

FS_{CC} = factor of safety for chemical clogging, 2.0

FS_{BC} = factor of safety for biological clogging, 1.0 (low pH precludes biological activity)

The factors of safety are used to calculate the allowable transmissivity:

$$\Theta_{allow} = 29\frac{gpm}{ft}\left[\frac{1}{1.5\times 2.0\times 2.0\times 1.0}\right] = 4.83\frac{gpm}{ft}$$

Using this transmissivity value, the average factor of safety for flow in the strip composite is estimated to be as follows:

$$FS = \frac{Q_D}{Q_R} = \frac{4.83\ gpm}{0.0049\ gpm} = 986 \quad \text{(Acceptable)}$$

The average allowable flow rate is much larger than the average maximum flow rate, even with the built-in partial factors of safety. Furthermore, as indicated on Tables 3, 4, and 5, the calculated flow rate within the strip drain decreases with time, which further increases the factor of safety.

<u>Calculate the minimum required AOS and permittivity for filtration geotextile component of strip drain</u>

The geotextile serves as a filter between the strip composite core and the tailings material. The geotextile minimizes fine particles of the tailings material from migrating into the strip composite, yet allows water to penetrate. Migration of fine particles would have the adverse effect of decreasing the transmissivity of the strip composite layer.

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To be conservative in these calculations, the tailings material soil is assumed to consist of more than 20 percent clay.

The retention requirements for geotextiles can be evaluated using the chart entitled "Soil Retention Criteria for Steady-State Flow Conditions" developed by Luettich et al., (1991) (Attachment G, 1/3). This chart uses soil properties to evaluate the required apparent opening size (AOS or O_{95}) of the geotextile. Using the Soil Retention Chart, the AOS of the filter fabrics shall be:

$O_{95} < 0.21$ mm, which corresponds to sieve No. 70.

The permeability of the filter fabric must be evaluated to allow flow through the filter fabric. The following equation can be used to evaluate the minimum allowable geotextile permeability:

$k_g > i_s k_s$ (Luettich et al. (1991), Att. G, 2/3)

where: k_g = permeability of geotextile (cm/s)
i_s = hydraulic gradient (dimensionless)
k_s = permeability of the tailings material (cm/s)

Hydraulic Gradient, i: Attachment G, page 3/3 from Luettich et al. (1991) lists typical hydraulic gradients for various geotextile drainage applications. In this attachment, a hydraulic gradient of 10 for liquid impoundment applications is recommended.

Soil Permeability, k_s: A permeability of 3.31×10^{-4} cm/s was assumed for the tailings material, as previously defined.

Therefore,

$k_g > \quad i_s k_s = (10)(3.31\text{x}10^{-4}\text{ cm/s})$
$k_g > \quad 3.31 \times 10^{-3}$ cm/s

Koerner (1999) suggests applying partial factors of safety to the ultimate flow capacity of the geotextile to account for clogging of the geotextile. Using recommendations given in Table 2.12 on p. 150 of Koerner (1999) (Attachment F, 1/4), the following partial safety values were applied:

soil clogging and blinding: 10 (5 – 10)

creep reduction of voids:	2.0 (1.5 – 2.0)
intrusion into voids:	1.2 (1.0 – 1.2)
chemical clogging:	1.5 (1.2 – 1.5)
biological clogging (low pH precludes biological activity):	1.0 (2 – 10)

Therefore,

$k_g >$ $(3.31 \times 10^{-3})(10)(2)(1.2)(1.5)(1)$

$k_g >$ 0.12 cm/s

The thickness of a typical nonwoven needled punched 4 oz/yd^2 (135 g/m^2) geotextile is approximately 40 mils (0.10 cm), see Attachment H. Dividing the permeability by the thickness of the geotextile results in a required minimum permittivity of 1.2 sec^{-1}. The geotextile used in this project has a permittivity of 2.0 sec^{-1}, which is greater than the required permittivity.

Check Pipe Flow Rate

Based on calculations from previous sections, the maximum daily flow rate to the sump is estimated to be 148 gpm (0.33 cfs) (Table 3). The capacity of the pipe is calculated based on Manning's equation for gravity flow as follows:

$$Q = \frac{1.486}{n} R_h^{2/3} S^{1/2} A$$

Where

n = 0.010 (Koerner (1999), Attachment F, 4/4)
S = Slope of liner (ft/ft) = 1.75 %
R_h = hydraulic radius, ft
Q = flow rate, cubic feet per second, ft^3/s
A = flow area, ft^2

Assuming 4-inch pipe:

A = π D^2/4 = 12.6 sq. inches = 0.088 ft^2
R_h = Area (π D^2/4)/Wetted Perimeter (π D)
= D/4 = 1 in = 0.083 ft

$$Q = \frac{1.486}{0.010} 0.083^{2/3} 0.0175^{1/2} 0.088 \text{ ft}^2 = 0.33 \frac{\text{ft}^3}{s} = 147\ gpm$$

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Since 147 gpm is less than the maximum required 148 gpm, this calculation shows that the 4-inch diameter slimes drain pipe is the limiting factor for dewatering the tailings in the early phase of dewatering (high flow rates). However, it does not mean that the pipe will be unable to handle this flow, but rather the pipe will require additional time to drain. The additional time needed is computed in the following section.

Effect of Maximum Pipe Capacity on Drainage Time

The maximum capacity of the pipe is 147 gpm, as computed above. Assuming the cell's total lateral length of strip drain is approximately 30,120 feet, the flow rate, per foot of strip drain is calculated to be:

$$\text{Flow Rate} = \frac{147\ gallon}{\text{min}} * \frac{60\,\text{min}}{1\ hr} * \frac{24\ hr}{1\ day} * \frac{1\,ft^3}{7.48\ gallon} * \frac{1}{30{,}120\,feet} = 0.94\frac{ft^3}{day}$$

The time needed to de-water first layer is:

$$Time = \frac{Volume}{Drain\ \ length\ \times flow\ rate} = \frac{(50\ x\ 1\ x\ 1\ x\ 0.22)\ ft^3}{1\ ft \times 0.94\ \dfrac{ft^3}{day}} = 11.70\ days$$

The difference between the maximum daily flow rate drainage time (11.62 days) and the maximum daily flow the pipe is able to deliver (11.70 days) is negligible. Therefore, the cell will take an estimated 5.63 years to drain.

Effect of Precipitation on Drainage Time

To account for the effect of precipitation added to the tailings cell, the HELP Model was used to estimate the average annual leakage through a 3 foot thick (tailings above the liquid) layer of silty sand material (Attachment I). HELP Model default parameters were used along with a maximum 16 inch evaporative zone (conservative for dry climate) and weather data from Grand Junction, Colorado. The model was performed for a 10 year period and included precipitation events ranging from 5.83 to 10.36 inches per year.

The results of this analysis suggest that a maximum average annual percolation through the 3 foot soil layer above the liquid will be approximately 12 ft^3 per acre or 504 ft^3 (3,770 gal.) for the entire Cell 5B area of 42 acres.

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The average flow rate during Cell 5B dewatering, as calculated from Table 3 is equal to 83 gpm (119,520 gallon/day).

The time required to drain the additional volume of precipitation in the tailings is computed using the following equation:

$$Time = \frac{Volume}{FlowRate} = \frac{3{,}770\ gal}{119{,}520 \frac{gal}{day}} = 0.03\ days$$

The additional time that the pond will require to empty due to precipitation is insignificant. Therefore, the total estimated time to dewater Cell 5B is 5.63 years.

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(Attachment D)

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(Attachment E)

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(Attachment C)

Koerner, R. M., "Designing With Geosynthetics," 4th Ed., Prentice Hall, 1999.
(Attachment F)

Luettich, S.M., Giroud, J.P., and Bachus, R.C., (1991), "Geotextile Filter Design Manual, report prepared for Nicolon Corporation, Norcross, GA.
(Attachment G)

Amoco Fabrics and Fibers Company, (1991), "*Amoco Waste Related Geotextiles.*"
(Attachment H)

Written by:	R. Flynn	Date:	11/11/12	Reviewed by:	G. Corcoran	Date:	12/13/12
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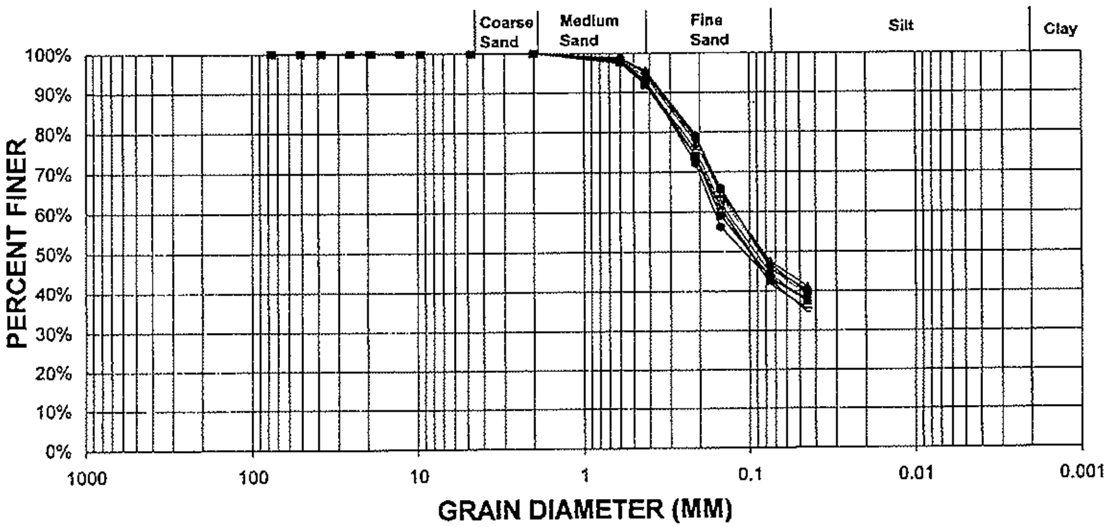
Amoco Fabrics and Fibers Company, (1991), "*Amoco Waste Related Geotextiles.*" *(Attachment H)*

Table 1
DSM Screen Undersize Gradation

SIEVE ANALYSIS

Sieve No.	Diameter (mm)	Grinding Test 1 Wt. Retained (grams)	Grinding Test 1 % Retained	Grinding Test 1 % Finer	Grinding Test 2A Wt. Retained (grams)	Grinding Test 2A % Retained	Grinding Test 2A % Finer	Grinding Test 2B Wt. Retained (grams)	Grinding Test 2B % Retained	Grinding Test 2B % Finer	Grinding Test 3A Wt. Retained (grams)	Grinding Test 3A % Retained	Grinding Test 3A % Finer	Grinding Test 3B Wt. Retained (grams)	Grinding Test 3B % Retained	Grinding Test 3B % Finer
3 in.	76.2	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
2 in.	50.8	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 1/2 in.	38.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 in.	25.4	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/4 in.	19.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1/2 in.	12.7	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/8 in.	9.530	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 4	4.750	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 10	2.000	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 30	0.600	1.2	1.2%	98.8%	2.0	2.0%	98.0%	1.7	1.7%	98.3%	2.4	2.4%	97.6%	1.9	1.9%	98.1%
No. 40	0.425	4.6	4.6%	95.4%	7.3	7.3%	92.7%	6.0	6.0%	94.0%	8.1	8.1%	91.9%	6.9	6.9%	93.1%
No. 70	0.212	20.8	20.8%	79.2%	24.5	24.5%	75.5%	22.6	22.6%	77.4%	26.2	26.2%	73.8%	27.9	27.9%	72.1%
No. 100	0.150	34.8	34.8%	65.2%	38.1	38.1%	61.9%	35.5	35.5%	64.5%	41.0	41.0%	59.0%	43.9	43.9%	56.1%
No. 200	0.075	53.4	53.4%	46.6%	55.7	55.7%	44.3%	52.5	52.5%	47.5%	56.6	56.6%	43.4%	57.4	57.4%	42.6%
No. 325	0.045	60.5	60.5%	39.5%	62.7	62.7%	37.3%	58.8	58.8%	41.2%	62.5	62.5%	37.5%	61.9	61.9%	38.1%
Pan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sieve No.	Diameter (mm)	Grinding Test 6A Wt. Retained (grams)	Grinding Test 6A % Retained	Grinding Test 6A % Finer	Grinding Test 6B Wt. Retained (grams)	Grinding Test 6B % Retained	Grinding Test 6B % Finer	Grinding Test 4A Wt. Retained (grams)	Grinding Test 4A % Retained	Grinding Test 4A % Finer	Grinding Test 4B Wt. Retained (grams)	Grinding Test 4B % Retained	Grinding Test 4B % Finer
3 in.	76.2	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
2 in.	50.8	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 1/2 in.	38.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 in.	25.4	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/4 in.	19.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1/2 in.	12.7	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/8 in.	9.530	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 4	4.750	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 10	2.000	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 30	0.600	1.3	1.3%	98.7%	1.0	1.0%	99.0%	2.7	2.7%	97.3%	2.7	2.7%	97.3%
No. 40	0.425	5.2	5.2%	94.8%	4.7	4.7%	95.3%	7.6	7.6%	92.4%	7.3	7.3%	92.7%
No. 70	0.212	21.7	21.7%	78.3%	21.4	21.4%	78.6%	26.2	26.2%	73.8%	25.9	25.9%	74.1%
No. 100	0.150	34.1	34.1%	65.9%	35.9	35.9%	64.1%	38.7	38.7%	61.3%	39.2	39.2%	60.8%
No. 200	0.075	54.4	54.4%	45.6%	54.4	54.4%	45.6%	57.3	57.3%	42.7%	58.3	58.3%	41.7%
No. 325	0.045	59.7	59.7%	40.3%	61.1	61.1%	38.9%	65.4	65.4%	34.6%	64.6	64.6%	35.4%
Pan	-	-	-	-	-	-	-	-	-	-	-	-	-



Average

Med Sand	6.4%
Fine Sand	49.1%
Silt	44.4%

%FINER = 100 - Σ%RETAINED

5/12/2007

Table 2
Tailings Parameters

Soil	Permeability[1] (cm/sec)	Drainable Porosity[2] (vol./vol.)
med sand	2.00E-02	0.35
fine sand	1.00E-02	0.29
silt	1.00E-04	0.14
silty clay	6.00E-07	0.11
average	7.53E-03	0.22
geomean	3.31E-04	0.20

Soil	Permeability[3] (cm/sec)	Drainable Porosity[3] (vol./vol.)
SM (LS)	1.70E-03	0.332
SM (LFS)	1.00E-03	0.326
SM (SL)	7.20E-04	0.263
SM (FSL)	5.20E-04	0.251
ML (L)	3.70E-04	0.231
ML (SiL)	1.90E-04	0.217
SC (SCL)	1.20E-04	0.154
average	6.60E-04	0.253
geomean	4.74E-04	0.246

Notes:

(1) Source - "Seepage, Drainage, and Flow Nets", Cedergren, H. R., 1989.

(2) Source - The Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3, EPA, 1994 - Figure 2 - Soil texture vs. Moisture Retention.

(3) Source - The Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3, EPA, 1994 - Table 1 - Low Density Soil Characteristics.

TABLE 3
White Mesa Mill
Cell 5B Slimes Drain
Maximum Liquid Depth

Permeability (cm/sec)	Permeability (ft/min)	Drainage Path Length (ft.)	Thickness (VF)	Q (cfm/ft)	Volume of Liquid (CF/ft)	Time to Dewater (min/VF/ft)	Time to Dewater (days/VF/ft)	Total Flow Rate (gpm)	Volume Removed (gal)	Pipe Limitation (days)
3.31E-04	6.51E-04	49.7	43	6.57E-04	11	16,731	11.62	148.14	2,478,439	0.08
3.31E-04	6.51E-04	49.2	42	6.49E-04	11	16,957	11.78	146.16	2,478,439	
3.31E-04	6.51E-04	48.6	41	6.41E-04	11	17,158	11.92	144.44	2,478,439	
3.31E-04	6.51E-04	48.1	40	6.32E-04	11	17,406	12.09	142.39	2,478,439	
3.31E-04	6.51E-04	47.6	39	6.23E-04	11	17,667	12.27	140.28	2,478,439	
3.31E-04	6.51E-04	47.1	38	6.13E-04	11	17,942	12.46	138.14	2,478,439	
3.31E-04	6.51E-04	46.7	37	6.02E-04	11	18,270	12.69	135.66	2,478,439	
3.31E-04	6.51E-04	46.3	36	5.91E-04	11	18,617	12.93	133.13	2,478,439	
3.31E-04	6.51E-04	45.9	35	5.79E-04	11	18,983	13.18	130.56	2,478,439	
3.31E-04	6.51E-04	45.5	34	5.68E-04	11	19,371	13.45	127.94	2,478,439	
3.31E-04	6.51E-04	45.1	33	5.56E-04	11	19,783	13.74	125.28	2,478,439	
3.31E-04	6.51E-04	44.8	32	5.43E-04	11	20,265	14.07	122.30	2,478,439	
3.31E-04	6.51E-04	44.5	31	5.29E-04	11	20,779	14.43	119.28	2,478,439	
3.31E-04	6.51E-04	44.3	30	5.15E-04	11	21,375	14.84	115.95	2,478,439	
3.31E-04	6.51E-04	44.0	29	5.01E-04	11	21,962	15.25	112.85	2,478,439	
3.31E-04	6.51E-04	43.8	28	4.86E-04	11	22,643	15.72	109.46	2,478,439	
3.31E-04	6.51E-04	43.7	27	4.70E-04	11	23,428	16.27	105.79	2,478,439	
3.31E-04	6.51E-04	43.5	26	4.54E-04	11	24,218	16.82	102.34	2,478,439	
3.31E-04	6.51E-04	43.4	25	4.38E-04	11	25,129	17.45	98.63	2,478,439	
3.31E-04	6.51E-04	43.3	24	4.21E-04	11	26,116	18.14	94.90	2,478,439	
3.31E-04	6.51E-04	43.3	23	4.04E-04	11	27,251	18.92	90.95	2,478,439	
3.31E-04	6.51E-04	43.2	22	3.87E-04	11	28,424	19.74	87.20	2,478,439	
3.31E-04	6.51E-04	43.2	21	3.69E-04	11	29,778	20.68	83.23	2,478,439	
3.31E-04	6.51E-04	43.3	20	3.51E-04	11	31,339	21.76	79.09	2,478,439	
3.31E-04	6.51E-04	43.3	19	3.33E-04	11	32,988	22.91	75.13	2,478,439	
3.31E-04	6.51E-04	43.4	18	3.15E-04	11	34,901	24.24	71.01	2,478,439	
3.31E-04	6.51E-04	43.6	17	2.96E-04	11	37,125	25.78	66.76	2,478,439	
3.31E-04	6.51E-04	43.7	16	2.78E-04	11	39,535	27.46	62.69	2,478,439	
3.31E-04	6.51E-04	43.9	15	2.60E-04	11	42,364	29.42	58.50	2,478,439	
3.31E-04	6.51E-04	44.1	14	2.41E-04	11	45,597	31.66	54.36	2,478,439	
3.31E-04	6.51E-04	44.4	13	2.22E-04	11	49,438	34.33	50.13	2,478,439	
3.31E-04	6.51E-04	44.7	12	2.04E-04	11	53,920	37.44	45.96	2,478,439	
3.31E-04	6.51E-04	45.0	11	1.86E-04	11	59,217	41.12	41.85	2,478,439	
3.31E-04	6.51E-04	45.3	10	1.68E-04	11	65,573	45.54	37.80	2,478,439	
3.31E-04	6.51E-04	45.7	9	1.50E-04	11	73,502	51.04	33.72	2,478,439	
3.31E-04	6.51E-04	46.0	8	1.32E-04	11	83,233	57.80	29.78	2,478,439	
3.31E-04	6.51E-04	46.5	7	1.14E-04	11	96,157	66.78	25.77	2,478,439	
3.31E-04	6.51E-04	46.9	6	9.72E-05	11	113,148	78.58	21.90	2,478,439	
3.31E-04	6.51E-04	47.4	5	8.02E-05	11	137,225	95.30	18.06	2,478,439	
3.31E-04	6.51E-04	47.8	4	6.36E-05	11	172,979	120.12	14.33	2,478,439	
3.31E-04	6.51E-04	48.3	3	4.72E-05	11	233,051	161.84	10.63	2,478,439	
3.31E-04	6.51E-04	48.9	2	3.11E-05	11	353,919	245.78	7.00	2,478,439	
3.31E-04	6.51E-04	49.4	1	1.54E-05	11	715,076	496.58	3.47	2,478,439	
						days	**2,055.93**		**96,659,131**	**0.08**
						years	**5.63**			

Average Soil Porosity	0.22	
Geomean Soil Permeability	3.31E-04	cm/sec
Distance Between Drains	50	ft
Thickness of Unit	1	ft
Maximum Depth	43	ft
Length of Strip Drain	30,120	ft

TABLE 4
White Mesa Mill
Cell 5B Slimes Drain
Average Liquid Depth

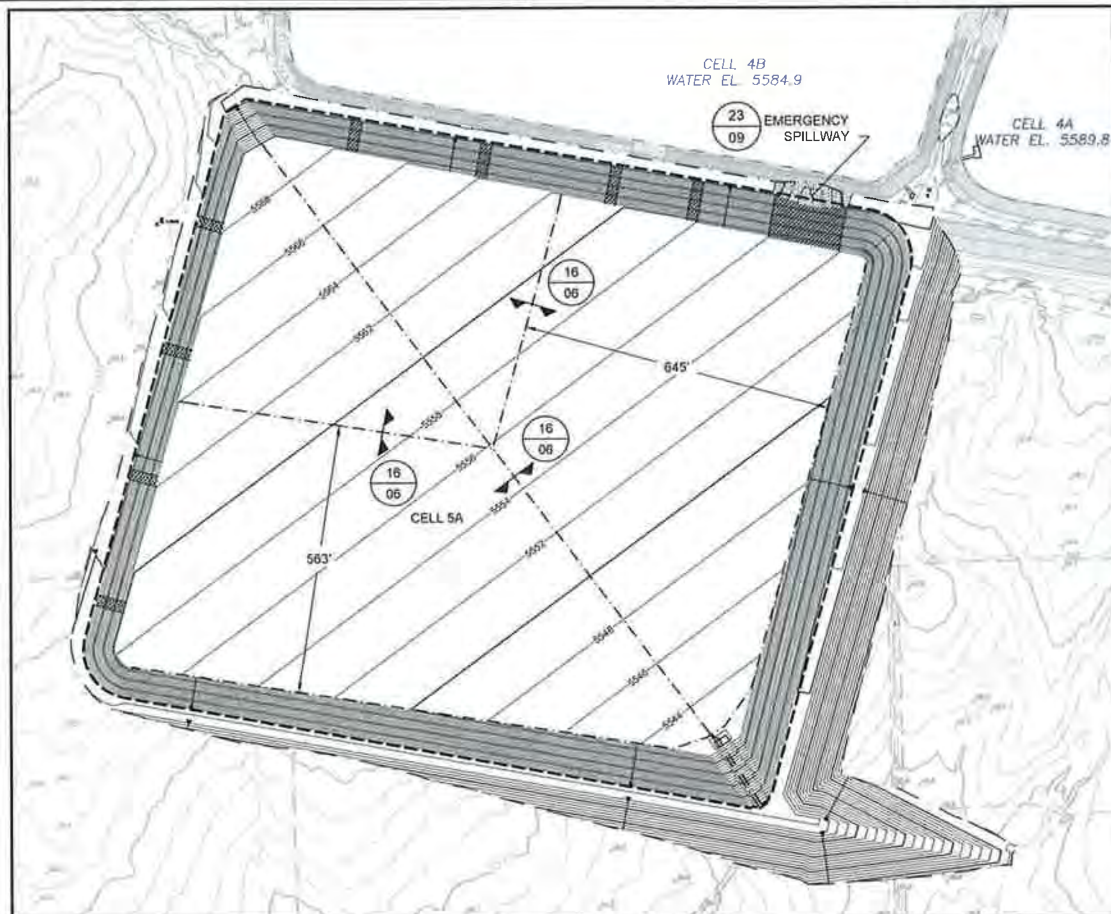
Permeability (cm/sec)	Permeability (ft/min)	Drainage Path Length (ft.)	Thickness (VF)	Q (cfm/ft)	Volume of Liquid (CF/ft)	Time to Dewater (min/VF/ft)	Time to Dewater (days/VF/ft)	Total Flow Rate (gpm)	Volume Removed (gal)
3.31E-04	6.51E-04	42.2	34	6.12E-04	11	17,966	12.48	137.95	2,478,439
3.31E-04	6.51E-04	41.8	33	6.00E-04	11	18,335	12.73	135.17	2,478,439
3.31E-04	6.51E-04	41.5	32	5.86E-04	11	18,773	13.04	132.02	2,478,439
3.31E-04	6.51E-04	41.2	31	5.72E-04	11	19,238	13.36	128.83	2,478,439
3.31E-04	6.51E-04	41.0	30	5.56E-04	11	19,783	13.74	125.28	2,478,439
3.31E-04	6.51E-04	40.8	29	5.40E-04	11	20,365	14.14	121.70	2,478,439
3.31E-04	6.51E-04	40.6	28	5.24E-04	11	20,989	14.58	118.08	2,478,439
3.31E-04	6.51E-04	40.5	27	5.07E-04	11	21,713	15.08	114.15	2,478,439
3.31E-04	6.51E-04	40.4	26	4.89E-04	11	22,492	15.62	110.19	2,478,439
3.31E-04	6.51E-04	40.3	25	4.71E-04	11	23,334	16.20	106.22	2,478,439
3.31E-04	6.51E-04	40.3	24	4.53E-04	11	24,306	16.88	101.97	2,478,439
3.31E-04	6.51E-04	40.3	23	4.34E-04	11	25,363	17.61	97.72	2,478,439
3.31E-04	6.51E-04	40.3	22	4.15E-04	11	26,516	18.41	93.47	2,478,439
3.31E-04	6.51E-04	40.4	21	3.95E-04	11	27,848	19.34	89.00	2,478,439
3.31E-04	6.51E-04	40.6	20	3.74E-04	11	29,385	20.41	84.34	2,478,439
3.31E-04	6.51E-04	40.7	19	3.55E-04	11	31,007	21.53	79.93	2,478,439
3.31E-04	6.51E-04	40.9	18	3.34E-04	11	32,891	22.84	75.35	2,478,439
3.31E-04	6.51E-04	41.2	17	3.14E-04	11	35,081	24.36	70.65	2,478,439
3.31E-04	6.51E-04	41.4	16	2.94E-04	11	37,455	26.01	66.17	2,478,439
3.31E-04	6.51E-04	41.8	15	2.73E-04	11	40,338	28.01	61.44	2,478,439
3.31E-04	6.51E-04	42.1	14	2.53E-04	11	43,529	30.23	56.94	2,478,439
3.31E-04	6.51E-04	42.5	13	2.32E-04	11	47,323	32.86	52.37	2,478,439
3.31E-04	6.51E-04	42.9	12	2.13E-04	11	51,749	35.94	47.89	2,478,439
3.31E-04	6.51E-04	43.3	11	1.93E-04	11	56,980	39.57	43.50	2,478,439
3.31E-04	6.51E-04	43.8	10	1.73E-04	11	63,402	44.03	39.09	2,478,439
3.31E-04	6.51E-04	44.3	9	1.54E-04	11	71,250	49.48	34.78	2,478,439
3.31E-04	6.51E-04	44.8	8	1.36E-04	11	81,061	56.29	30.57	2,478,439
3.31E-04	6.51E-04	45.4	7	1.17E-04	11	93,882	65.20	26.40	2,478,439
3.31E-04	6.51E-04	46.0	6	9.91E-05	11	110,977	77.07	22.33	2,478,439
3.31E-04	6.51E-04	46.6	5	8.15E-05	11	134,909	93.69	18.37	2,478,439
3.31E-04	6.51E-04	47.2	4	6.44E-05	11	170,808	118.62	14.51	2,478,439
3.31E-04	6.51E-04	47.9	3	4.76E-05	11	231,121	160.50	10.72	2,478,439
3.31E-04	6.51E-04	48.6	2	3.13E-05	11	351,748	244.27	7.05	2,478,439
3.31E-04	6.51E-04	49.3	1	1.54E-05	11	713,629	495.58	3.47	2,478,439
						days	**1,899.68**		**76,831,617**
						years	**5.20**		

Average Soil Porosity	0.22	
Geomean Soil Permeability	3.31E-04	cm/sec
Distance Between Drains	50	ft
Thickness of Unit	1	ft
Average Depth	34	ft
Length of Strip Drain	30,120	ft

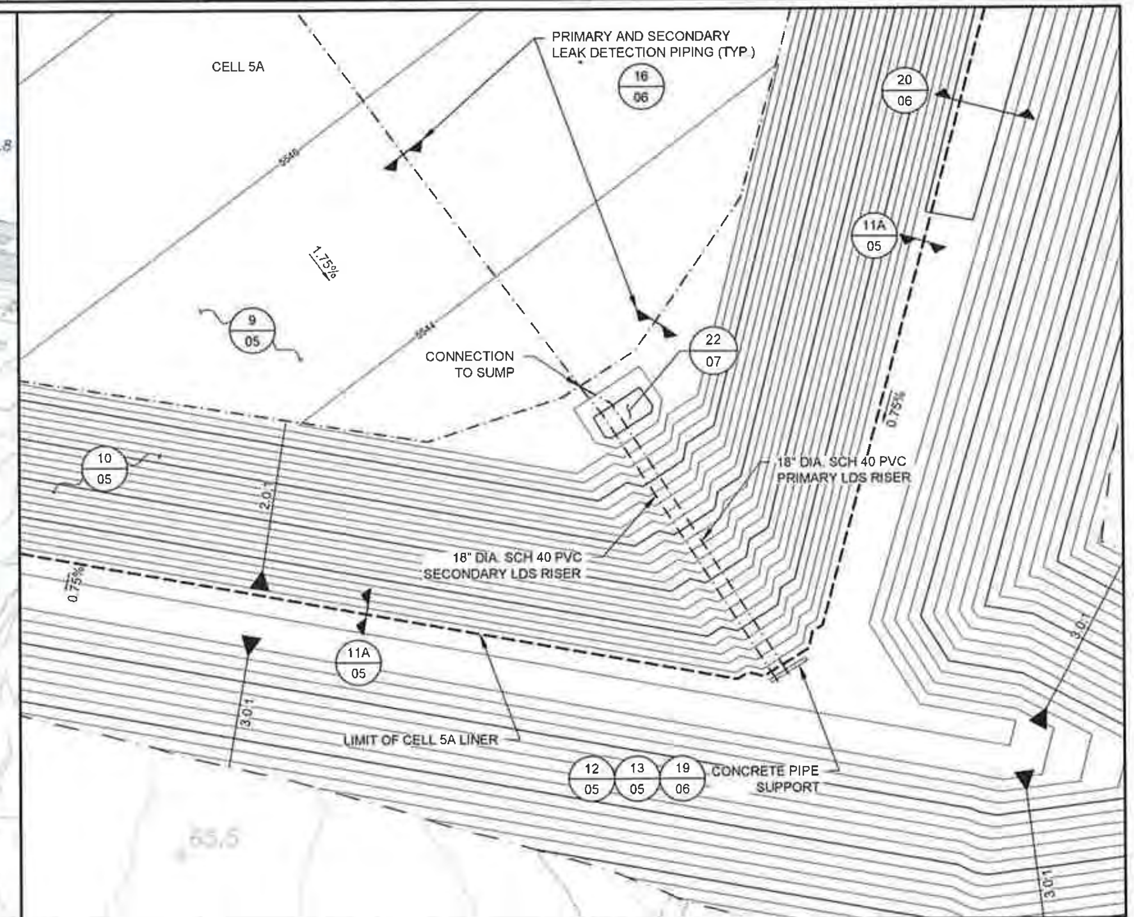
TABLE 5
White Mesa Mill
Cell 5B Slimes Drain
Minimum Liquid Depth

Permeability (cm/sec)	Permeability (ft/min)	Drainage Path Length (ft.)	Thickness (VF)	Q (cfm/ft)	Volume of Liquid (CF/ft)	Time to Dewater (min/VF/ft)	Time to Dewater (days/VF/ft)	Total Flow Rate (gpm)	Volume Removed (gal)
3.31E-04	6.51E-04	35.4	25	5.37E-04	11	20,497	14.23	120.92	2,478,439
3.31E-04	6.51E-04	35.4	24	5.15E-04	11	21,351	14.83	116.08	2,478,439
3.31E-04	6.51E-04	35.5	23	4.92E-04	11	22,342	15.52	110.93	2,478,439
3.31E-04	6.51E-04	35.6	22	4.70E-04	11	23,424	16.27	105.81	2,478,439
3.31E-04	6.51E-04	35.8	21	4.46E-04	11	24,677	17.14	100.44	2,478,439
3.31E-04	6.51E-04	36.1	20	4.21E-04	11	26,128	18.14	94.86	2,478,439
3.31E-04	6.51E-04	36.4	19	3.97E-04	11	27,731	19.26	89.37	2,478,439
3.31E-04	6.51E-04	36.7	18	3.73E-04	11	29,513	20.50	83.98	2,478,439
3.31E-04	6.51E-04	37.1	17	3.48E-04	11	31,590	21.94	78.46	2,478,439
3.31E-04	6.51E-04	37.6	16	3.23E-04	11	34,017	23.62	72.86	2,478,439
3.31E-04	6.51E-04	38.1	15	2.99E-04	11	36,767	25.53	67.41	2,478,439
3.31E-04	6.51E-04	38.6	14	2.76E-04	11	39,910	27.72	62.10	2,478,439
3.31E-04	6.51E-04	39.2	13	2.52E-04	11	43,648	30.31	56.78	2,478,439
3.31E-04	6.51E-04	39.8	12	2.29E-04	11	48,010	33.34	51.62	2,478,439
3.31E-04	6.51E-04	40.5	11	2.06E-04	11	53,295	37.01	46.50	2,478,439
3.31E-04	6.51E-04	41.2	10	1.84E-04	11	59,638	41.42	41.56	2,478,439
3.31E-04	6.51E-04	42.0	9	1.63E-04	11	67,551	46.91	36.69	2,478,439
3.31E-04	6.51E-04	42.8	8	1.42E-04	11	77,442	53.78	32.00	2,478,439
3.31E-04	6.51E-04	43.6	7	1.22E-04	11	90,160	62.61	27.49	2,478,439
3.31E-04	6.51E-04	44.4	6	1.03E-04	11	107,117	74.39	23.14	2,478,439
3.31E-04	6.51E-04	45.3	5	8.39E-05	11	131,146	91.07	18.90	2,478,439
3.31E-04	6.51E-04	46.2	4	6.58E-05	11	167,189	116.10	14.82	2,478,439
3.31E-04	6.51E-04	47.1	3	4.84E-05	11	227,261	157.82	10.91	2,478,439
3.31E-04	6.51E-04	48.0	2	3.17E-05	11	347,406	241.25	7.13	2,478,439
3.31E-04	6.51E-04	49.0	1	1.55E-05	11	709,286	492.56	3.49	2,478,439
						days	**1,713.26**		**57,004,103**
						years	**4.69**		

Average Soil Porosity	0.22	
Geomean Soil Permeability	3.31E-04	cm/sec
Distance Between Drains	50	ft
Thickness of Unit	1	ft
Minimum Depth	25	ft
Length of Strip Drain	30,120	ft



1
04A
PLAN
CELL 5A LEAK DETECTION SYSTEM
SCALE: 1" = 200'



3
04A
DETAIL
CELL 5A LEAK DETECTION SYSTEM
SCALE: 1" = 50'

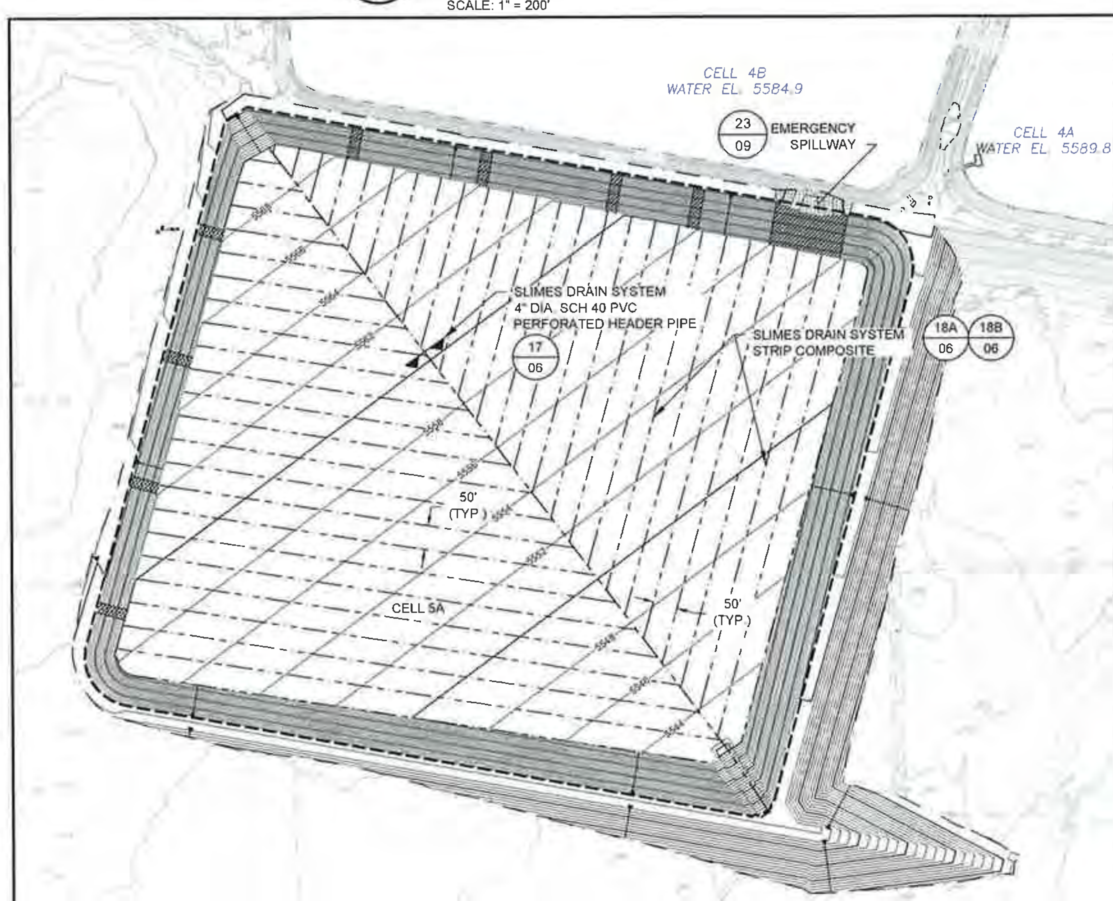
12 / 05 13 / 05 19 / 06

LEGEND

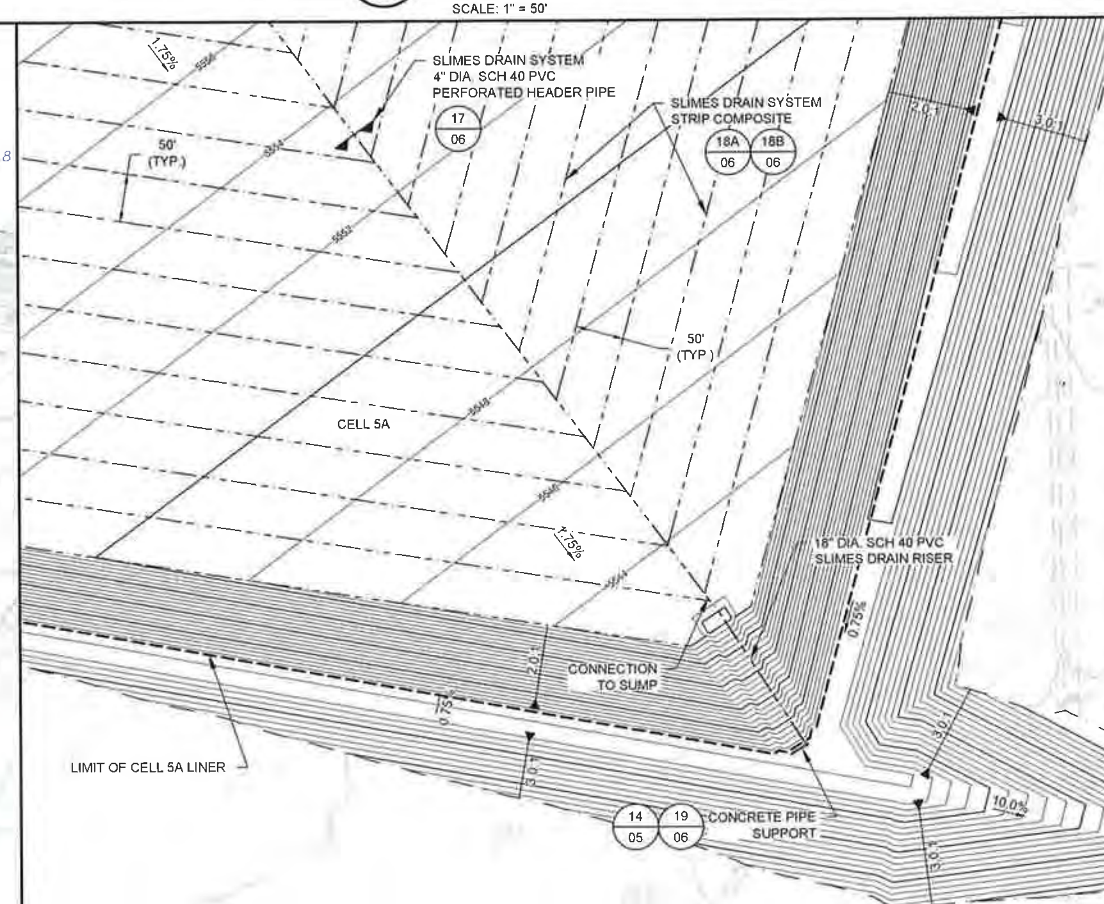
- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- 5602 — PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- LIMIT OF LINER SYSTEM
- PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- SPLASH PAD 21 / 06

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BE ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.



2
04A
PLAN
CELL 5A SLIMES DRAIN SYSTEM
SCALE: 1" = 200'



4
04A
DETAIL
CELL 5A SLIMES DRAIN SYSTEM
SCALE: 1" = 100'

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

FIGURE 1A

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE 858 674 6559

Energy Fuels Resources (USA) Inc

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5A

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

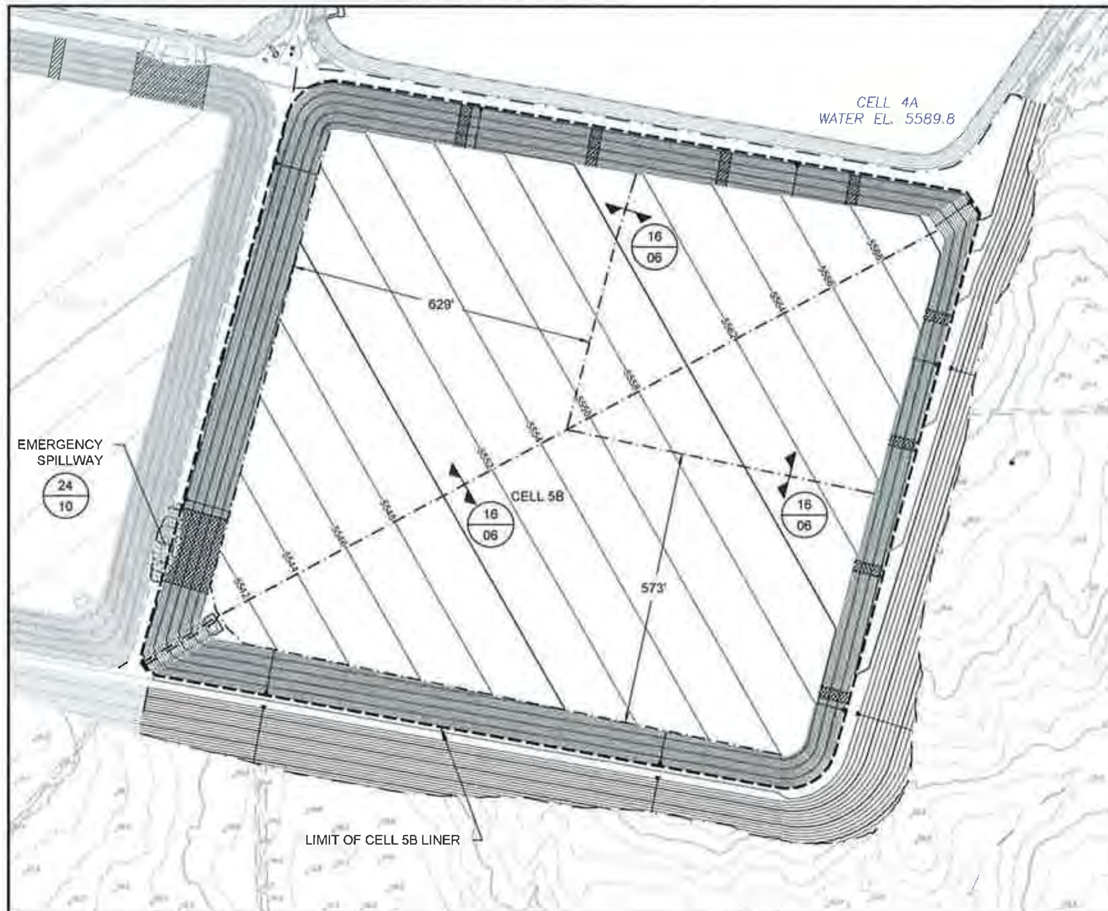
SITE: WHITE MESA MILL, BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION UNLESS SEALED

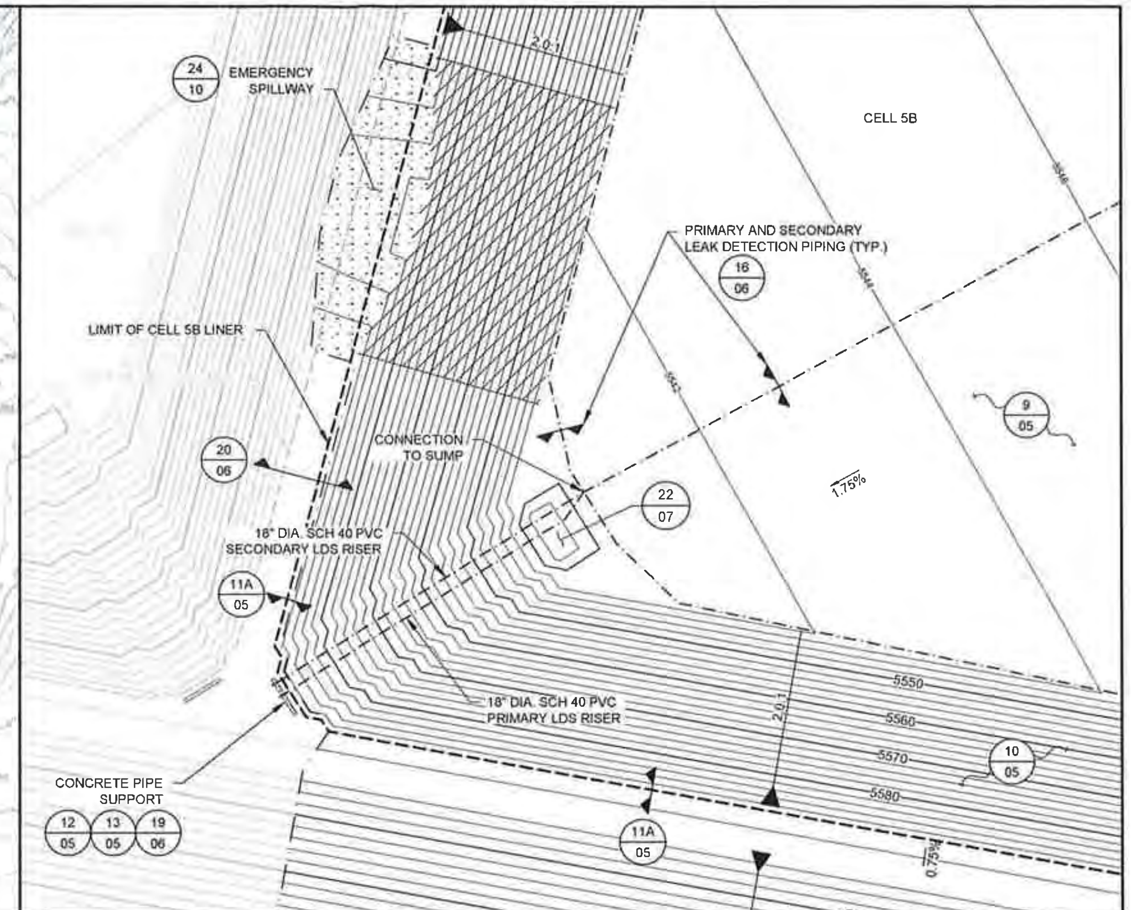
SIGNATURE

DATE

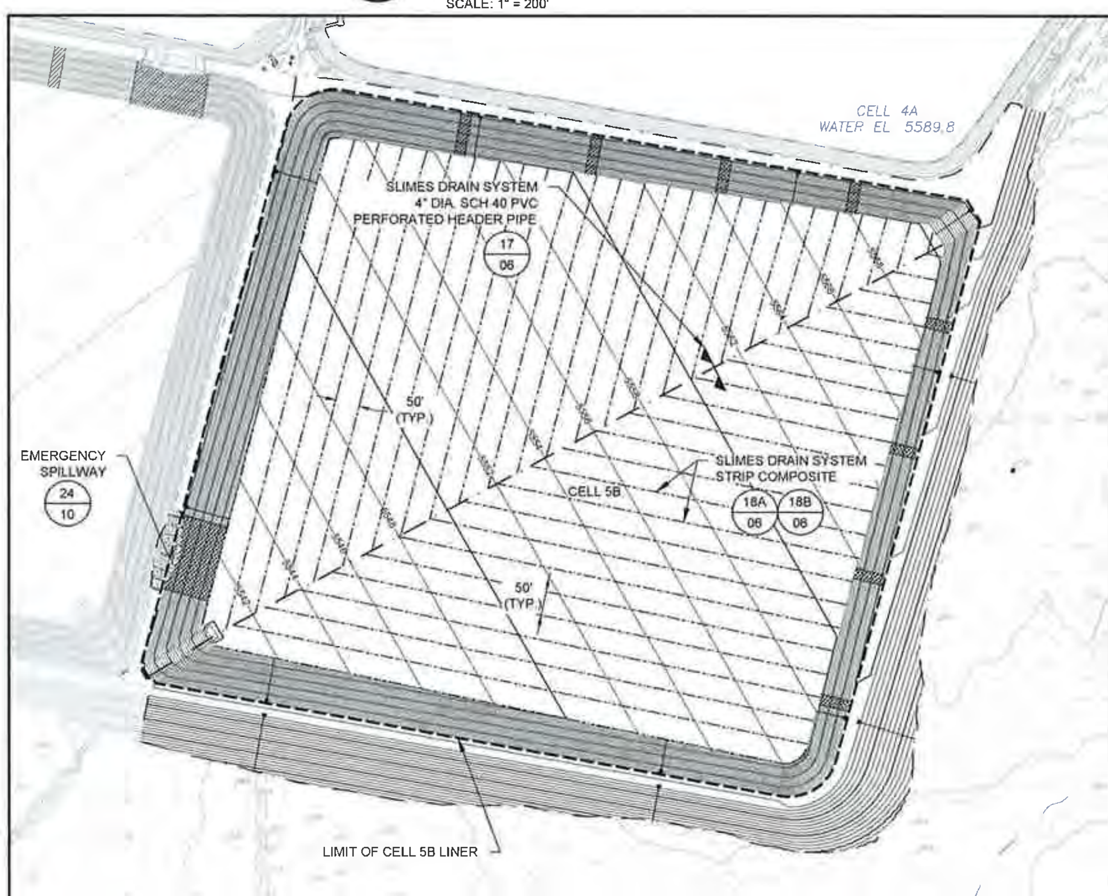
DESIGN BY	GTC	DATE	JANUARY 2013
DRAWN BY	MMC	PROJECT NO	SC0634
CHECKED BY	RBF	FILE	SC0634 - 03A-04B
REVIEWED BY	GTC	DRAWING NO	
APPROVED BY	GTC	04A	OF 12



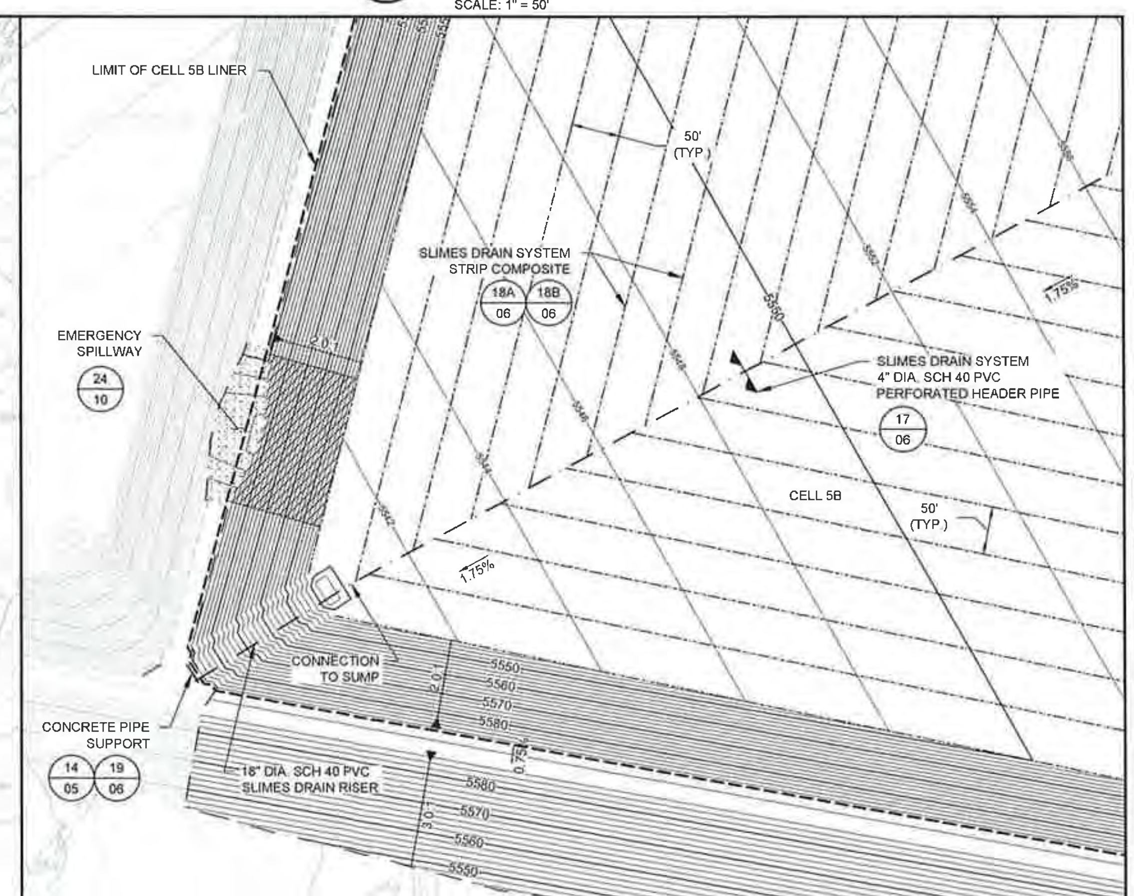
21 / 04B PLAN
CELL 5B LEAK DETECTION SYSTEM
SCALE: 1" = 200'



6 / 04B DETAIL
CELL 5B LEAK DETECTION SYSTEM
SCALE: 1" = 50'



7 / 04B PLAN
CELL 5B SLIMES DRAIN SYSTEM
SCALE: 1" = 200'
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



8 / 04B DETAIL
CELL 5B SLIMES DRAIN SYSTEM
SCALE: 1" = 100'

LEGEND

- JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- 5602 — PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- LIMIT OF LINER SYSTEM
- PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- SPLASH PAD (21 / 06)

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BE ENERGY FUELS RESOURCES (USA) INC.
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3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.

FIGURE 1B

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858 674 6559

Energy Fuels Resources (USA) Inc

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5B

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL, BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION UNLESS SEALED

SIGNATURE

DATE

DESIGN BY	GTC	DATE	JANUARY 2013
DRAWN BY	MMC	PROJECT NO	SC0634
CHECKED BY	RBF	FILE	SC0634 - 03A-04B
REVIEWED BY	GTC	DRAWING NO	04B OF 12
APPROVED BY	GTC		

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

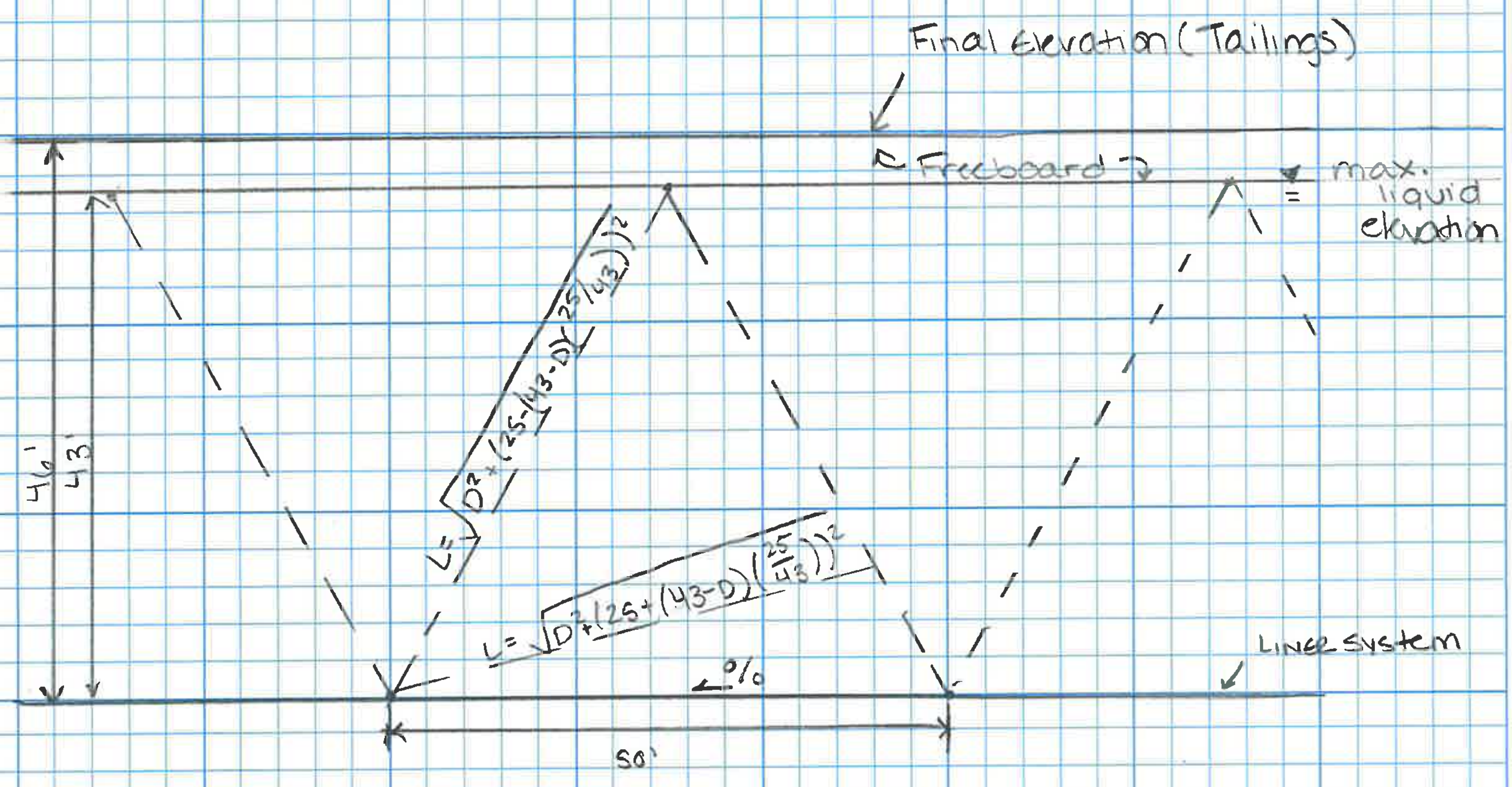
P:\PRJ\SD\Cadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634 - 03A-04B.dwg Last Edited by: MikeC on 12/13/2012 11:35 AM

Geosyntec consultants

Written by: ____________ Date: __/__/__ (DD MM YY) Reviewed by: ____________ Date: __/__/__ (DD MM YY)

Client: ____________ Project: ____________ Project/Proposal No. ____________ Task No. ____________

Maximum Depth Flow Geometry



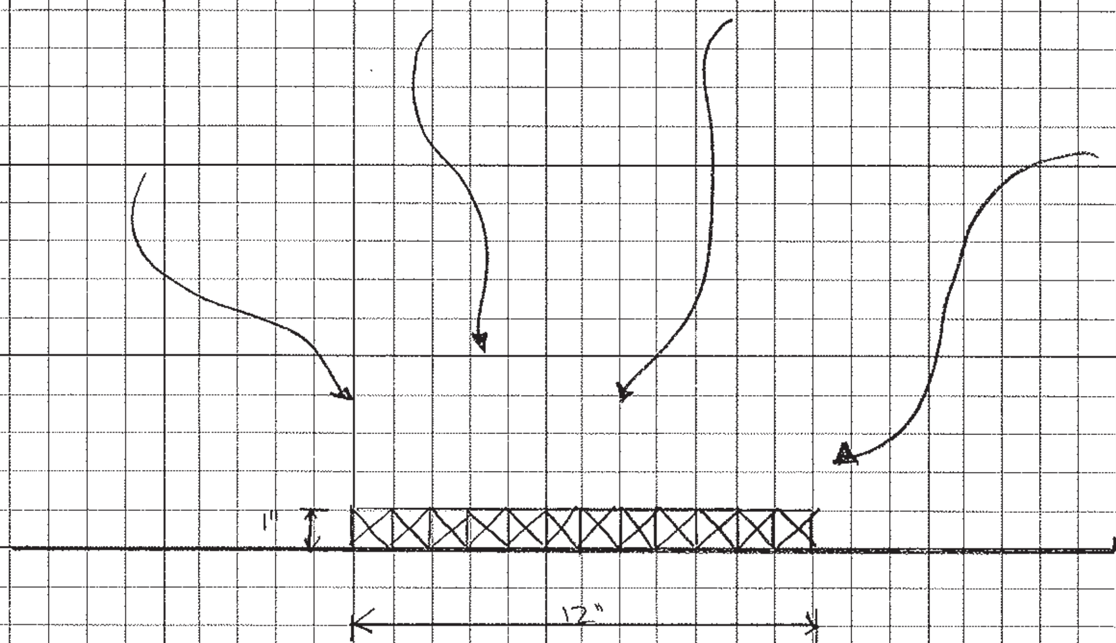
Examples:

$D = 43' \rightarrow L = \sqrt{43^2 + (25 - (43-43)(25/43))^2} = 49.7'$

$D = 10' \rightarrow L = \sqrt{10^2 + (25 - (43-10)(25/43))^2} = 45.3'$

FIGURE 2

Geosyntec consultants



FLOW AREA - STRIP COMPOSITE

$$A = \frac{14''}{12''/1} = 1.17\ ft^2/ft$$

FIGURE 3

EXHIBIT 1

SAMPLE DESCRIPTION AND PREPARATION

CSMRI Sample 1

Sponsor's Designation of Sample: Run-of-mine.

Date Received at Institute: June 5, 1978.

Sample Weight: 100,520 lb.

Sample Container: Two truckloads.

Sample Description: Mine ore -- estimate 5% +10-in. material. Largest boulder -- 48 in. x 24 in. x 14 in. Only two or three rocks were greater than 36 in.

Method of Preparation: All +10-in. material broken to -10 in. by sledgehammer and jackhammer. The sample was screened at 6 in. and 1-1/2 in. with the +6 in. fraction, put in barrels, and the -1/2 in. fraction piled. The -6 in. +1-1/2 in. material was screened at 4 in. and 1-1/2 in. with the -6 in. +4 in. and -4 in. +1-1/2 in. fractions barreled. The additional -1-1/2 in. fraction was piled with the previous -1-1/2 in. fraction. A screen size analysis of the entire quantity of mill feed material is presented in Exhibit 3. A summary screen size analysis of the ore is as follows:

Screen Product in.		Weight %
Head (calculated)		100.00
-10	+6	2.92
-6	+4	9.48
-4	+1-1/2	15.30
-1-1/2		72.30

EXHIBIT 1

CSMRI Sample 2

Sponsor's Designation of Sample:	Crushed ore.
Date Received at Institute:	June 5, 1978.
Sample Weight:	47,380 lb.
Sample Container:	One truckload.
Sample Description:	Ore previously crushed to -3 in., maximum particles approximately 2-1/2 in.
Method of Preparation:	The ore was used as received.

EXHIBIT 2

GRINDING TESTS

Grinding Test 1, Autogenous

Date:	June 13, 1978
Feed Rate, stph:	2
Ore:	Run-of-mine
DSM Screen, in. width:	12
DSM Screen Opening, mm:	1.27
Measured Mill Power Tare (empty mill), kw:	2.06
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Meter Reading watt-hr	Mill-Bearing Oil Temp. °F	Ore Feed Rate (as received)(1) -1-1/2 in. lb/hr	-4 in. +1-1/2 in. lb/hr	-6 in. +4 in. lb/hr	-10 in. +6 in. lb/hr	Mill Discharge Solids %	Mill Discharge Solids lb/hr	Sweco Screen Oversize Solids %	Sweco Screen Oversize Solids lb/hr	DSM Screen Overflow Solids %	DSM Screen Overflow Solids lb/hr	DSM Screen Underflow Solids %	DSM Screen Underflow Solids lb/hr	Mill Water Meter %	Mill Water Rate lb/hr	Mill Load Volume %	Remarks
0910	0	--	--	104	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Start mill.
0915	5	12.2	12,964	--	3,150	612	380	116	63	8,335	--	--	--	--	--	--(2)	90	2,858	--	--
1005	55	8.7	--	--	2,880	612	380	116	62	--	90	506	60	3,348	57	2,616(2)	90	2,858	--	--
1030	80	6.8	--	105	2,835	612	380	116	69	--	90	304	70	3,591	58	710(2)	90	2,858	--	--
1100	110	6.5	12,977	106	2,993	612	380	116	66	--	--	--	69	4,223	58	679(2)	80	2,540	--	--
1135	145	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Mill down, elevator plugged.
1142	145	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Start mill.
1150	153	6.2	--	109	2,993	612	380	116	69	12,420	90	1,114	70	5,544	56	2,583	--	--	--	--
1230	193	6.0	12,988	111	2,903	612	380	116	64	10,829	90	405	69	6,955	60	4,388	75	2,382	--	--
1300	223	6.2	--	112	3,319	612	380	116	65	11,232	90	365	70	6,048	60	3,861	81	2,572	--	--
1345	238	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Pump plugged. DSM feed.
1400	253	6.4	--	112	3,128	612	380	116	65	11,700	90	122	69	3,229	60	3,996	80	2,540	--	Sample
1415	268	6.3	13,004	112	2,970	612	380	116	65	9,945	90	547	71	3,515	59	2,907	79	2,509	15	Sample.
Average					3,019	612	380	116	65	10,744	90	480	69	4,557	59	3,547	83	2,640		

(1) Moisture: -1-1/2 in., 2.8%; -4 in. +1-1/2 in., 1.0%; -6 in. +4 in., 0.8%; -10 in. +6 in., 0.7%. Average dry ore feed rate: -1-1/2 in., 2,934.5 lb/hr; -4 in. +1-1/2 in., 605.9 lb/hr; -6 in. +4 in., 376.8 lb/hr; -10 in. +6 in., 115.0 lb/hr; total, 4,032.2 lb/hr, 2.016 dry stph. Mill volume end of test: 15%.

(2) Excluded from average.

Feed Rate, stph dry:	2.016
Ball Charge:	None
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Instantaneous Gross Power (meter reading) kwhr	Instantaneous Corrected Power (from input-output curve) kwhr	Power Consumption Gross kwhr/st	Power Consumption Net kwhr/st	Circulating Load Weight % of Feed(1)	Mill Discharge Solids %	Remarks
0910	0	--	--	--	--	--	--	--	--
0915	5	12.2	4.25	2.64	1.31	1.01	--	63	--
1005	55	8.7	5.96	4.25	2.11	1.81	--	62	--
1030	80	6.8	7.62	5.80	2.88	2.58	--	69	--
1100	110	6.5	7.97	6.10	3.03	2.73	--	66	--
1135	145	--	--	--	--	--	--	--	Unplug bucket elevator.
1150	153	6.2	8.36	6.47	3.21	2.91(2)	162.0	69	--
1230	193	6.0	8.64	6.73	3.34	3.04(2)	183.0	64	--
1300	223	6.2	8.36	6.47	3.21	2.91(2)	145.0	65	--
1345	238	--	--	--	--	--	--	--	Unplug DSM feed pump.
1400(3)	253	6.4	8.10	6.23	2.09	2.79(2)	79.0	65	--
1415(3)	268	6.3	8.23	6.35	3.15	2.85(2)	100.0	65	--
Average						2.90	133.8		

(1) Calculated: Sum of Sweco oversize and DSM oversize as percentage of dry mill feed.

(2) Average for power (last five readings): 2.90 kwhr/st.

(3) Sample run.

EXHIBIT 2

Grinding Test 1 -- continued

Procedure: Sample was wet screened on a 325M screen, products dried, and the +325M material dry screened using a Ro-Tap for 30 min.

Test Product	Screen Size Analysis DSM Screen Undersize
Sample Time:	1415
Sample Weight, g:	4,630.5
Screen Product (Tyler) Mesh	**Weight %**
Head (calculated)	100.0
+28	1.2
-28 +35	3.4
-35 +65	16.2
-65 +100	14.0
-100 +200	18.6
-200 +325	7.1
-325	39.5

GTC
5/10/07

US SIEVE

No. 30
No. 40
No. 70
No. 100
No. 200
No. 325

EXHIBIT 2

Grinding Test 2

Date:	June 14, 1978
Feed Rate, stph:	2.0
Ore:	Run-of-mine
Ball Charge:	Total: 301.8 lb; 2% mill volume
-1-1/2 in. +1 in. Balls, lb:	114.5
-2 in. +1-1/2 in. Balls, lb:	151.3
3 in. Balls, lb:	36.0
DSM Screen, in. width:	12
DSM Screen Openings, mm:	1.27
Measured Mill Power Tare (empty mill), kw:	2.06
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Meter Reading watt-hr	Mill-Bearing Oil Temp. °F	Ore Feed Rate (as received)(1) -1-1/2 in. lb/hr	-4 in. +1-1/2 in. lb/hr	-6 in. +4 in. lb/hr	-10 in. +6 in. lb/hr	Mill Discharge Solids %	Mill Discharge Solids lb/hr	Sweco Screen Oversize Solids %	Sweco Screen Oversize Solids lb/hr	DSM Screen Overflow Solids %	DSM Screen Overflow Solids lb/hr	DSM Screen Underflow Solids %	DSM Screen Underflow Solids lb/hr	Mill Water Meter %	Mill Water Rate lb/hr	Mill Load Volume %	Remarks
1040	0	8.7	13,004	102	--	612	380	116	--	--	--	--	--	--	--	--	95	3,017	-	Start mill.
1110	30	5.2	--	104	--	612	380	116	--	--	--	--	--	--	--	--	83	2,636	-	--
1130	50	5.3	--	106	3,060	612	380	116	62	8,147	50	248	74	1,565	54	2,989(2)	84	2,668	-	--
1200	80	5.0	--	108	2,846	612	380	116	63	6,577	67	653	71	1,150	--	--	82	2,604	-	--
1230	110	4.8	13,023	111	3,105	612	380	116	64	8,467	64	605	73	1,281	--	--	82	2,604	-	--
1300	140	4.8	--	112	3,139	612	380	116	63	6,917	62	391	73	2,102	57	3,694	81	2,572	-	--
1330	170	4.8	--	113	3,263	612	380	116	66	8,494	63	595	69	3,571	56	3,881	81	2,572	-	--
1400	200	4.9	--	113	2,981	612	380	116	66	9,029	64	624	71	2,939	58	3,680	81	2,572	-	--
1415	215	5.0	--	113	2,869	612	380	116	66	10,098	64	547	70	3,119	58	3,811	79	2,509	-	Sample.
1430	230	5.0	13,044	113	2,993	612	380	116	65	8,483	64	557	71	3,259	57	3,565	79	2,509	9	Sample. End of test.
Average					3,032	612	380	116	65	8,277	62	528	72	2,373	57	3,726	83	2,626		

(1) Moisture: -1-1/2 in., 2.8%; -4 in. +1-1/2 in., 1.0%; -6 in. +4 in., 0.8%; -10 in. +6 in., 0.7%. Average dry ore feed rate: -1-1/2 in., 2,947.0 lb/hr; -4 in. +1-1/2 in., 605.9 lb/hr; -6 in. +4 in., 376.8 lb/hr; -10 in. +6 in., 115.0 lb/hr; total: 4,044.7 lb/hr, 2.022 dry stph. Mill volume end of test: 9%.
(2) Excluded from average.

Feed Rate, stph dry:	2.022
Ball Charge:	301.8 lb, 2% mill volume
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Instantaneous Gross Power (meter reading) kwhr	Instantaneous Corrected Power (from input-output curve) kwhr	Power Consumption Gross kwh/st	Power Consumption Net kwh/st	Circulating Load Weight % of Feed(1)	Mill Discharge Solids %
1040	0	8.7	5.96	4.22	2.09	1.79	--	--
1110	30	5.2	9.97	7.93	3.92	3.63	--	--
1130	50	5.3	9.78	7.78	3.85	3.55	--	62
1200	80	5.0	10.36	8.25	4.08	3.78	--	63
1230	110	4.8	10.80	8.63	4.27	3.97	--	64
1300	140	4.8	10.80	8.63	4.27	3.97	59.0(4)	63
1330	170	4.8	10.80	8.63	4.27	3.97	95.0	66
1400	200	4.9	10.58	8.44	4.17	3.88	87.0	66
1415(3)	215	5.0	10.36	8.25	4.08	3.78(2)	92.0	66
1430(3)	230	5.0	10.36	8.25	4.08	3.78(2)	93.0	65
Average						3.78	91.8	

(1) Calculated: Sum of Sweco oversize and DSM oversize as a percentage of dry mill feed.
(2) Average for power (last two readings): 3.78 kwhr/st.
(3) Sample run.
(4) Omitted from average.

EXHIBIT 2

Grinding Test 2 -- continued

Procedure: Samples were wet screened on a 325M screen, products dried, and the +325M material dry screened using a Ro-Tap for 30 min.

	Screen Size Analysis								
Test Product	Mill Discharge		Sweco Screen Oversize		DSM Screen Oversize		DSM Screen Undersize		Circulating Load
Sample Time	1415	1430	1415	1430	1415	1430	1415	1430	
Sample Weight, g:	1,058.8	1,206.6	669.3	979.0	915.6	1,106.8	888.1	932.3	
Screen Product (Tyler) Mesh	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %
Head (calculated)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
+28	23.8	21.6	65.5	71.8	40.4	37.6	2.0	1.7	43.4
-28 +35	6.8	6.4	2.5	1.6	8.4	9.9	5.3	4.3	8.1
-35 +65	13.5	13.3	4.2	3.6	8.8	12.0	17.2	16.6	9.4
-65 +100	9.4	10.2	3.2	3.0	4.7	7.6	13.6	12.9	5.7
-100 +200	11.9	13.4	5.0	5.0	7.3	10.3	17.6	17.0	8.3
-200 +325	4.2	5.9	3.0	2.1	1.6	4.7	7.0	6.3	3.1
-325	30.4	29.2	16.6	12.9	28.8	17.9	37.3	41.2	22.0

EXHIBIT 2

Grinding Test 3

Date:	June 15, 1978
Feed Rate, stph:	3.0
Ore:	Run-of-mine
Ball Charge:	Total: 301.8 lb, 2% mill volume
-1-1/2 in. +1 in. Balls, lb:	114.5
-2 in. +1-1/2 in. Balls, lb:	151.3
3 in. Balls, lb:	36.0
DSM Screen, in. width:	12
DSM Screen Openings, mm:	1.27
Measured Mill Power Tare (empty mill), kw:	2.06
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Meter Reading watt-hr	Mill-Bearing Oil Temp. °F	Ore Feed Rate (as received)(1) -1-1/2 in. lb/hr	-4 in. +1-1/2 in. lb/hr	-6 in. +4 in. lb/hr	-10 in. +6 in. lb/hr	Mill Discharge Solids %	Mill Discharge Solids lb/hr	Sweco Screen Oversize Solids %	Sweco Screen Oversize Solids lb/hr	DSM Screen Overflow Solids %	DSM Screen Overflow Solids lb/hr	DSM Screen Underflow Solids %	DSM Screen Underflow Solids lb/hr	Mill Water Meter %(2)	Mill Water Rate lb/hr	Mill Load Volume %	Remarks
1050	0	5.0	13,045	93	--	918	570	174	--	--	--	--	--	--	--	--	--	--	--	Start mill.
1135	45	4.5	--	--	--	918	570	174	--	--	--	--	--	--	--	--	--	--	--	--
1200	70	4.4	--	99	4,350	918	570	174	65	13,631	68	857	70	6,237	58	5,090	105	3,350	--	--
1207	77	--	--	--	--	918	570	174	--	--	--	--	--	--	--	--	--	--	--	Shutdown, rock jammed in feeder.
1230	77	--	--	--	--	918	570	174	--	--	--	--	--	--	--	--	--	--	--	Start mill.
1300	107	4.9	--	109	3,435	918	570	174	65	10,530	63	808	73	3,679	55	4,430	106	3,366	--	--
1330	137	4.8	--	108	4,815	918	570	174	66	11,642	64	878	72	5,508	61	5,408	104	3,303	--	--
1400	167	4.9	--	110	4,275	918	570	174	67	11,095	58	639	73	5,059	61	5,545	104	3,303	--	--
1430	197	4.7	--	111	4,590	918	570	174	67	11,156	65	761	72	5,573	61	4,804	103	3,271	--	Sample.
1445	212	4.8	13,085	112	5,040	918	570	174	67	15,135	67	1,010	71	6,646	62	5,692	104	3,303	--	Sample.
1500	242	--	--	--	--	918	570	174	--	--	--	--	--	--	--	--	--	--	25	Shut down.
Average					4,417	918	570	174	66	12,198	64	826	72	5,450	60	5,162	104	3,316		

(1) Moisture: -1-1/2 in., 2.8%; -4 in. +1-1/2 in., 1.0%; -6 in. +4 in., 0.8%, -10 in. +6 in., 0.7%. Average dry ore feed rate: -1-1/2 in., 4,293.8 lb/hr, -4 in. +1-1/2 in., 908.8 lb/hr; -6 in. +4 in., 565.4 lb/hr; -10 in. +6 in., 172.8 lb/hr; total, 5,940.8 lb/hr, 2.970 dry stph. Mill volume end of test: 25%.

(2) Auxilliary water line used -- measured twice, averaged, and added as percentage of regular water meter.

Feed Rate, stph dry:	2.970 stph dry
Ball Charge:	301.8 lb, 2% of mill volume
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Instantaneous Gross Power (meter reading) kwhr	Instantaneous Corrected Power (from input-output curve) kwhr	Power Consumption Gross kwhr/st	Power Consumption Net kwhr/st	Circulating Load Weight % of Feed(1)	Mill Discharge Solids %	Remarks
1050	0	5.0	10.36	8.26	2.78	2.58	--	--	--
1135	45	4.5	11.52	9.24	3.11	2.91	--	--	--
1200	70	4.4	11.78	9.45	3.18	2.98	118.0(4)	65	--
1207	77	--	--	--	--	--	--	--	Rock jammed in feeder.
1230	77	--	--	--	--	--	--	--	--
1300	107	4.9	10.58	8.43	2.84	2.64	88.0	65	--
1330	137	4.8	10.80	8.62	2.90	2.70(2)	99.0	66	--
1400	167	4.9	10.58	8.43	2.84	2.64(2)	96.0	67	--
1430(3)	197	4.7	11.03	8.82	2.97	2.77(2)	101.0	67	--
1445(3)	212	4.8	10.80	8.62	2.90	2.70(2)	114.0	67	--
1500	242								
Average						2.70	99.6		

(1) Calculated: Sum of Sweco oversize and DSM oversize as a percentage of dry mill feed.
(2) Average for power (last four readings): 2.70 kwhr/st.
(3) Sample run.
(4) Omitted from average.

EXHIBIT 2

Grinding Test 3

Procedure: Samples were wet screened on a 325M screen, products dried, and the +325M material dry screened using a Ro-Tap for 30 min.

	Screen Size Analysis								
Test Product	Mill Discharge		Sweco Screen Oversize		DSM Screen Oversize		DSM Screen Undersize		Circulating Load
Sample Time	1430	1445	1430	1445	1430	1445	1430	1445	--
Sample Weight, g:	1,174.9	1,310.3	1,365.7	1,223.1	1,183.4	1,245.5	850.1	962.4	--
Screen Product (Tyler) Mesh	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %
Head (calculated)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
+28	27.8	25.1	65.0	67.5	47.4	33.3	2.4	1.9	43.7
-28 +35	6.5	7.1	1.8	2.0	9.1	7.9	5.7	5.0	7.6
-35 +65	12.8	14.6	3.7	4.0	12.4	13.2	18.1	21.0	11.7
-65 +100	9.2	9.0	3.1	3.4	6.5	8.5	14.8	16.0	7.0
-100 +200	11.4	13.5	5.4	5.5	8.9	9.9	15.6	13.5	8.9
-200 +325	4.8	3.4	3.4	3.3	1.6	3.3	5.9	4.5	2.5
-325	27.5	27.3	17.6	14.3	14.1	23.9	37.5	38.1	18.6

EXHIBIT 2

Grinding Test 4

Date:	June 16, 1978
Feed Rate, stph:	2.5
Ore:	Crushed
Ball Charge:	Total: 301.8 lb, 2% mill volume
-1-1/2 in. +1 in. Balls, lb:	114.5
-2 in. +1-1/2 in. Balls, lb:	151.3
3 in. Balls, lb:	36.0
DSM Screen, in. width:	12
DSM Screen Openings, mm:	1.27
Measured Mill Power Tare (empty mill), kw:	2.06
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Meter Reading watt-hr	Mill-Bearing Oil Temp. °F	Ore Feed Rate (as received)(1) -3 in. lb/hr	Mill Discharge Solids %	Mill Discharge Solids lb/hr	Sweco Screen Oversize Solids %	Sweco Screen Oversize Solids lb/hr	DSM Screen Overflow Solids %	DSM Screen Overflow Solids lb/hr	DSM Screen Underflow Solids %	DSM Screen Underflow Solids lb/hr	Mill Water Meter %(1)	Mill Water Rate lb/hr	Mill Load Volume %	Remarks
1010	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9	Start mill.
1030	20	6.6	13,094	96	--	--	--	--	--	--	--	--	--	90	2,858	--	--
1100	50	6.3	--	97	5,130	63	7,598	67	362	74	1,931	61	5,243	87	2,763	--	--
1130	80	5.9	--	99	5,350	62	8,091	64	418	72	2,398	60	4,482	82	2,604	--	--
1200	110	5.9	--	99	4,995	65	12,519	66	535	70	3,717	61	3,953	80	2,540	--	--
1215	125	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Feed off (feed belt jammed).
1218	125	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Start mill.
1230	137	6.0	--	100	4,770	62	5,692	62	288	71	2,077	58	3,628	80	2,540	--	--
1300	167	6.0	--	100	5,423	65	6,786	62	326	71	1,885	60	4,428	80	2,540	--	--
1320	187	--	--	--	--	--	--	--	--	--	--	60	4,316(3)	--	--	--	--
1330	197	5.8	--	102	4,826	65	6,728	65	449	69	2,298	59	4,806	79	2,509	--	--
1400	227	5.7	--	104	4,635	64	6,797	62	260	72	1,134	60	4,617	79	2,509	--	Sample.
1415	242	5.7	13,128	104	6,793	63	6,010	64	230	70	819	59	4,328	79	2,509	15	Sample.
1500	257	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Average					5,240	64	7,528	64	359	71	2,032	60	4,422	82	2,597	--	

(1) Moisture: -3 in., 4.3%. Average dry ore feed rate: -3 in., 5,015 lb/hr. 2.508 dry stph. Mill volume end of test: 15%.
(2) Auxiliary water line used -- measured twice, averaged, and added as percentage of regular water meter.
(3) 55-gal drum timed sample.

Feed Rate, stph:	2.508
Ball Charge:	301.8 lb, 2% of mill volume
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Instantaneous Gross Power (meter reading) kwhr	Instantaneous Corrected Power (from input-output curve) kwhr	Power Consumption Gross kwhr/st	Power Consumption Net kwhr/st	Circulating Load Weight % of Feed(1)	Mill Discharge Solids %	Remarks
1010	0	--	--	--	--	--	--	--	--
1030	20	6.6	7.85	6.00	2.39	2.15	--	--	--
1100	50	6.3	8.23	6.35	2.53	2.29	--	63	--
1130	80	5.9	8.78	6.87	2.74	2.50	50.0(4)	62	--
1200	110	5.9	8.78	6.87	2.74	2.50	81.0(4)	65	--
1215	125	--	--	--	--	--	--	--	Feed belt jammed.
1230	137	6.0	8.64	6.73	2.68	2.44	48.0	62	--
1300	167	6.0	8.64	6.73	2.68	2.44	39.0	65	--
1320	187	--	--	--	--	--	--	--	--
1330	197	5.8	8.93	7.00	2.79	2.55(2)	54.0	65	--
1400(3)	227	5.7	9.09	7.13	2.84	2.60(2)	29.0	64	--
1415(3)	242	5.7	9.09	7.13	2.84	2.60(2)	14.0	63	--
Average						2.58	36.8		

(1) Calculated; Sum of Sweco oversize and DSM oversize as a percentage of dry mill feed.
(2) Average for power (last three readings): 2.58 kwhr/st.
(3) Sample run.
(4) Omitted from average.

EXHIBIT 2

Grinding Test 4 -- continued

Procedure: Samples were wet screened on a 325M screen, products dried, and the +325M material dry screened using a Ro-Tap for 30 min.

	Screen Size Analysis								
Test Product	Mill Discharge		Sweco Screen Oversize		DSM Screen Oversize		DSM Screen Undersize		Circulating Load
Sample Time	1140	1415	1400	1415	1400	1415	1400	1415	--
Sample Weight, g:	1,139.4	886.7	715.4	726.2	1,152.9	1,020.0	763.8	769.4	--
Screen Product (Tyler) Mesh	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %
Head (calculated)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
+28	15.3	13.1	86.5	91.8	39.1	43.1	2.7	2.7	55.5
-28 +35	5.8	5.2	0.3	0.3	8.9	7.6	4.9	4.6	5.9
-35 +65	17.8	17.9	0.9	0.5	14.9	12.7	18.6	18.6	9.9
-65 +100	11.1	11.8	0.7	0.3	6.8	6.3	12.5	13.3	4.7
-100 +200	15.8	16.7	1.6	0.7	8.8	8.9	18.6	19.1	6.6
-200 +325	7.7	6.4	0.9	0.4	3.3	4.1	8.1	6.3	2.8
-325	26.5	28.9	9.1	6.0	18.2	17.3	34.6	35.4	14.6

EXHIBIT 2

Grinding Test 5

Date:	June 19, 1978
Feed Rate, stph:	2.0
Ore:	Crushed
Ball Charge:	Total 301.8 lb, 2% mill volume
-1-1/2 in. Balls, lb:	114.5
-2 in. +1-1/2 in. Balls, lb:	151.3
3 in. Balls, lb:	36.0
DSM Screen, in. width:	12
DSM Screen Openings, mm:	1.27
Measured Mill Power Tare (empty mill), kw:	2.06
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Meter Reading watt-hr	Mill-Bearing Oil Temp. °F	Ore Feed Rate (as received)(1) -3 in. lb/hr	Mill Discharge Solids %	Mill Discharge Solids lb/hr	Sweco Screen Oversize Solids %	Sweco Screen Oversize Solids lb/hr	DSM Screen Overflow Solids %	DSM Screen Overflow Solids lb/hr	DSM Screen Underflow Solids %	DSM Screen Underflow Solids lb/hr	Mill Water Meter %	Mill Water Rate lb/hr	Mill Load Volume %	Remarks
0840	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	Start mill.
0910	30	6.7	13,136	90	3,623	--	--	--	--	--	--	--	--	75	2,382	--	--
0930	50	6.3	--	91	3,960	67	8,744	48	356	67	3,558	60	2,970	71	2,255	--	--
1000	80	6.2	--	92	3,803	66	6,663	45	324	70	2,079	60	4,077	68	2,159	--	--
1030	110	6.5	--	91	--	56	3,578	15	68	70	347	59	3,452	66	2,096	--	Shut down -- out of feed.
1035	115	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1040	115	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Start mill.
1100	135	6.5	--	94	4,230	66	4,990	38	182	75	346	62	4,241	68	2,159	--	--
1130	165	6.6	--	96	4,298	66	5,049	42	239	72	729	62	4,101	69	2,191	--	--
1155	190	--	--	--	--	--	--	--	--	--	--	--	--	--	--	13	--
1200	195	6.7	--	97	4,320	63	3,856	37	200	75	405	61	3,870	69	2,191	--	--
1230	225	6.7	--	100	3,533	62	3,894	27	101	73	394	58	3,445	64	2,032	--	--
1300	255	6.6	--	103	4,016	66	4,693	29	111	70	851	61	3,870	68	2,159	--	--
1330	285	6.3	--	104	4,005	68	9,058	34	173	68	3,672	64	3,744	61	1,937	--	--
1345	300	6.5	--	104	3,645	63	4,139	32	134	71	250	59	3,452	68	2,159	--	Sample.
1400	315	6.1	--	104	4,005	64	4,781	34	143	72	238	57	3,104	69	2,191	--	Sample.
1430	345	6.1	--	105	4,140	63	4,820	33	193	69	598	59	3,505	69	2,191	--	--
1445	360	6.0	--	106	3,713	62	4,018	38	182	71	423	56	2,696	69	2,191	--	Sample.
1500	375	5.7	13,184	107	4,028	63	4,139	36	151	70	1,323	56	2,696	69	2,191	--	Sample.
1510	380	--	--	--	--	--	--	--	--	--	--	--	--	--	--	15	Shut down.
1513	388	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Collecting mill discharge sample.
1522	397	--	--	--	3,690	--	--	--	--	--	--	--	--	--	--	--	Second barrel.
1529	404	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Third barrel.
1536	411	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Hopper went empty.
1537	412	--	--	--	--	--	--	--	--	--	--	--	--	--	--	15	Shut down mill.
Average	--	--	--	--	3,934	64	5,173	35	183	71	1,087	59	3,516	68	2,165	--	--

(1) Moisture: -3 in., 2.0%. Average dry ore feed rate: -3 in., 3,855 lb/hr, 1.928 dry stph. Mill volume end of test: 15%.

EXHIBIT 2

Grinding Test 5 -- continued

Feed Rate, stph (dry): 1.928
Ball Charge: 301.8 lb, 2% of mill charge
Corrected Mill Power Tare (empty mill), kw: 0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Instantaneous Gross Power (meter reading) kwhr	Instantaneous Corrected Power (from input-output curve) kwhr	Power Consumption Gross kwhr/st	Power Consumption Net kwhr/st	Circulating Load Weight % of Feed(1)	Mill Discharge Solids %	Remarks
0840	0	--	--	--	--	--	--	--	--
0910	30	6.7	7.73	5.89	3.05	2.74	--	--	--
0930	50	6.3	8.23	6.35	3.29	2.98	--	67	--
1000	80	6.2	8.36	6.47	3.36	3.04	--	66	--
1030	110	6.5	7.97	6.10	3.16	2.85	--	56	--
1035	115	--	--	--	--	--	--	--	Ran out of ore.
1100	135	6.5	7.97	6.10	3.16	2.85	12.0(4)	66	--
1130	165	6.6	7.85	6.00	3.11	2.80	23.0(4)	66	--
1155	190	--	--	--	--	--	--	--	Check mill volume.
1200	195	6.7	7.73	5.89	3.05	2.74	14.0	63	--
1230	225	6.7	7.73	5.89	3.05	2.74	14.0	62	--
1300	255	6.6	7.85	6.00	3.11	2.80	24.0	66	--
1330	285	6.3	8.23	6.35	3.29	2.98	96.0(4)	68	--
1345(3)	300	6.5	7.97	6.10	3.16	2.85	11.0	63	--
1400(3)	315	6.1	8.50	6.60	3.42	3.11(2)	10.0	64	--
1430	345	6.1	8.50	6.60	3.42	3.11(2)	19.0	63	--
1445(3)	360	6.0	8.64	6.73	3.49	3.18(2)	16.0	62	--
1500(3)	375	5.7	9.09	7.13	3.70	3.37	37.0	63	--
1510	385	--	--	--	--	--	--	--	Check mill load level.
1513	388	--	--	--	--	--	--	--	Start filling No. 1 mill discharge sample barrel.
1522	397	--	--	--	--	--	--	--	Start filling No. 2 mill discharge sample barrel.
1529	404	--	--	--	--	--	--	--	Start filling No. 3 mill discharge sample barrel.
1536	411	--	--	--	--	--	--	--	End filling No. 3 mill discharge sample barrel.
1537	412	--	--	--	--	--	--	--	End of test.
Average						3.13	18.0		

(1) Calculated: Sum of Sweco oversize and DSM oversize as a percentage of dry mill feed.
(2) Average for power (three readings, omitted reading at 1,500 from average): 3.13 kwhr/st.
(3) Sample run.
(4) Omitted from average.

Procedure: Samples were wet screened on a 325M screen, products dried, and the +325M material dry screened using a Ro-Tap for 30 min.

Screen Size Analysis

Test Product	Mill Discharge				Sweco Screen Oversize				DSM Screen Oversize				DSM Screen Underflow				Circulating Load
Sample Time	1345	1400	1445	1500	1345	1400	1445	1500	1345	1400	1445	1500	1345	1400	1445	1500	--
Sample Weight, g:	1,058.6	1,062.1	911.3	859.1	442.5	300.3	282.2	381.8	1,065.9	713.5	478.8	920.6	817.4	757.0	743.7	787.8	--
Screen Product (Tyler) Mesh	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %
Head (calculated)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
+28	12.0	11.5	10.2	10.8	78.4	82.9	81.4	87.5	67.0	54.5	51.9	32.0	1.8	2.0	1.9	1.6	58.1
-28 +35	3.7	3.7	2.7	2.9	1.5	0.8	1.0	0.4	5.0	4.6	4.5	3.9	3.1	3.1	2.8	2.3	3.7
-35 +65	15.3	16.3	12.9	13.4	4.1	1.9	3.0	1.1	6.2	7.4	6.9	10.9	16.8	16.3	15.8	14.2	6.7
-65 +100	12.3	13.4	12.8	12.7	2.4	1.2	1.9	0.8	3.4	5.2	5.2	9.1	14.7	14.6	14.2	14.5	4.8
-100 +200	19.1	18.5	21.3	20.6	4.1	2.7	3.7	1.6	5.3	8.2	9.3	14.2	20.5	20.5	21.7	21.8	8.0
-200 +325	8.0	6.6	9.0	8.6	1.1	1.0	1.1	1.2	1.6	2.8	4.0	5.3	8.1	8.4	7.4	7.4	2.9
-325	29.6	30.0	31.1	31.0	8.4	9.5	7.9	7.4	11.5	17.3	18.2	24.6	35.0	35.1	36.2	38.2	15.8

EXHIBIT 2

Grinding Test 6

Date:	June 20, 1978
Feed Rate, stph:	2.5
Ore:	Run-of-mine
Ball Charge:	Total: 301.8 lb, 2% mill volume
-1-1/2 in. +1 in. Balls, lb:	114.5
-2 in. +1-1/2 in. Balls, lb:	151.3
3 in. Balls, lb:	36.0
DSM Screen, in. width:	12
DSM Screen Openings, mm:	1.27
Measured Mill Power Tare (empty mill), kw:	2.06
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Meter Reading watt-hr	Mill-Bearing Oil Temp. °F	Ore Feed Rate (as received)(1) -1-1/2 in. lb/hr	-4 in. +1-1/2 in. lb/hr	-6 in. +4 in. lb/hr	-10 in. -6 in. lb/hr	Mill Discharge Solids %	Mill Discharge Solids lb/hr	Sweco Screen Oversize Solids %	Sweco Screen Oversize Solids lb/hr	DSM Screen Overflow Solids %	DSM Screen Overflow Solids lb/hr	DSM Screen Underflow Solids %	DSM Screen Underflow Solids lb/hr	Mill Water Meter %	Mill Water Rate lb/hr	Mill Load Volume %	Remarks
0820	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--(Grind out)--		Start mill.
0925	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Start feed.
0930	5	6.8	13,195	82	--	768	474	219	--	--	--	--	--	--	--	--	80	2,540	--	--
1000	35	5.9	--	80	--	768	474	219	66	11,286	60	662	71	4,090	61	5,737	85	2,699	--	--
1030	65	5.3	--	82	3,713	768	474	219	66	9,742	54	535	68	4,896	61	3,486	84	2,668	--	--
1100	95	5.2	--	83	3,825	768	474	219	67	10,492	60	608	68	4,651	61	4,255	85	2,699	--	--
1135	130	5.2	--	84	3,510	768	474	219	66	7,960	59	597	68	3,733	61	4,255	84	2,668	25	--
1200	155	5.2	--	87	3,758	768	474	219	68	10,588	57	487	68	4,651	60	3,699	85	2,699	--	--
1230	185	5.1	--	88	3,420	768	474	219	68	10,037	55	545	69	3,974	60	4,104	89	2,826	--	--
1245	200	5.1	--	88	3,420	768	474	219	67	9,950	52	714	68	4,223	59	4,275	89	2,826	--	Sample.
1300	215	5.0	--	89	3,600	768	474	219	67	11,759	62	781	68	6,487	62	3,627	85	2,699	--	Sample.
1330	245	5.0	12,236	92	--	768	474	219	67	8,924	60	1,337	68	4,039	60	3,780	88	2,795	--	--
1337	252	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27	Shut down.
Average					3,607	768	474	219	67	10,082	58	696	68	4,527	61	4,135	85	2,712		

(1) Moisture: -1-1/2 in., 2.3%; -4 in. +1-1/2 in., 1.0%; -6 in. +4 in., 0.8%; -10 in. +6 in., 0.7%. Average dry ore feed rate: -1-1/2 in., 3,524 lb/hr; -4 in. +1-1/2 in., 760.3 lb/hr; -6 in. +4 in., 470.2 lb/hr; -10 in. +6 in., 217.5 lb/hr; Total: 4,972 lb/hr; 2.486 dry stph. Mill volume end of test: 27%.

Feed Rate, stph (dry):	2.486
Ball Charge:	301.8 lb, 2% of mill volume
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Instantaneous Gross Power (meter reading) kwhr	Instantaneous Corrected Power (from input-output curve) kwhr	Power Consumption Gross kwhr/st	Power Consumption Net kwhr/st	Circulating Load Weight % of Feed(1)	Mill Discharge Solids %	Remarks
0820	--	--	--	--	--	--	--	--	Grind out.
0925	--	--	--	--	--	--	--	--	Start feed.
0930	5	6.8	7.62	5.80	2.33	2.09	--	--	--
1000	35	5.9	8.78	6.87	2.76	2.52	--	66	--
1030	65	5.3	9.78	7.78	3.13	2.92	105.0	66	--
1100	95	5.2	9.97	7.92	3.18	2.94	99.0	67	--
1135	130	5.2	9.97	7.92	3.18	2.94	87.0	66	--
1200	155	5.2	9.97	7.92	3.18	2.94	98.0	68	--
1230	185	5.1	10.16	8.09	3.25	3.01	93.0	68	--
1245(3)	200	5.1	10.16	8.09	3.25	3.01	101.0	67	--
1300(3)	215	5.0	10.36	8.26	3.32	3.08(2)	144.0	67	--
1330	245	4.0	10.36	8.26	3.32	3.08(2)	--	67	--
1337	252	--	--	--	--				End of test.
Average						3.08	103.9		

(1) Calculated: Sum of Sweco oversize and DSM oversize as a percentage of dry mill feed.
(2) Average for power (two readings): 3.08 kwhr/st.
(3) Sample run.

EXHIBIT 2

Grinding Test 6 -- continued

Procedure: Samples were wet screened on a 325M screen, products dried, and the +325M material dry screened using a Ro-Tap for 30 min.

	Screen Size Analysis								
Total Product	Mill Discharge		Sweco Screen Oversize		DSM Screen Oversize		DSM Screen Undersize		Circulating Load
Sample Time	1245	1300	1245	1300	1245	1300	1245	1300	
Sample Weight, g:	1,258.8	1,237.7	673.8	642.6	1,361.9	1,079.3	832.1	918.1	--
Screen Product (Tyler) Mesh	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %
Head (calculated)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
+28	21.0	18.4	64.8	70.7	32.9	23.1	1.3	1.0	32.9
-28 +35	6.4	6.5	1.9	1.2	9.4	8.5	3.9	3.7	8.1
-35 +65	13.9	15.1	3.8	2.7	12.8	14.3	16.5	16.7	12.2
-65 +100	10.5	11.4	3.2	2.2	8.8	8.6	12.4	14.5	8.0
-100 +200	13.3	14.2	5.4	5.0	11.8	14.2	20.3	18.5	12.0
-200 +325	5.5	5.6	3.1	2.2	4.8	3.7	5.3	6.7	4.1
-325	29.4	28.8	17.8	16.0	19.5	27.6	40.3	38.9	22.7

Sediment Description and Classification Background

U.S. Standard Sieves

Note that the same size mesh can be a differing sieve number depending on the Sieve manufacturer (Tyler vs. ASTM)

Mesh Size (microns)	TYLER	ASTM-E11	BS-410	DIN-4188
µm	Mesh	No.	Mesh	mm
5	2500		2500	0.005
10	1250		1250	0.010
15	800		800	0.015
20	625		625	0.020
22				0.022
25	500		500	0.025
28				0.028
32				0.032
36				0.036
38	400	400	400	
40				0.040
45	325	325	350	0.045
50				0.050
53	270	270	300	
56				0.056
63	250	230	240	0.063
71				0.071
75	200	200	200	
80				0.080
90	170	170	170	0.090
100				0.100
106	150	140	150	
112				0.112
125	115	120	120	0.125
140				0.140
150	100	100	100	

Attachment B, 1/10

160				0.160
180	80	80	85	0.180
200				0.200
212	65	70	72	
250	60	60	60	0.250
280				0.280
300	48	50	52	
315				0.315
355	42	45	44	0.355
400				0.400
425	35	40	36	
450				0.450
500	32	35	30	0.500
560				0.560
600	28	30	25	
630				0.630
710	24	25	22	0.710
800				0.800
850	20	20	18	
900				0.900
1000	16	18	16	1.0
1120				1.12
1180	14	16	14	
1250				1.25
1400	12	14	12	1.4
1600				1.6
1700	10	12	10	
1800				1.8
2000	9	10	8	2.0
2240				2.24
2360	8	8	7	
2500				2.5
2800	7	7	6	2.8
3150				3.15
3350	6	6	5	
3550				3.55
4000	5	5	4	4.0
4500				4.5

4750	4	4	3.5	
5000				5.0

Sediment Classification based on Grain Size:

Unified Soil Classification System (USCS)

Sediment Name	**Diameter (mm)**	**Sieve No.**
Cobble	greater than 75 mm	
Gravel	4.75 to 75 mm	4
Sand	0.075 to 4.75 mm	200
Fines (silt and clay)	less than 0.075 mm	

USCS Division of Sands

Sediment Name	Diameter Range (mm)	Passes through Sieve No.	Retained on Sieve No.
Coarse Sand	2.0 - 4.8	4	10
Medium Sand	0.43 - 2.0	10	40
Fine Sand	0.075 - 0.43	40	200

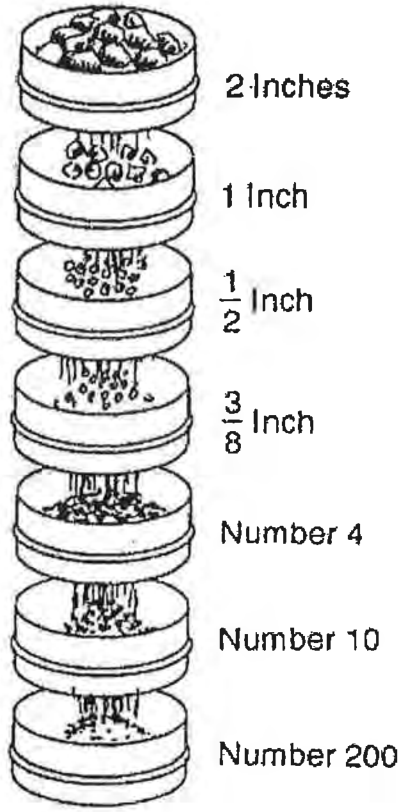


Figure 4-3. Dry sieve analysis.

USCS Classification System

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOLS	DESCRIPTIONS
COARSE GRAINED SOILS More Than Half Retained on 200 Sieve	GRAVELS More Than Half Coarse Fraction Retained on No. 4 Sieve	Clean Gravels (Little or no Fines)	GW	Well Graded Gravels, Gravel - Sand Mixtures, Little or no Fines
			GP	Poorly Graded Gravels, Gravel - Sand Mixtures, Little or no Fines
		Gravels With Fines (Appreciable Fines)	GM	Silty Gravels, Gravel-Sand-Silt Mixtures
			GC	Clayey Gravels, Gravel-Sand-Clay Mixtures
	SANDS More Than Half Coarse Fraction Passes a No. 4 Sieve	Clean Sands (Little or no Fines)	SW	Well Graded Sands, Gravelly Sands, Little or no Fines
			SP	Poorly Graded Sands, Gravelly Sands, Little or no Fines
		Sands With Fines (Appreciable Fines)	SM	Silty Sands, Sand - Silt Mixtures
			SC	Clayey Sands, Sand - Clay Mixtures
FINE GRAINED SOILS More Than Half Passes 200 Sieve	SILTS and CLAYS Liquid Limit Less Than 50		ML	Inorganic Silts & Very Fine Sands, Silty or Clayey Fine Sands, Clayey Silts
			CL	Inorganic Clays of Low to Medium Plasticity, Lean Clays
			OL	Organic Silts & Organic Silty Clays of Low Plasticity
	SILTS and CLAYS Liquid Limit Greater Than 50		MH	Inorganic Silts, Fine Sand or Silty Soils, Elastic Silts
			CH	Inorganic Clays of High Plasticity, Fat Clays
			OH	Organic Clays of Medium to High Plasticity, Organic Silts
Highly Organic Soils			PT	Peat and Other Highly Organic Soils

Visual logging of sediments entails estimating percentages of gravels, sands and fines (silt and clays). Practice and the use of the Geotechnical Gage will increase your confidence and ability in visually logging sediments.

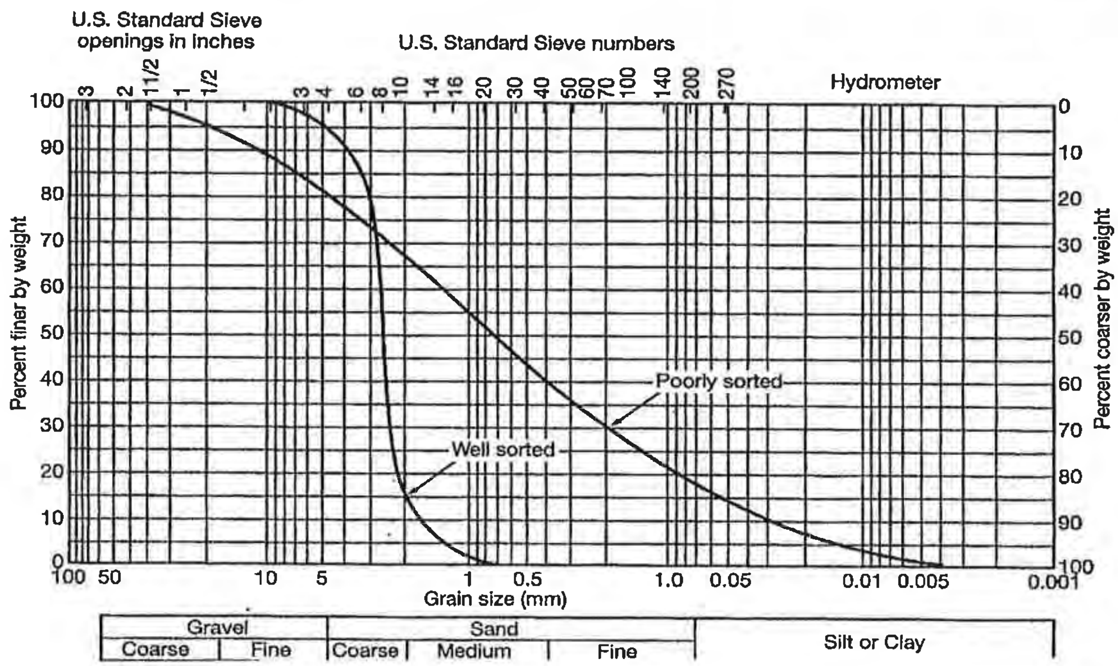
Read: Visual Exam Test

Read: Field Identification Guidelines

Ultimately, sediment samples may undergo grain size analysis through sieves. Graphing the cumulative weight percent retained/passing by sieve no. or grain size will result in the sediment grain-size distribution curve. The grain-size distribution curve is used to quantitatively classify the sediment type (your visual identification is a qualitative classification).

Read: Grain Size Distribution Measurement

Grain Size Distribution Curve



The grain-size distribution curve is used with the USCS classification chart to classify the sediment type. Other measures used to describe the sediment are the sorting or gradation of the sediment. As can be seen in the above chart, a well-sorted sediment has a small range of sediment grain sizes while a poorly sorted sediment has a large range of sediment grain sizes. In the USCS classification scheme, the gradation of the sediment is used instead of the sorting. A well-graded sediment has a large range of grain sizes while a poorly or uniformly graded sediment has a small range of grain sizes.

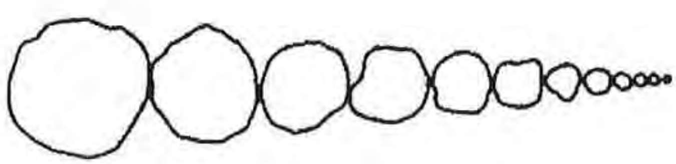


Figure 4-6. Well-graded soil.

POORLY SORTED SEDIMENT = WELL GRADED SEDIMENT

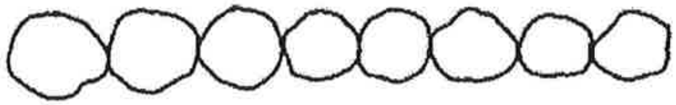


Figure 4-7. Uniformly graded soil.

WELL-SORTED SEDIMENT = POORLY OR UNIFORMLY GRADED SEDIMENT

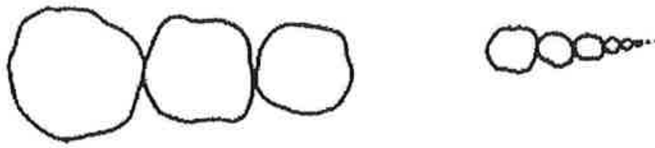


Figure 4-8. Gap-graded soil.

After sieve analysis, the data are tabulated showing the weight of sediment retained on each sieve. The cumulative weight retained is calculated starting from the largest sieve size and adding subsequent sediment weights from the smaller size sieves (see table below). The percent retained is calculated from the weight retained and the total weight of the sample. [Don't get confused by the graph - it is individual percent retained in Column 16 and cumulative percent passing in Column 17]. The cumulative percent passing in Column 17 of the table below is calculated by sequentially subtracting percent retained from 100 %. In table below, cumulative percent passing 1/4 inch sieve = 100 - 16 = 84; cumulative percent passing #4 sieve = 84-5.2 = 78.8; etc.

SIEVE ANALYSIS DATA

1. DATE STARTED: 22 FEB 91
2. PROJECT: BRAVO AIRFIELD
3. EXCAVATION: 1+00
4. DATE COMPLETED: 28 FEB 91
5. SAMPLE DESCRIPTION: LIGHT BROWN SANDY SOIL
6. SAMPLE NUMBER: 1A
7. PREWASHED: XX YES | NO
8. ORIGINAL SAMPLE WEIGHT: 2459
9. + #200 SAMPLE WEIGHT: 2359
10. − #200 SAMPLE WEIGHT: 100

11. SIEVE SIZE	12. WEIGHT OF SIEVE	13. WEIGHT OF SIEVE + SAMPLE	14. WEIGHT RETAINED	15. CUMULATIVE WEIGHT RETAINED	16. PERCENT RETAINED	17. PERCENT PASSING
1½	202					
1	231					
½	210	210	0	0	0	100.0
¼	230	624	394	394	16.0	84.0
#4	205	332	127	521	5.2	78.8
#8	225	691	466	987	19.0	59.8
#20	215	612	397	1384	16.2	43.6
#60	235	581	346	1730	14.1	29.5
#100	250	612	362	2092	14.7	14.8
#200	260	515	255	2347	10.4	4.4

18. TOTAL WEIGHT RETAINED IN SIEVES (Sum Column 14)	2347
20. WEIGHT SIEVED THROUGH #200 (Weight in pan) 270-260	10
21. WASHING LOSS (8 - (9 + 10)) 2459-(2359+100)	0
22. TOTAL WEIGHT PASSING #200 (20 + 10) 10+100	110
23. TOTAL WEIGHT OF FRACTIONS (18 + 22)	2457

19. ERROR (8 − 23): 2459-2457 = 2

24. REMARKS

USCS SP
PERCENT - G 21.2
PERCENT - S 74.4
PERCENT - F 4.4

25. ERROR (Percent)

ERROR (19) / ORIGINAL WT (8) x 100 =

$\frac{2}{2459} \times 100 = .08$

26. TECHNICIAN: Joe Blob PVZ
27. COMPUTED BY (Signature): Joe Blob PVZ
28. CHECKED BY (Signature): Fred Jones SSG

DD Form 1206, DEC 86 *Previous editions are obsolete*

Figure 4-4. Data sheet, example of dry sieve analysis.

The cumulative percent passing is plotted on the grain-size distribution graph. The percentage passing the No. 4 and 200 sieves is used to classify the sediments as gravels (G), sands (S) or fines (must use plasiticity index to differentiate between silts and clays).

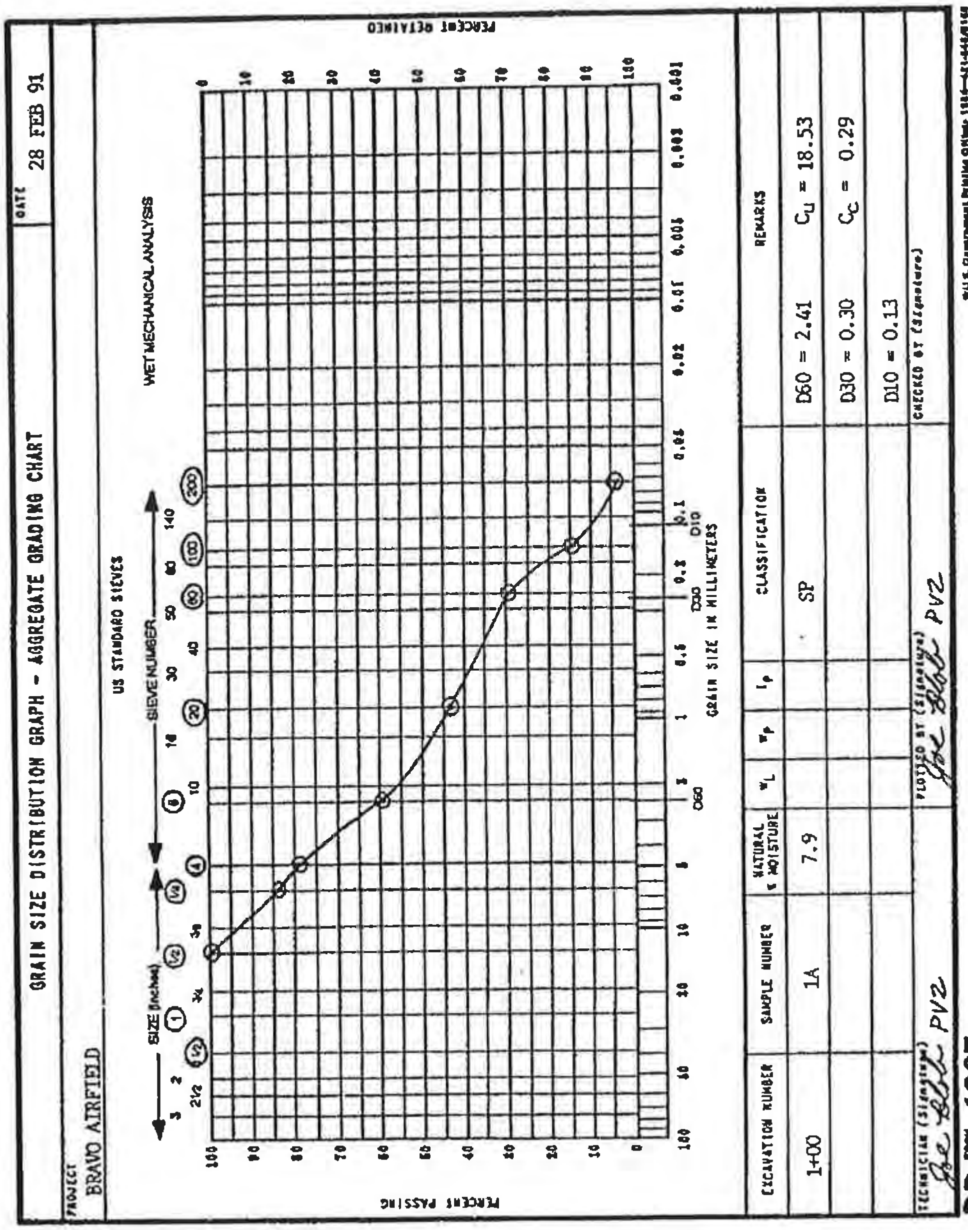


Figure 4-5. Grain-size distribution curve from sieve analysis.

The grain-size distribution graph is used to read off the grain size at which 10% of the sample passed (D_{10}), 30% of the sample passed (D_{30}) and 60% of the sample passed (D_{60}). These numbers are used to calculate several coefficients:

Hazen's effective size, D_{10}, which will be used to estimate permeability

Uniformity Coefficient, $C_u = D_{60}/D_{10}$

In the above graph,

$$D_{60} = 2.4 \text{ mm and } D_{10} = 0.13 \text{ mm}$$

$$\text{then} \quad C_u = 2.4/0.13 = 18.5$$

The uniformity coefficient is used to judge gradation.

Coefficient of Curvature, C_c

$$C_c = \frac{(D_{30})^2}{(D_{60} \times D_{10})}$$

In the above graph,

$$D_{30} = 0.3 \text{ mm}$$

$$\text{and } C_c = \frac{(0.3)^2}{(2.4)(0.13)} = .29$$

In the graph below, well-graded soils (GW and SW) are long curves spanning a wide range of sizes with a constant or gently varying slope. Uniformly graded soils (SP) are steeply sloping curves spanning a narrow range of sizes. For a gap-graded soil (GP), the curve flattens out in the area of the grain-size deficiency or gap.

The USCS criteria for well-graded gravels (GW) and sands (SW) are:

1. Less than 5% finer than No. 200 sieve
2. Uniformity coefficient greater than 4
3. Coefficient of curvature between 1 and 3

If Criterion 1 is met, but not Criteria 2 and 3, the gravels are gap-graded or uniform gravels (GP) or sands (SP)

If you are interested in more information: Gradation and Bearing Capacity

United States
Environmental Protection
Agency

Office of Research and
Development
Washington DC 20460

EPA/600/R-94/168b
September 1994

EPA

The Hydrologic Evaluation of Landfill Performance (HELP) Model

Engineering Documentation for Version 3

Attachment C, 1/3

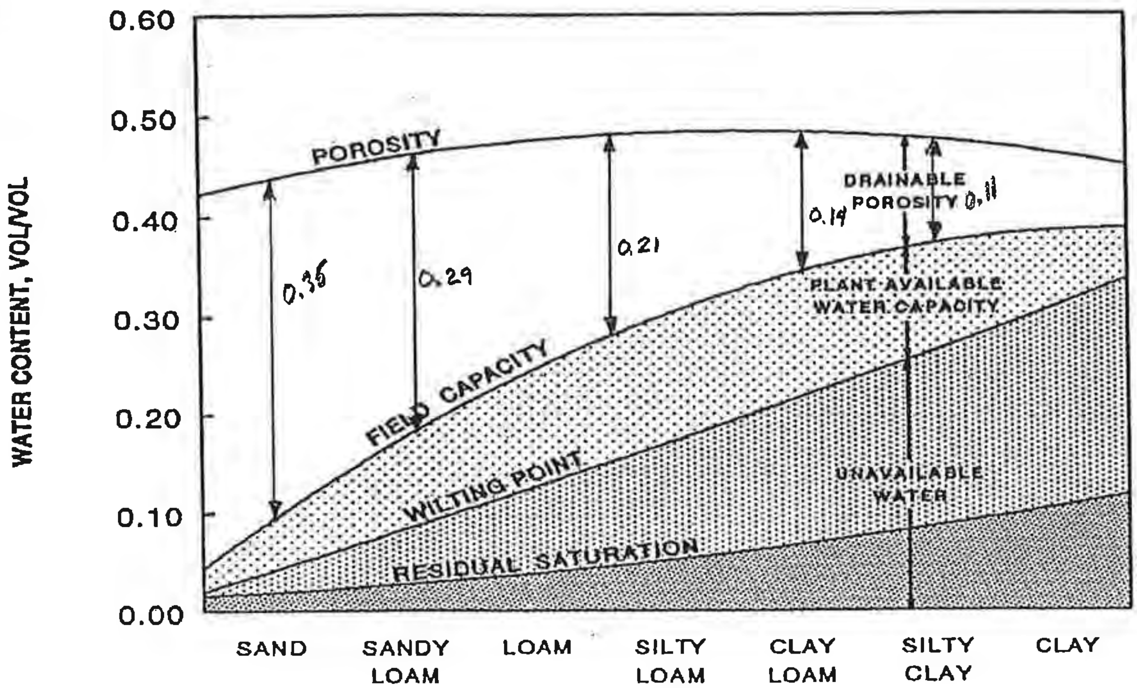


Figure 2. Relation Among Moisture Retention Parameters and Soil Texture Class

are not specified, the program assumes values near the steady-state values (allowing no long-term change in moisture storage) and runs a year of simulation to initialize the moisture contents closer to steady state. The soil water contents at the end of this year are substituted as the initial values for the simulation period. The program then runs the complete simulation, starting again from the beginning of the first year of data. The results of the volumetric water content initialization period are not reported in the output.

3.3.2 Unsaturated Hydraulic Conductivity

Darcy's constant of proportionality governing flow through porous media is known quantitatively as hydraulic conductivity or coefficient of permeability and qualitatively as permeability. Hydraulic conductivity is a function of media properties, such as particle size, void ratio, composition, fabric, degree of saturation, and the kinematic viscosity of the fluid moving through the media. The HELP program uses the saturated and unsaturated hydraulic conductivities of soil and waste layers to compute vertical drainage, lateral drainage and soil liner percolation. The vapor diffusivity for geomembranes is specified as a saturated hydraulic conductivity to compute leakage through geomembranes by vapor diffusion.

Attachment C, 2/3

TABLE 1. DEFAULT LOW DENSITY SOIL CHARACTERISTICS

Soil Texture Class			A Total Porosity vol/vol	B Field Capacity vol/vol	Wilting Point vol/vol	Saturated Hydraulic Conductivity cm/sec	A-B Drainable Porosity vol/vol
HELP	USDA	USCS					
1	CoS	SP	0.417	0.045	0.018	1.0×10^{-2}	
2	S	SW	0.437	0.062	0.024	5.8×10^{-3}	
3	FS	SW	0.457	0.083	0.033	3.1×10^{-3}	
4	LS	SM	0.437	0.105	0.047	1.7×10^{-3}	0.332
5	LFS	SM	0.457	0.131	0.058	1.0×10^{-3}	0.326
6	SL	SM	0.453	0.190	0.085	7.2×10^{-4}	0.263
7	FSL	SM	0.473	0.222	0.104	5.2×10^{-4}	0.251
8	L	ML	0.463	0.232	0.116	3.7×10^{-4}	0.231
9	SiL	ML	0.501	0.284	0.135	1.9×10^{-4}	0.217
10	SCL	SC	0.398	0.244	0.136	1.2×10^{-4}	0.154
11	CL	CL	0.464	0.310	0.187	6.4×10^{-5}	
12	SiCL	CL	0.471	0.342	0.210	4.2×10^{-5}	
13	SC	SC	0.430	0.321	0.221	3.3×10^{-5}	
14	SiC	CH	0.479	0.371	0.251	2.5×10^{-5}	
15	C	CH	0.475	0.378	0.251	2.5×10^{-5}	
21	G	GP	0.397	0.032	0.013	3.0×10^{-1}	

a = constant representing the effects of various fluid constants and gravity, 21 cm^3/sec

ϕ = total porosity, vol/vol

θ_r = residual volumetric water content, vol/vol

ψ_b = bubbling pressure, cm

λ = pore-size distribution index, dimensionless

A more detailed explanation of Equation 11 can be found in Appendix A of the HELP program Version 3 User's Guide and the cited references.

ATTACHMENT C, 3/3

ered that when well-graded mixtures of sand and gravel contained as little as 5% of fines (sizes smaller than a No. 200 sieve) high compactive efforts reduced the effective porosities nearly to zero and the permeabilities to less than 0.01% of those at moderate densities. These tests explain one of the reasons that blends of sand and gravel often used for drains are virtually useless as drainage aggregates if they contain more than insignificant amounts of fines.

In the preceding paragraphs variations in the permeability of remolded materials caused by variable compaction were discussed. Any factor that densifies soils reduces permeability. Studies of the rate of consolidation of clay and peat foundations are sometimes made by using initial coefficients of permeability of compressible formations. While the consolidation process is going on in foundations their permeabilities are becoming less. Generally, decreases in the permeabilities of clay foundations are rather moderate, but they can be large in highly compressible organic silts and clays and in peats. Modified calculation methods utilizing the changing permeability are needed in the analysis of highly compressible foundations. Some typical variations in permeability caused by consolidation are given in Fig. 2.10, a plot of consolidation pressure versus permeability.

$\sigma_n \simeq 31' \times 130\,pcf$
$\simeq 4000\,psf$
$\simeq 2\,Tsf$

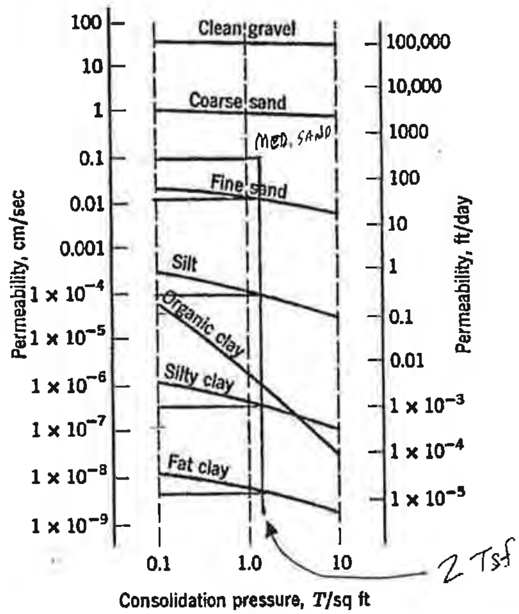


FIG. 2.10 Permeability versus consolidation pressure.

Attachment D

"Seepage, Drainage, and Flow Nets" 3rd Edition, Cedergren, H.R. 1989

1/2

$$k = \frac{Q}{iAt} \tag{2.2}$$

Darcy's *discharge velocity* multiplied by the entire cross-sectional area, including voids e and solids 1, gives the seepage quantity Q under a given hydraulic gradient $i = \Delta h/\Delta l$ or h/L. It is an imaginary velocity that does not exist anywhere. The average *seepage velocity* v_s of a mass of water progressing through the pore spaces of a soil is equal to the discharge velocity $(v_d = ki)$ multiplied by $(1 + e)/e$ or the discharge velocity divided by the effective porosity n_e; hence permeability is related to seepage velocity by the expression

$$k = \frac{v_s n_e}{i} \tag{2.3}$$

For any seepage condition in the laboratory or in the field in which the *seepage quantity*, the area perpendicular to the direction of flow, and the hydraulic gradient are known the coefficient of permeability can be calculated. Likewise, for any situation where the *seepage velocity* is known at a point at which the hydraulic gradient and soil porosity also are known, permeability can be calculated.

Experimentally determined coefficients of permeability can be combined with prescribed hydraulic gradients and discharge areas in solving practical problems involving seepage quantities and velocities. When a coefficient of permeability has been properly determined, it furnishes a very important factor in the analysis of seepage and in the design of drainage features for engineering works.

The coefficient of permeability as used in this book and in soil mechanics in general should be distinguished from the physicists' coefficient of permeability K, which is a more general term than the engineers' coefficient and has units of centimeters squared rather than a velocity; it varies with the porosity of the soil but is independent of the viscosity and density of the fluid. The transmissibility factor T represents the capability of an aquifer to discharge water and is the product of permeability k and aquifer thickness t.

The engineers' coefficient, which is used in practical problems of seepage through masses of earth and other porous media, applies only to the flow of water and is a simplification introduced purely from the standpoint of convenience. It has units of a velocity and is expressed in centimeters per second, feet per minute, feet per day, or feet per year, depending on the habits and personal preferences of individuals using the coefficient. In standard soil mechanics terminology k is expressed in centimeters per second.

Although coefficient of permeability is often considered to be a constant for a given soil or rock, it can vary widely for a given material, depending on a number of factors. Its absolute values depend, first of all, on the properties of water, of which viscosity is the most important. For individual materials

Attachment D, 2/2

Cedergren, "Seepage, Drainage, and Flow Nets", 3rd Ed. 1989

Multi-FLO

Technical Properties

Drainage Core

Property	Test Method	Value
Thickness, inches	ASTM D-1777	1.0
Flow Rate, gpm/ft*	ASTM D-4716	29
Compressive Strength	ASTM D-1621	6000

*

Geotextile Filter

Property	Test Method	Value
Weight, oz/sq yd2	ASTM D-3776	4.0
Tensile Strength, lb.	ASTM D-4632	100
Elongation, %	ASTM D-4632	50
Puncture, lb.	ASTM D-4833	50
Mullen Burst, psi	ASTM D-3786	200
Trapezoidal Tear, lb.	ASTM D-4533	42
Coeffecient of Perm,cm/sec	ASTM D-4491	0.1
Flow Rate, gpm/ft2	ASTM D-4491	100
Permittivity, 1/sec	ASTM D-4491	1.8
A.O.S Max US Std Sieve	ASTM D 4751	70
UV Stability, 500 hrs., %	ASTM D-4355	70
Seam Strength, lb./ft	ASTM D-4595	100
Fungus	ASTM G-21	No Growth

* Horizontal Installation , gradient = 0.01, compressive force = 10 psi for 1(

All values given represent minimum average roll values

GDE Control Products, Inc. Laguna Hills, CA. 949-305-7117

GDE, Multi-Flow
<http: www.gdecontrol.com/Multi-Flow5.html> Attachment E 1/1

TABLE 2.12 RECOMMENDED REDUCTION FACTOR VALUES FOR USE IN EQ. (2.25a)

	Range of Reduction Factors				
Application	Soil Clogging and Blinding*	Creep Reduction of Voids	Intrusion into Voids	Chemical Clogging†	Biological Clogging
Retaining wall filters	2.0 to 4.0	1.5 to 2.0	1.0 to 1.2	1.0 to 1.2	1.0 to 1.3
Underdrain filters	5.0 to 10	1.0 to 1.5	1.0 to 1.2	1.2 to 1.5	2.0 to 4.0
Erosion-control filters	2.0 to 10	1.0 to 1.5	1.0 to 1.2	1.0 to 1.2	2.0 to 4.0
* Landfill filters	5.0 to 10	1.5 to 2.0	1.0 to 1.2	1.2 to 1.5	5 to 10‡
Gravity drainage	2.0 to 4.0	2.0 to 3.0	1.0 to 1.2	1.2 to 1.5	1.2 to 1.5
Pressure drainage	2.0 to 3.0	2.0 to 3.0	1.0 to 1.2	1.1 to 1.3	1.1 to 1.3

*If stone riprap or concrete blocks cover the surface of the geotextile, use either the upper values or include an additional reduction factor.
†Values can be higher particularly for high alkalinity groundwater.
‡Values can be higher for turbidity and/or for microorganism contents greater than 5000 mg/l.

$$q_{\text{allow}} = q_{\text{ult}}\left(\frac{1}{\Pi \text{RF}}\right) \tag{2.25b}$$

where

q_{allow} = allowable flow rate,
q_{ult} = ultimate flow rate,
RF_{SCB} = reduction factor for soil clogging and blinding,
RF_{CR} = reduction factor for creep reduction of void space,
RF_{IN} = reduction factor for adjacent materials intruding into geotextile's void space,
RF_{CC} = reduction factor for chemical clogging,
RF_{BC} = reduction factor for biological clogging, and
ΠRF = value of cumulative reduction factors.

As with Eqs. (2.24) for strength reduction, this flow-reduction equation could also have included additional site-specific terms, such as blocking of a portion of the geotextile's surface by riprap or concrete blocks.

2.5 DESIGNING FOR SEPARATION

Application areas for geotextiles used for the separation function were given in Section 1.3.3. There are many specific applications, and it could be said, in a general sense, that geotextiles always serve a separation function. If they do not also serve this function, any other function, including the primary one, will not be served properly. This should not give the impression that the geotextile function of separation always plays a secondary role. Many situations call for separation only, and in such cases the geotextiles serve a significant and worthwhile function.

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4.1.6 Allowable Flow Rate

As described previously, the very essence of the design-by-function concept is the establishment of an adequate factor of safety. For geonets, where flow rate is the primary function, this takes the following form.

$$FS = \frac{q_{allow}}{q_{reqd}} \tag{4.3}$$

where

FS = factor of safety (to handle unknown loading conditions or uncertainties in the design method, etc.),
q_{allow} = allowable flow rate as obtained from laboratory testing, and
q_{reqd} = required flow rate as obtained from design of the actual system.

Alternatively, we could work from transmissivity to obtain the equivalent relationship.

$$FS = \frac{\theta_{allow}}{\theta_{reqd}} \tag{4.4}$$

where θ is the transmissivity, under definitions as above. As discussed previously, however, it is preferable to design with flow rate rather than with transmissivity because of nonlaminar flow conditions in geonets.

Concerning the allowable flow rate or transmissivity value, which comes from hydraulic testing of the type described in Section 4.1.3, we must assess the realism of the test setup in contrast to the actual field system. If the test setup does not model site-specific conditions adequately, then adjustments to the laboratory value must be made. This is usually the case. Thus the laboratory-generated value is an ultimate value that must be reduced before use in design; that is,

$$q_{allow} < q_{ult}$$

One way of doing this is to ascribe reduction factors on each of the items not adequately assessed in the laboratory test. For example,

$$q_{allow} = q_{ult}\left[\frac{1}{RF_{IN} \times RF_{CR} \times RF_{CC} \times RF_{BC}}\right] \tag{4.5}$$

or if all of the reduction factors are considered together.

$$q_{allow} = q_{ult}\left[\frac{1}{\Pi RF}\right] \tag{4.6}$$

where

q_{ult} = flow rate determined using ASTM D4716 or ISO/DIS 12958 for short-term tests between solid platens using water as the transported liquid under laboratory test temperatures,

ATTACHMENT F

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: flow rate is the primary

(4.3)

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RF_{BC} (4.5)

(4.6)

ISO/DIS 12958 for short-
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q_{allow} = allowable flow rate to be used in Eq. (4.3) for final design purposes,
RF_{IN} = reduction factor for elastic deformation, or intrusion, of the adjacent geosynthetics into the geonet's core space,
RF_{CR} = reduction factor for creep deformation of the geonet and/or adjacent geosynthetics into the geonet's core space,
RF_{CC} = reduction factor for chemical clogging and/or precipitation of chemicals in the geonet's core space,
RF_{BC} = reduction factor for biological clogging in the geonet's core space, and
ΠRF = product of all reduction factors for the site-specific conditions.

Some guidelines for the various reduction factors to be used in different situations are given in Table 4.2. Please note that some of these values are based on relatively sparse information. Other reduction factors, such as installation damage, temperature effects, and liquid turbidity, could also be included. If needed, they can be included on a site-specific basis. On the other hand, if the actual laboratory test procedure has included the particular item, it would appear in the above formulation as a value of unity. Examples 4.2 and 4.3 illustrate the use of geonets and serve to point out that high reduction factors are warranted in critical situations.

Example 4.2

What is the allowable geonet flow rate to be used in the design of a capillary break beneath a roadway to prevent frost heave? Assume that laboratory testing was done at the proper design load and hydraulic gradient and that this testing yielded a short-term between-rigid-plates value of 2.5×10^{-4} m²/s.

Solution: Since better information is not known, average values from Table 4.2 are used in Eq. (4.5).

TABLE 4.2 RECOMMENDED PRELIMINARY REDUCTION FACTOR VALUES FOR EQ. (4.5) FOR DETERMINING ALLOWABLE FLOW RATE OR TRANSMISSIVITY OF GEONETS

Application Area	RF_{IN}	RF_{CR}*	RF_{CC}	RF_{BC}
Sport fields	1.0 to 1.2	1.0 to 1.5	1.0 to 1.2	1.1 to 1.3
Capillary breaks	1.1 to 1.3	1.0 to 1.2	1.1 to 1.5	1.1 to 1.3
Roof and plaza decks	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2	1.1 to 1.3
Retaining walls, seeping rock, and soil slopes	1.3 to 1.5	1.2 to 1.4	1.1 to 1.5	1.0 to 1.5
Drainage blankets	1.3 to 1.5	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2
Surface water drains for landfill covers	1.3 to 1.5	1.1 to 1.4	1.0 to 1.2	1.2 to 1.5
Secondary leachate collection (landfills)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 2.0
Primary leachate collection (landfills)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 2.0

*These values are sensitive to the density of the resin used in the geonet's manufacture. The higher the density, the lower the reduction factor. Creep of the covering geotextile(s) is a product-specific issue.

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The above formula can be readily converted to flow rate, Q, by multiplying the velocity by the cross-sectional area A of the pipe.

For pipelines that are either flowing full or flowing partially full, the *Manning equation* is generally used.

$$V = \frac{1}{n} R_H^{0.66} S^{0.5} \tag{7.10}$$

where

V = velocity of flow (m/s),
R_H = hydraulic radius (m),
S = slope or gradient of pipeline (m/m), and
n = coefficient of roughness (see Table 7.7) (dimensionless).

Note that plastic pipe of the type discussed in this chapter, with a *smooth interior*, has a Manning coefficient from 0.009 to 0.010. Plastic pipe with a *profiled or corrugated interior* has a Manning coefficient ranging from 0.018 to 0.025.

Eqs. (7.9) and (7.10) are generally used in the form of charts or nomographs to determine pipe sizes, flow velocity or discharge flow rates (see Figures 7.6 and 7.7). For each chart we include an example from Hwang [7], illustrated on the respective nomographs by heavy lines. Note that both nomographs are for pipes flowing full.

Example 7.1

A 100 m long pipe with $D = 200$ mm and $C = 120$ carries a discharge of 30 l/s. Determine the head loss in the pipe. (See the Hazen-Williams chart in Figure 7.6.)

Solution: Applying the conditions given to the solution chart in Figure 7.6, the energy gradient is obtained.

$$S = 0.0058 \text{ m/m}$$

TABLE 7.7 VALUES OF MANNING ROUGHNESS COEFFICIENT, N, FOR REPRESENTATIVE SURFACES

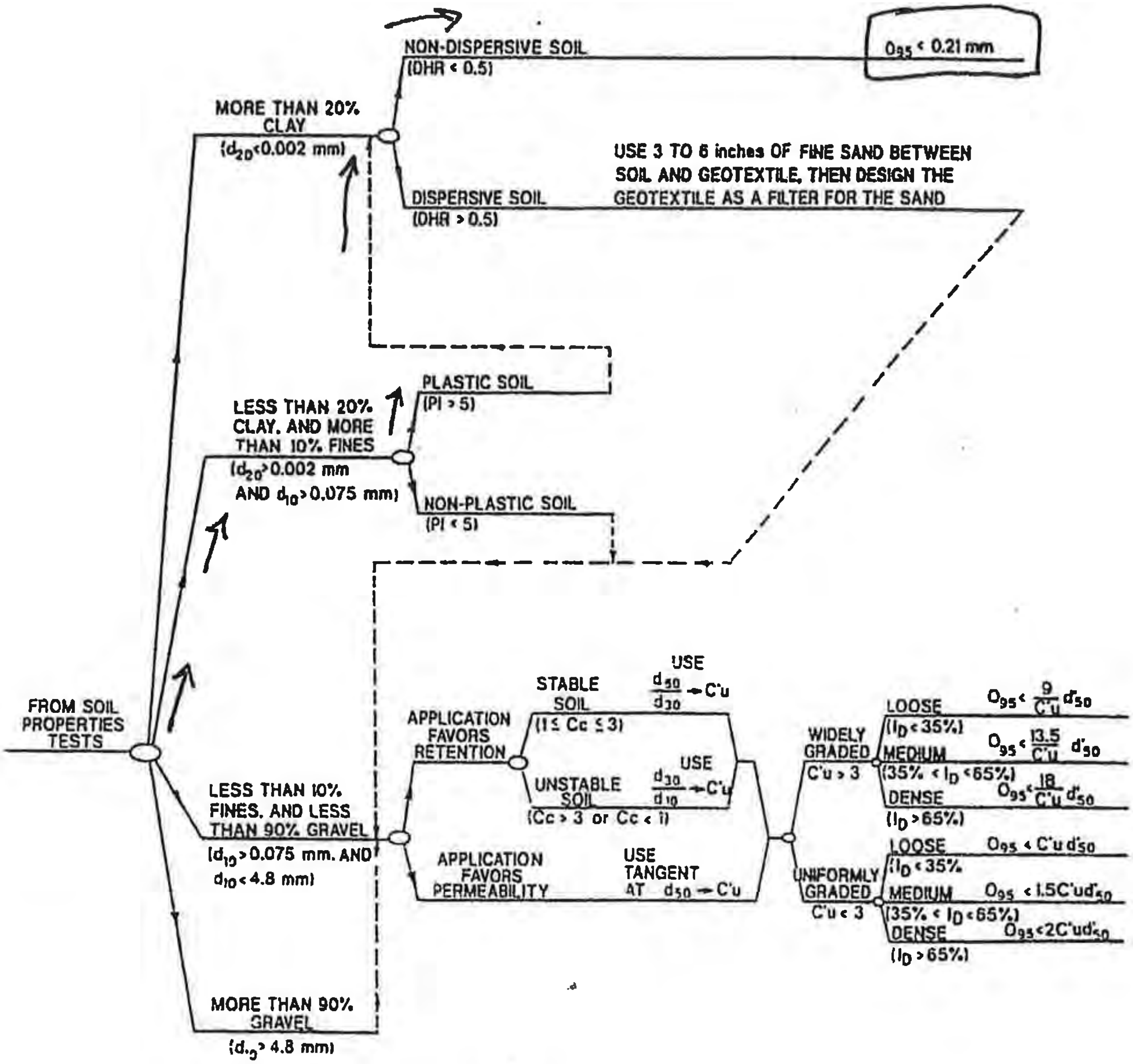
Type of Pipe Surface	Representative n value
Lucite, glass, or plastic*	0.010
Wood or finished concrete	[illegible]
Unfinished concrete, well-laid brickwork, concrete or cast iron pipe	[illegible]
Riveted or spiral steel pipe	[illegible]
Smooth, uniform earth channel	[illegible]
Corrugated flumes, typical canals, river free from large stones and heavy weeds	[illegible]
Canals and rivers with many stones and weeds	[illegible]

*The table does not distinguish between different types of plastic, or between smooth wall [illegible] pipes with perforations.

Source: After Fox and McDonald [9].

Koerner, R.M., "Designing with Geosynthetics," 4th Ed., 1999
Attachment F[illegible]

CHART 1
SOIL RETENTION CRITERIA FOR STEADY-STATE FLOW CONDITIONS



NOTES:

d_x is the particle size of which x percent is smaller

$C'u = \sqrt{\frac{d'_{100}}{d'_0}}$ where: d'_{100} and d'_0 are the extremities of a straight line drawn through the particle-size distribution, as directed above; and d'_{50} is the midpoint of this line.

$Cc = \frac{(d_{30})^2}{d_{60} \times d_{10}}$

I_D is the relative denisty of the soil

PI is the plasticity index of the soil

DHR is the double-hydrometer ratio of the soil

Portions of this flow chart modified from Giroud (1988)

Source: Luettich, S.M., Giroud, J.P., and Bachus, R.C. (1991). "Geotextile Filter Design Manual". Report prepared for Nicolon Corporation, Norcross, Georgia.

Attachment G 1/3

4.2 Define the Hydraulic Gradient for the Application (i_s)

The hydraulic gradient will vary depending on the application of the filter. Anticipated hydraulic gradients for various applications may be estimated using Figure 3.

4.3 Determine the Minimum Allowable Geotextile Permeability (k_g)

After determining the soil hydraulic conductivity and the hydraulic gradient, the following equation can be used to determine the minimum allowable geotextile permeability [Giroud, 1988]:

$$k_g > i_s \, k_s$$

The hydraulic conductivity (permeability) of the geotextile can be calculated from the permittivity test method ASTM D 4491; this value can often be obtained from the manufacturer's literature as well. The geotextile permeability is defined as the product of the permittivity, ψ, and the geotextile thickness, t_g:

$$k_g > \varphi \, t_g$$

STEP 5. DETERMINE ANTI-CLOGGING REQUIREMENTS

To minimize the risk of clogging, the following criteria should be met:

- Use the largest opening size (O_{95}) that satisfies the retention criteria.
- For nonwoven geotextiles, use the largest porosity available, but not less than 30 percent.
- For woven geotextiles, use the largest percent open area available, but not less than 4 percent.

Source: Luettich, S.M., Giroud, J.P., and Bachus, R.C. (1991). "Geotextile Filter Design Manual". Report prepared for Nicolon Corporation, Norcross, Georgia.

Attachment G 2/3

Table 4-5

Typical Hydraulic Gradients[a]

DRAINAGE APPLICATION	TYPICAL HYDRAULIC GRADIENT
Standard Dewatering Trench	1.0
Vertical Wall Drain	1.5
Pavement Edge Drain	1[b]
Landfill LCDRS	1.5
Landfill LCRS	1.5
Landfill SWCRS	1.5
Inland Channel Protection	1[b]
Shoreline Protection	10[b]
Dams	10[b]
Liquid Impoundments	10[b]

NOTES: [a] Table developed after Giroud [1988].

[b] Critical applications may require designing with higher gradients than those given.

Attachment G
3/3

AMOCO WASTE RELATED GEOTEXTILES

MINIMUM PHYSICAL PROPERTIES
(Minimum Average Roll Values)

Property	Test Method	Units	4504	4506	4508	4510	4512	4516
Unit Weight	ASTM D-3776	Oz./yd.²	4.0 *	6.0	8.0	10.0	12.0	16.0
Grab Tensile	ASTM D-4632	lbs.	95	150	200	235	275	350
Grab Elongation	ASTM D-4632	%	50	50	50	50	50	50
Mullen Burst	ASTM D-3787	psi	225	350	450	550	650	750
Puncture	ASTM D-4833	lbs.	55	90	130	165	185	220
Trapezoid Tear	ASTM D-4533	lbs.	35	65	80	95	115	130
Apparent Opening Size	ASTM D-4751	US Sieve Number	70	70	100	100	100	100
Permittivity	ASTM D-4491	gal/min/ft² sec⁻¹	100 2.0	90 1.7	80 1.5	70 1.1	60 0.9	50 0.7
Permeability	ASTM D-4491	cm/sec	.2	.2	.2	.2	.2	.2
Thickness	ASTM D-1777	mils	40 *	65	90	110	130	175
U.V. Resistance	ASTM D-4355[1]	%[2]	70	70	70	70	70	70

1. Fabric conditioned per ASTM-D-4355 2. Percent of minimum grab tensile after conditioning.

TYPICAL PHYSICAL PROPERTIES

Property	Test Method	Units	4504	4506	4508	4510	4512	4516
Grab Tensile	ASTM D-4632	lbs.	130/115	225/200	275/270	315/310	410/370	510/470
Grab Elongation	ASTM D-4632	%	75	65	65	65	65	65
Mullen Burst	ASTM D-3786	psi	285	410	575	650	825	920
Puncture	ASTM D-4833	lbs.	75	120	170	190	210	270
Trapezoid Tear	ASTM D-4533	lbs.	60/50	100/80	140/120	160/140	185/155	220/180
Apparent Opening Size	ASTM D-4751	US Sieve Number	70/120	70/140	100/200	100+	100+	100+
Permittivity	ASTM D-4491	gal/min/ft² sec⁻¹	150 3.1	110 2.0	100 1.8	80 1.5	70 1.3	60 1.0
Permeability	ASTM D-4491	cm/sec	.35	.31	.27	.26	.25	.23
Thickness	ASTM D-1777	mils	50	75	115	130	150	195

PACKAGING

Dimensions		4504	4506	4508	4510	4512	4516
Roll Width	ft.	15	15	15	15	15	15
Roll Length	ft.	1200	900	600	600	450	300
Gross Weight	lbs.	500	550	500	600	550	500
Area	sq. yds.	2000	1500	1000	1000	750	500

Amoco Fabrics and Fibers Company 900 Circle 75 Parkway, Suite 300 Atlanta, Georgi[illegible]

Code #19100512;20 000;6/91

Amoco Fabrics & Fibers Company, 1991. "Amoco Waste Related Geotextiles" H 1/1

APPENDIX E

Boring Logs and Geotechnical Laboratory Results

Appendix E-1

Seismic Refraction Summary

TABLE E-1
SUMMARY OF SEISMIC REFRACTION SURVEYS
Energy Fuels, White Mesa Mill
Blanding, Utah

Geosyntec consultants

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
SL-12-01-01F	N37.52603	W109.51611	Fwd S32E	5A	0 to 4 4 to 36 > 36	1287 to 1392 4944 to 5053 6195 to 7403	Rippable Rippable Rippable	
SL-12-01-01R	N37.52554	W109.51566	Rev N32W	5A	0 to 6 > 6	1312 to 2563 5358 to 6372	Rippable Rippable	
SL-12-02-01F	N37.52603	W109.51611	Fwd N32W	5A	0 to 4 4 to 14 > 14	1341 to 1408 3457 to 5578 6512 to 6802	Rippable Rippable Rippable	
SL-12-02-01R	N37.52647	W109.51649	Rev S32E	5A	0 to 8 8 to 12 >12	1571 to 2191 4245 to 5672 6538 to 7012	Rippable Rippable Rippable	
TP12-02	N37.52600	W109.51614	Fwd N30W	5A	-	-		0-5.25 FT Residual Soil 5.25-6.75 FT Weathered Sandstone 6.75 to 7.0 FT Dakota Sandstone
SL-12-03-01F	N37.52499	W109.51506	Fwd S30W	5A	0 to 5 5 to 21 >21	1482 to 1658 3866 to 4754 6087 to 6492	Rippable Rippable Rippable	
SL-12-03-01R	N37.52447	W109.51466	Rev N30E	5A	0 to 6 >6	1804 to 2078 4854 to 5966	Rippable Rippable	
TP12-04	N37.52507	W109.51506	Fwd N32W	5A	-	-		0-1.5 FT Residual Soil 1.5-7.5 FT Weathered Sandstone 7.5-8.0 FT Shale Layer 8.0 FT Dakota Sandstone
SL-12-04-01F	N37.52546	W109.51749	Fwd S75E	5A	0 to 4 4 to 25 >25	1059 to 1317 3264 to 4564 5918 to 6499	Rippable Rippable Rippable	
SL-12-04-01R	N37.52532	W109.51675	Rev N75W	5A	0 to 5 5 to 14 >14	1052 to 1681 2998 to 5299 5663 to 7907	Rippable Rippable Marginal	
TP12-01	N37.52546	W109.51749	Fwd S65E	5A	-	-		0-5 FT Residual Soil 5.0-6.75 FT Weathered Sandstone 6.75 to 7.0 FT Dakota Sandstone
SL-12-05-01F	N37.52384	W109.51791	Fwd N62E	5A	0 to 9 >9	1137 to 1691 6235 to 7003	Rippable Rippable	
SL-12-05-01R	N37.52416	W109.51729	Rev S62W	5A	0 to 7 >7	1684 to 1939 6281 to 8285	Rippable Marginal	
TP12-07	N37.52388	W109.51793	Fwd N20E	5A	-	-		0-7.0 FT Residual Soil 7.0-8.5 FT Weathered Sandstone 8.5-9.5 FT Dakota Sandstone
SL-12-06-01F	N37.52438	W109.51460	Fwd S30E	5A	0 to 3 3 to 46	2083 to 2347 4826 to 4905	Rippable Rippable	

TABLE E-1
SUMMARY OF SEISMIC REFRACTION SURVEYS
Energy Fuels, White Mesa Mill
Blanding, Utah

Geosyntec consultants

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
SL-12-06-01R	N37.52388	W109.51418	Rev N30W	5A	0 to 4 >4	1489 to 2965 4955 to 6415	Rippable Rippable	
TP12-06	N37.52408	W109.51434	Fwd N30W	5A	-	-		0-2.0 FT Residual Soil 2.0-3.5 FT Weathered Sandstone 3.5 FT Dakota Sandstone
SL-12-07-01F	N37.52438	W109.51460	Fwd S30E	5A	0 to 4 4 to 19 > 19	1488 to 2035 4757 to 5046 6696	Rippable Rippable Rippable	
SL-12-07-01R	N37.52338	W109.51372	Rev N30W	5A	0 to 4 4 to 34 > 34	1308 to 2080 4899 to 5169 8444 to 8736	Rippable Rippable Marginal	
TP12-09	N37.52294	W109.51320	Fwd N20E	5A/5B	-	-		0-5.5 FT Residual Soil 5.5-6.5 FT Weathered Sandstone 6.5-7.5 FT Dakota Sandstone
SL-12-08-01F	N37.52443	W109.51648	Fwd N62E	5A	0 to 5 5 to 17 > 17	1061 to 1283 3354 to 4800 6025	Rippable Rippable Rippable	
SL-12-08-01R	N37.52477	W109.51582	Rev S62W	5A	0 to 7 > 7	1521 to 1732 4927 to 5849	Rippable Rippable	
TP12-05	N37.52443	W109.51621	Fwd N40E	5A	-	-		0-4.5 FT Residual Soil 4.5-6.5 FT Weathered Sandstone 6.5-7.5 FT Dakota Sandstone
TP12-08	N37.52326	W109.51534	Fwd N10W	5A	-	-		0-6.0 FT Residual Soil 6.0-7.5 FT Weathered Sandstone 7.5 FT Dakota Sandstone
SL-12-09-01F	N37.52544	W109.51392	Fwd N65E	5A	0 to 5 >5	1211 to 2207 5570 to 6148	Rippable Rippable	
SL-12-09-01R	N37.52570	W109.51324	Rev S65W	5A	0 to 6 6 to 17 >17	1269 to 1639 4661 to 6630 7230 to 7274	Rippable Rippable Rippable	
TP12-03	N37.52559	W109.51355	Fwd S65W	5A	-	-		0-5.5 FT Residual Soil 5.5-7.0 FT Weathered Sandstone 7.0 FT Dakota Sandstone
TP12-10	N37.52464	W109.51260	Fwd N88W	5A/5B	-	-		0-4.5 FT Residual Soil 4.5-9.0 FT Weathered Sandstone 9.0-9.5 FT Dakota Sandstone
SL-12-10-01F	N37.524778	W109.50861	Fwd S68W	5B	0 to 6 >6	1442 to 1904 5620 to 7611	Rippable Marginal	
SL-12-10-01R	N37.52452	W109.50928	Rev N68E	5B	0 to 4 >4	1835 to 2395 6387 to 7509	Rippable Marginal	

TABLE E-1
SUMMARY OF SEISMIC REFRACTION SURVEYS
Energy Fuels, White Mesa Mill
Blanding, Utah

Geosyntec consultants

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
TP12-12	N37.52479	W109.50859	Fwd S65W	5B	-	-		0-6.5 FT Residual Soil 6.5-7.5 FT Weathered Sandstone 7.5-8.0 FT Dakota Sandstone
SL-12-11-01F	N37.525045	W109.507928	Fwd N68E	5B	0 to 6 >6	1157 to 1227 7036 to 7052	Rippable Rippable	
SL-12-11-01R	N37.524778	W109.50861	Rev S68W	5B	0 to 10 >10	1411 to 1480 7343 to 8088	Rippable Marginal	
SL-12-12-01F	N37.52419	W109.51025	Fwd N70E	5B	0 to 4 4 to 17 > 17	1061 to 1488 3331 to 4947 8999 to 9761	Rippable Rippable Non-Rippable	
SL-12-12-01R	N37.52441	W109.50956	Rev S70W	5B	0 to 3 3 to 18 >18	1672 to 1955 4721 to 5496 6643 to 7372	Rippable Rippable Rippable	
TP12-13	N37.52419	W109.51025	Fwd S70W	5B	-	-	-	0-0.5 FT Residual Soil 0.5-1.0 FT Weathered Sandstone 1.0-2.0 FT Dakota Sandstone
SL-12-13-01F	N37.5249	W109.51025	Fwd S70W	5B	0 to 6 >6	1349 to 3557 7286 to 9352	Rippable Non-Rippable	
SL-12-13-01R	N37.52389	W109.51102	Rev N70E	5B	0 to 5 >5	1138 to 1248 6186 to 8977	Rippable Marginal	
SL-12-14-01F	N37.52330	W109.51234	Fwd N62E	5B	0 to 6 6 to 28 >28	1098 to 1775 6361 to 6041 8046 to 8964	Rippable Rippable Marginal	
SL-12-14-01R	N37.52361	W109.51167	Rev S62W	5B	0 to 6 >6	1369 to 1419 7171 to 7762	Rippable Marginal	
TP12-15	N37.52361	W109.51167	Fwd S60W	5B	-	-		0-5.5 FT Residual Soil 5.5-6.0 FT Weathered Sandstone 6.5 FT Dakota Sandstone
TP12-17	N37.52253	W109.51065	Fwd N8E	5B	-	-	-	0-0.5 FT Residual Soil 0.5-2.0 FT Weathered Sandstone 2.0-3.5 FT Dakota Sandstone
SL-12-15-01F	N37.52542	W109.51112	Fwd S20E	5B	0 to 8 >8	1478 to 3030 6346 to 7738	Rippable Marginal	
SL-12-15-01R	N37.52493	W109.51077	Rev S30E	5B	0 to 9 9 to 16 >16	1305 to 1554 3197 to 4279 7886 to 8107	Rippable Rippable Marginal	
TP12-11	N37.52512	W109.51098	Fwd N25W	5B	-	-		0-3.5 FT Residual Soil 3.5-11.0 FT Weathered Sandstone 11.0-12.0 FT Dakota Sandstone

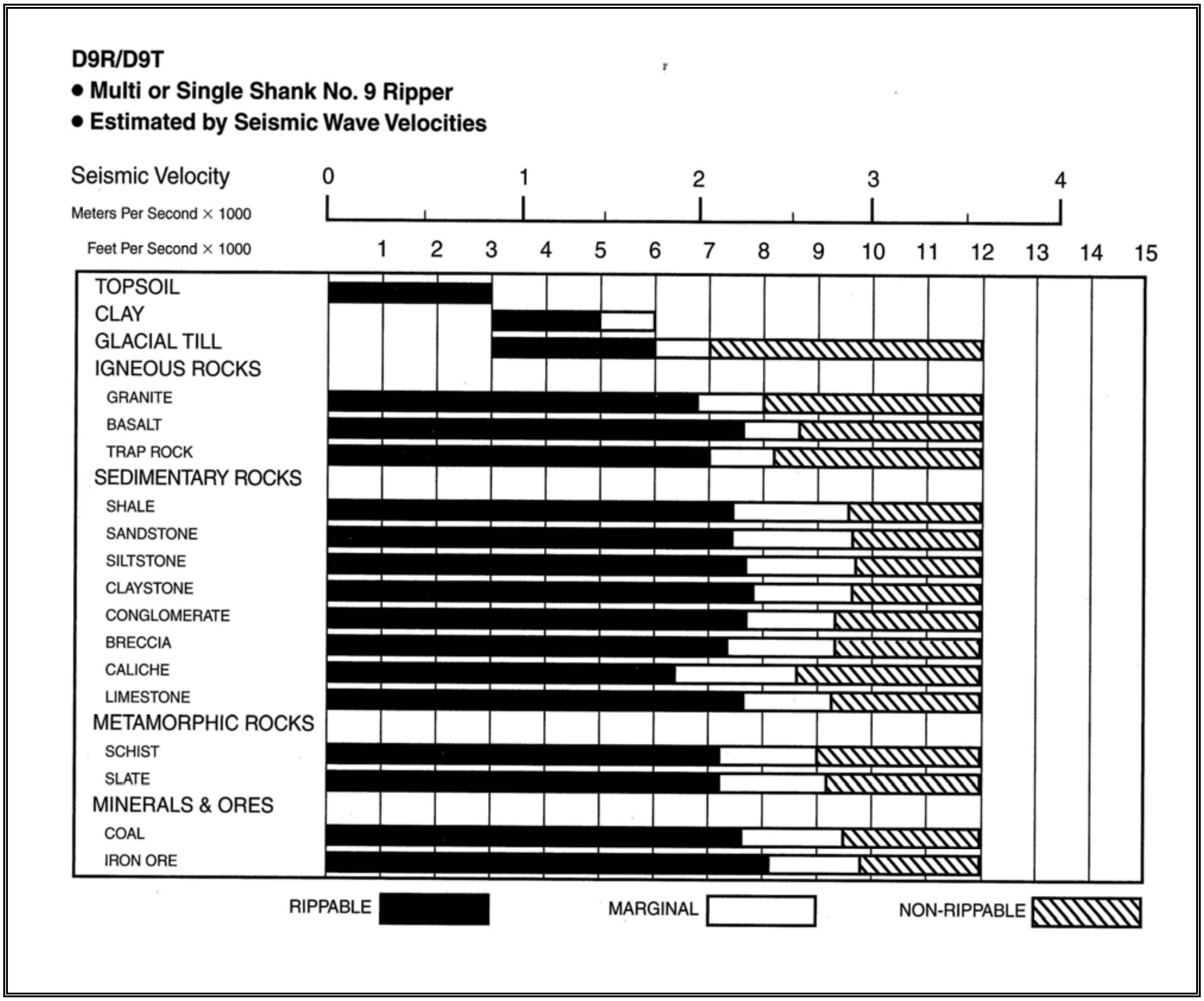
TABLE E-1
SUMMARY OF SEISMIC REFRACTION SURVEYS
Energy Fuels, White Mesa Mill
Blanding, Utah

Geosyntec consultants

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
TP12-19	N37.52550	W109.50965	Fwd N15W	5B	-	-		0-1.5 FT Residual Soil 1.5 FT Dakota Sandstone
SL-12-16-01F	N37.52330	W109.50919	Fwd N32W	5B	0 to 6 6 to 22 >22	1388 2951 to 5517 9648	Rippable Rippable Non-Rippable	
SL-12-16-01R	N37.52380	W109.50957	Rev S32E	5B	0 to 6 >6	1215 to 1816 6435 to 6930	Rippable Rippable	
TP12-16	N37.52329	W109.50913	Fwd S40E	5B	-	-	-	0-0.5 FT Residual Soil 0.5-6.0 FT Weathered Sandstone 6.0-6.5 FT Dakota Sandstone
SL-12-17-01F	N37.52330	W109.50919	Fwd S32E	5B	0 to 4 4 to 37 >37	1391 to 2336 4801 to 4874 7554	Rippable Rippable Marginal	
SL-12-17-01R	N37.52280	W109.50872	Rev N32W	5B	0 to 5 5 to 22 >22	1694 to 1730 4762 to 5491 6479 to 6483	Rippable Rippable Rippable	
TP12-18	N37.52223	W109.50835	Fwd N30W	5B	-	-		0-4.5 FT Residual Soil 4.5-6.0 FT Weathered Sandstone 6.0-6.5 FT Dakota Sandstone
SL-12-18-01F	N37.52431	W109.50755	Fwd E-W	5B	0 to 5 5 to 26 >26	1090 to 1379 5202 to 6893 7491 to 10938	Rippable Rippable Non-Rippable	
SL-12-18-01R	N37.52430	W109.50829	Rev E-W	5B	0 to 4 4 to 20 >20	1361 to 1420 5110 to 5363 7861 to 11264	Rippable Rippable Non-Rippable	
TP12-14	N37.52431	W109.50749	Fwd S88W	5B	-	-	-	0-4.5 FT Residual Soil 4.5-7.5 FT Weathered Sandstone 7.5 FT Dakota Sandstone

Notes:
1 - Surveyed end point of refraction survey lines coordinates in Latitude/Longitude decimal degree World Geodetic System (WGS) 84. Data collected in field.
2 - Calculated depth of seismic refractor based on P-wave first arrival times using Snells Law.
3 - Excavatability assessment based on correlations between seismic wave velocities and rippability using a Single Shank No. 9 ripper on a D9N dozer (Caterpillar, 2006)
RS - Residual Soil
wxs - weathered sandstone
Kds - Cretaceous Dakota Sandstone

TABLE E-2
SEISMIC VELOCITY AND RIPPABILITY CORRELATION
Energy Fuels, White Mesa Mill
Blanding, Utah



Excavatability assessment based on correlations between seismic wave velocities and rippability of various materials using a Single Shank No. 9 ripper on a D9N dozer (Caterpillar, 2006)

Appendix E-2

Trench Logs

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BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/5/12
Boring I.D.:	TP12-1	Date Completed:	11/5/12
Geologist/Eng.:	A. GREENE / J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	7 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N 37.52346°, W109.51749° (S65E)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1345		SURFACE: SILTY FINE TO VERY SAND, BUSHES, GRASS RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR 4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				16 FT TRENCH
				INCREASE CARBONATE CONC @ 3FT					HARD DIGGING
5				DAKOTA SANDSTONE HIGHLY WEATHERED SANDSTONE, MEDIUM STRONG FINE GRAINED PINKISH WHITE TO PINK (2.5YR 8/2 TO 8/3)					
				DAKOTA SANDSTONE MODERATELY WEATHERED, MED STRONG TO STRONG FINE GRAINED PINKISH WHITE (2.5YR 8/2)					
				BOTTOM OF TESTPIT AT 7.0 FT (BACKHOE REFUSAL)					
10									
15									

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BORING LOG

Project No.: SC0634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-2
Geologist/Eng.: A. GREENE / J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N37.52600 W109.51614 (N30'W)

Date Started: 11/5/12
Date Completed: 11/5/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 7.0 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1320		SURFACE: RESIDUAL SOIL DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				16 FT TRENCH
				INCREASING CARBONATE AT 3.25 FT					
5				DAKOTA SANDSTONE @ 5.25'					
				HIGHLY WEATHERED SANDSTONE, WEAK TO MOD STRONG, PINKISH WHITE (2.5YR 8/2) - ABUNDANT CARBONATE CEMENT					VERY HARD DIGGING
				DAKOTA SANDSTONE - MODERATELY WX, MEDIUM STRONG FINE GRAINED PINKISH WHITE (2.5YR 8/2)					
				BOTTOM OF TESTPIT AT ~7 FT (BACKHOE REFUSAL)					
10									
15									

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BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/8/12
Boring I.D.:	TP12-3	Date Completed:	11/8/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	7.0 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N37.52559° W109.51355° (S65W)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1415		SURFACE: SILTY FINE TO VERY FINE SAND, GRASS					21 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				@ 3 FT TOP OF CARBONATE HORIZON, GRADUAL CHANGE INTO WEATHERED SANDSTONE					
5				@ 5.5 FT DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, PINKISH WHITE (2.5YR-8/2)					VERY HARD DIGGING
				@ 7.0 FT DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PALE YELLOW (2.5Y-8/2 TO 8/3)					
				BOTTOM OF TEST PIT AT 7.0 FT					
10									

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BORING LOG

Project No.: SC0634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-4
Geologist/Eng.: J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N37.52507 W109.51506' (N32W)

Page 1 of 1
Date Started: 11/8/12
Date Completed: 11/8/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 8.0 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1320		SURFACE: SILTY FINE TO VERY FINE SAND, GRASS RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				24 FT TRENCH
	X			@1.5 FT DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, PINKISH WHITE (2.5YR - 8/2)					
5	X								
	X			@7.5 FT MED STRONG, MOIST, VERY DARK GRAYISH BROWN (10YR-3/2) SHALE LAYER WITH FE OXIDATION DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PALE YELLOW (2.5Y-8/2 TO 8/3)					↓ VERY HARD DIGGING
10				BOTTOM OF TEST PIT AT 8.0 FT					

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BORING LOG

Project No.: SC06
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP 12-5
Geologist/Eng.: A. GREENE / J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N37.52443 W109.51621 (NAOE)

Page 1 of 1
Date Started: 11/5/12
Date Completed: 11/5/12
Borehole Diameter: 24-INCH BUCKET
Borehole Depth: 7.5 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1215		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS					14 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]. - CONTAINS ROOTLETS TO ~2FT	SM				
5				@4.5' TOP OF CARBONATE HORIZ. BECOMES REDDISH YELLOW (5YR-6/6) GRADATIONAL CHANGE INTO WEATHERED SANDSTONE					
				@6.5' DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE. PINKISH WHITE TO PINK (2.5YR 8/2 TO 8/3)					VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 7.5 FT					
10									
15									

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BORING LOG

Project No.: SC0634 Page 1 of 1 11/8/12 TD = 3.5 FT

Site Name: WHITE MESA MILL (BLANDING) Boring I.D.: TP12-6 24 INCH BUCKET BACKHOE JD 310

Comments: N 37.52408° W109.51454° (N30W)

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1020		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM] - MODERATELY WEATHERED SANDSTONE BOULDERS AT 1.0 FT	SM				15 FT TRENCH
				@ 2.0 FT TOP OF CARBONATE HORIZ. GRADUAL CHANGE INTO MODERATELY WEATHERED SANDSTONE					RESISTANT SANDSTONE KNOB IN CENTER OF TEST PIT AT 2.5 FT ↓ VERY HARD DIGGING
				@ 3.5 FT DAKOTA SANDSTONE MODERATELY WEATHERED, STRONG FINE GRAINED SANDSTONE, PINKISH WHITE TO PINKISH GRAY (7.5YR 8/2 TO 6/2)					
				BOTTOM OF TEST PIT 3.5 FT					

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BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/9/12
Boring I.D.:	TP12-7	Date Completed:	11/9/12
Geologist/Eng.:	J WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	9.5 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N 37.52388° W109.51793° (N20E)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0800		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS					22 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				TOP OF CARBONATE HORIZON AT 2.0 FT, GRADUAL CHANGE INTO WEATHERED SANDSTONE					
5									
				@7 FT					
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO PINK (2.5YR-8/2 TO 8/3)					
				@8.5FT					VERY HARD DIGGING
				DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, FINE GRAINED, PINKISH WHITE (2.5YR-8/2)					
10				BOTTOM OF THE TEST PIT AT 9.5 FT					

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BORING LOG

Project No.: SCO 634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-8
Geologist/Eng.: J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N37.52326° W109.51534° (N10W)

Page 1 of 1
Date Started: 11/9/12
Date Completed: 11/9/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 7.5 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0830		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS					22 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				TOP OF CARBONATE HORIZON AT 2.5 FT, GRADUAL CHANGE INTO WEATHERED SANDSTONE					
5				- CONTAINS ROOTLETS TO 5.5 FT					
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO PINK (2.5YR- 8/2 TO 8/3)					
				@ 7.5 FT DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PINKISH WHITE (2.5YR-8/2)					↓ VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 7.5 FT					
10									

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BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/8/12
Boring I.D.:	TP12-9	Date Completed:	11/8/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	7.5 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N37. 52294° W109. 51320° (N20E)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1500		SURFACE: SILTY FINE TO VERY SAND, SHORT GRASS					22 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				- CONTAINS ROOTLETS AT 2.0 FT					
				INCREASE CARBONATE AT 2.5 FT					
5									
				@ 6.5 FT					
				DAKOTA SANDSTONE: HIGHLY WEATHERED SANDSTONE, WEAK TO MED STRONG, PINKISH WHITE (2.5YR-8/2)					VERY HARD DIGGING
				DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG FINE GRAINED, PALE YELLOW (2.5Y-8/2-8/3)					
				BOTTOM OF TEST PIT AT 7.5 FT					
10									

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BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/8/12
Boring I.D.:	TP12-10	Date Completed:	11/8/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	9.5 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N37.52464 W109.51260° (N88W)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1215		SURFACE: SILTY FINE TO VERY FINE SAND, GRASS					12 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				TOP OF CARBONATE HORIZON, GRADUAL CHANGE INTO WEATHERED SANDSTONE AT 3.0 FT					
				@4.5 FT					
5				DAKOTA SANDSTONE: HIGHLY WEATHERED SANDSTONE, WEAK TO MED STRONG, PINKISH WHITE (7.5YR-8/2)					
				@ 9.0 FT					
				DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PALE YELLOW (2.5Y-8/2 TO 8/3)					VERY HARD DIGGING
10				BOTTOM OF THE TEST PIT AT 9.5 FT					

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BORING LOG

Project No.:	SCO 634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/9/12
Boring I.D.:	TP12-11	Date Completed:	11/9/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	12.0 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A

Comments: N37.52512° W109.51098° (N25W)

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0720		SURFACE: SILTY FINE TO VERY FINE SAND, GRASSES					24 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR 4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				TOP OF CARBONATE HORIZON AT 2.0 FT, GRADUAL CHANGE INTO WEATHERED SANDSTONE					
	X			@ 3.5 FT					
				DAKOTA SANDSTONE HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO PINK (10YR 8/1 TO 8/2)					
5	X			- CONTAINS ROOTLETS TO 4FT					
10									
				@ 11.0 FT					
	X			DAKOTA SANDSTONE: MODERATELY WEATHERED, WEAK TO MED STRONG FINE GRAINED SANDSTONE, WHITE TO PINKISH WHITE (10YR 8/1 TO 8/2)					↓ VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 12.0 FT					

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BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/9/12
Boring I.D.:	TP12-12	Date Completed:	11/9/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	8.0 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N37. 52479' W109.50859' (S65W)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1230		SURFACE: SILTY FINE TO VERY FINE SAND, BRUSH RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR - 4/6 TO 5/6) SILTY FINE, TO VERY FINE SAND [SM]					HEAVY RAIN PRESENT 16 FT TRENCH
				TOP OF CARBONATE HORIZON AT 2 FT, GRADUALLY BECOMES WEATHERED SANDSTONE					
5									
				@ 6.5 FT					
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO WHITE (7.5YR - 8/2 TO 8/3) BECOMES PALE YELLOW (2.5Y - 8/2 - 8/3)					
			@7.5	DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PALE YELLOW TO WHITE					VERY HARD DIGGING
10				BOTTOM OF TEST PIT AT 8.0 FT					

Reviewed by: ______________________ R.G.# ______________

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BORING LOG

Project No.: SC0634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-13
Geologist/Eng.: J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N37.52419° W109.51025° (S70W)

Page 1 of 1
Date Started: 11/8/12
Date Completed: 11/8/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 2.0 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0920		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS					17 FT TRENCH
			@0.5FT	RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO PINK (2.5YR-8/2 TO 8/3)					
			@2.0FT	DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, VERY PALE YELLOW (10YR-8/3)					↓ VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 2.0 FT					

Reviewed by: R.G.#

j:\standard\forms\Field Forms 21.xlsx\Sed boring Log

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BORING LOG

Project No.: SCO 634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-14
Geologist/Eng.: J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N 37.52431° W109.50749° (S88W)

Page 1 of 1
Date Started: 11/8/12
Date Completed: 11/8/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 7.5 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
0		0745		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				16 FT TRENCH
				- CONTAINS ROOTLETS AT 2.5 FT					
				@ 4.5 FT					
5				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG FINE GRAINED, PINKISH WHITE TO PINK (2.5YR-8/2 TO 8/3)					
				@ 7.5 FT					
				DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, WHITE TO VERY PALE BROWN (10YR-8/1 TO 8/2)					VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 7.5 FT					
10									

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BORING LOG

Project No.: SCO634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-15
Geologist/Eng.: J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N 37. 52361° W109. 51167° (SGOW)

Page 1 of 1
Date Started: 11/8/12
Date Completed: 11/8/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 6.5 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
0		0950		SURFACE: SILTY FINE TO VERY FINE SAND, GRASS, BUSHES					15 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				- CONTAINS ROOTLETS AT 1.5 FT					
				TOP OF CARBONATE HORIZON, GRADUAL CHANGE INTO WEATHERED SANDSTONE @ 3.5 FT					
5				- CONTAINS ROOTLETS TO 5.0 FT					
				@ 5.5 FT					
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO PINK (2.5YR 8/2 TO 8/3)					VERY HARD DIGGING
				DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, VERY PALE YELLOW (10YR-8/3)					
				BOTTOM OF TEST PIT AT 6.5 FT					
10									

Reviewed by: R.G.#

Geosyntec consultants

BORING LOG

Project No.:	SC0634	Page 1 of 1	
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/8/12
Boring I.D.:	TP12-16	Date Completed:	11/8/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	6.5 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N 37.52329° W109.50913° (S40E)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0830		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS					14 FT TRENCH
			@0.5	RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]					
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE (5YR-8/1 TO 8/2)					
				INCREASE SILTY FINE TO VERY FINE SAND BECOMES REDDISH BROWN (5YR-6/4)					
5									
				@ 6.0FT					
				DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, WHITE TO VERY PALE BROWN (10YR-8/1 TO 8/2)					VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 6.5 FT					
10									

Reviewed by: R.G.#

Geosyntec consultants

BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/9/12
Boring I.D.:	TP12-17	Date Completed:	11/9/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	3.5 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N37.52253° W109.51065° (NAD83)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0910		SURFACE: SILTY FINE TO VERY FINE SAND, BRUSH					14 FT TRENCH
			@0.5 →	RESIDUAL SOIL: SILTY FINE TO VERY FINE SAND, YELLOWISH RED					
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO WHITE (7.5YR - 8/2 TO 8/3) - CONTAINS RIVULETS TO 1.5 FT					
			@2.0 FT →	DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, VERY PALE YELLOW (2.5Y - 8/2 TO 8/3)					↓ VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 3.5 FT					

Reviewed by: ______________________ R.G.# ______________

Geosyntec consultants

BORING LOG

Project No.: SC0634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-18
Geologist/Eng.: J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N37.52223° W109.50835° (N30W)

Page 1 of 1
Date Started: 11/9/12
Date Completed: 11/9/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 6.5 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0930		SURFACE: SILTY FINE TO VERY FINE SAND, BRUSH RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				RAIN PRESENT 18 FT TRENCH
				TOP OF CARBONATE HORIZON AT 4.5 FT, GRADUAL CHANGE INTO WEATHERED SANDSTONE					
5				@ 6.0 FT DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PALE YELLOW (2.5Y-8/2 TO 8/3)					VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 6.5 FT					
10									

Reviewed by: R.G.#

Geosyntec consultants

BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/9/12
Boring I.D.:	TP12-19	Date Completed:	11/9/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	1.5 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A

Comments: N37.52550' W109.50968' (N15W)
TP12-19 MOVED (S26W) 52 FT OFF ACCESS RD

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1200		SURFACE: SILTY FINE TO VERY FINE SAND, BRUSH RESIDUAL SOIL; TOP OF CARBONATE HORIZ AT 1.5 FT, GRADUAL CHANGE INTO WEATHERED SANDSTONE					RAIN + LIGHTNING PRESENT; 14 FT TRENCH; VERY HARD DIGGING
			@1.5 FT	DAKOTA SANDSTONE MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PALE YELLOW (2.5Y- 8/2 TO 8/3)					
				BOTTOM OF TEST PIT AT 1.5 FT					

Reviewed by: ______________________ R.G.# ______________

Appendix E-3

Geotechnical Laboratory Data

Excel Geotechnical Testing, Inc.
"Excellence in Testing"

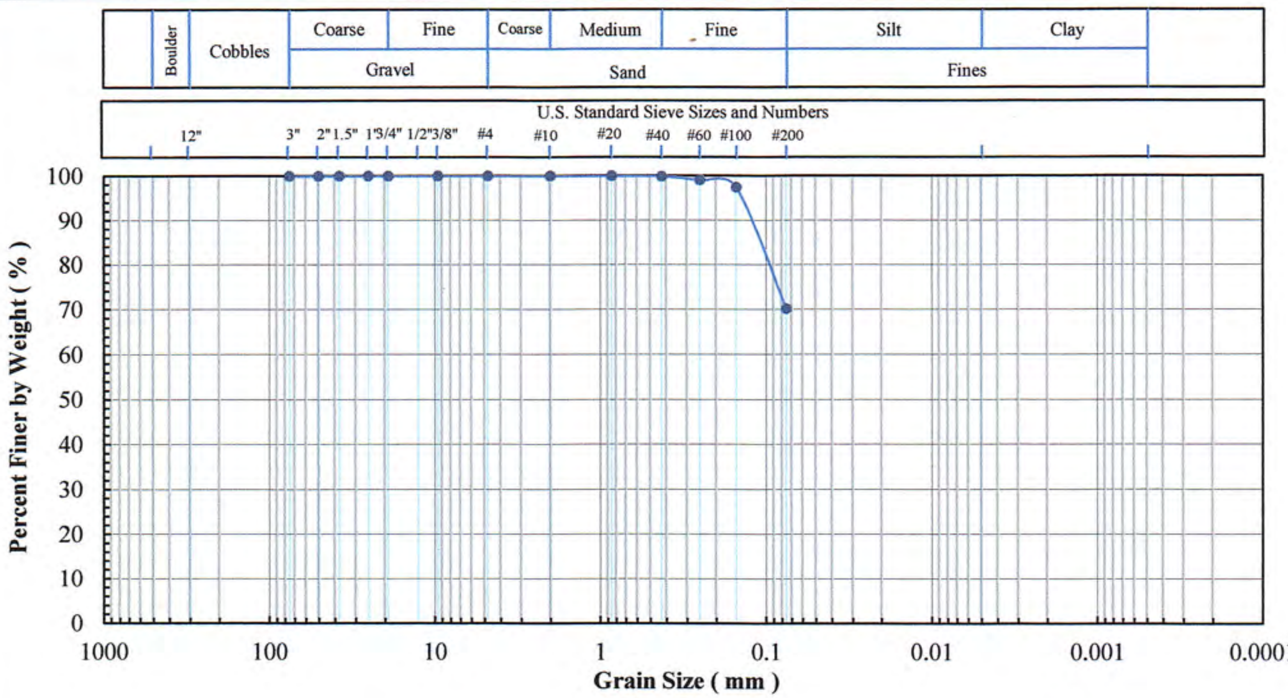
953 Forrest Street, Roswell, Georgia 30075
Tel: (770) 910 7537 Fax: (770) 910 7538

Project Name:	Energy Fuels - Cell 5A and 5B
Project No:	574
Client Sample ID:	TP12-11 (2.5')
Lab Sample No:	12K026

ASTM C 136, D 422, D 854, D 1140, D2216, D 2487, D4318

SOIL INDEX PROPERTIES

Grain Size, Spec. Gravity, Moist. Content, Eng. Classification, Atterberg Limits



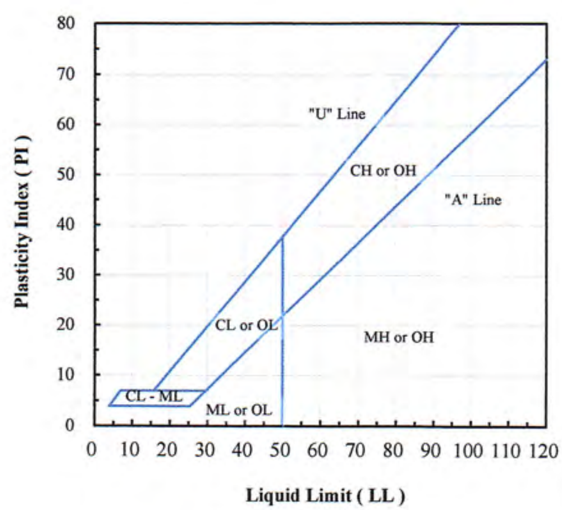
Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2.00	100.0
#20	0.850	100.0
#40	0.425	99.9
#60	0.250	99.1
#100	0.150	97.5
#200	0.075	70.2

Specific Gravity (-):	

Hydrometer Particle Diameter (mm)	% Finer

Gravel (%):	
Sand (%):	29.8
Fines (%):	70.2
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	
Coeff. Curv. (Cc):	



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (-)	PL (-)	PI (-)	Engineering Classification
TP12-11 (2.5')	12K026	4.2	70.2	NP	NP	NP	ML - Sandy silt

Note(s):

12-21-12
NSR

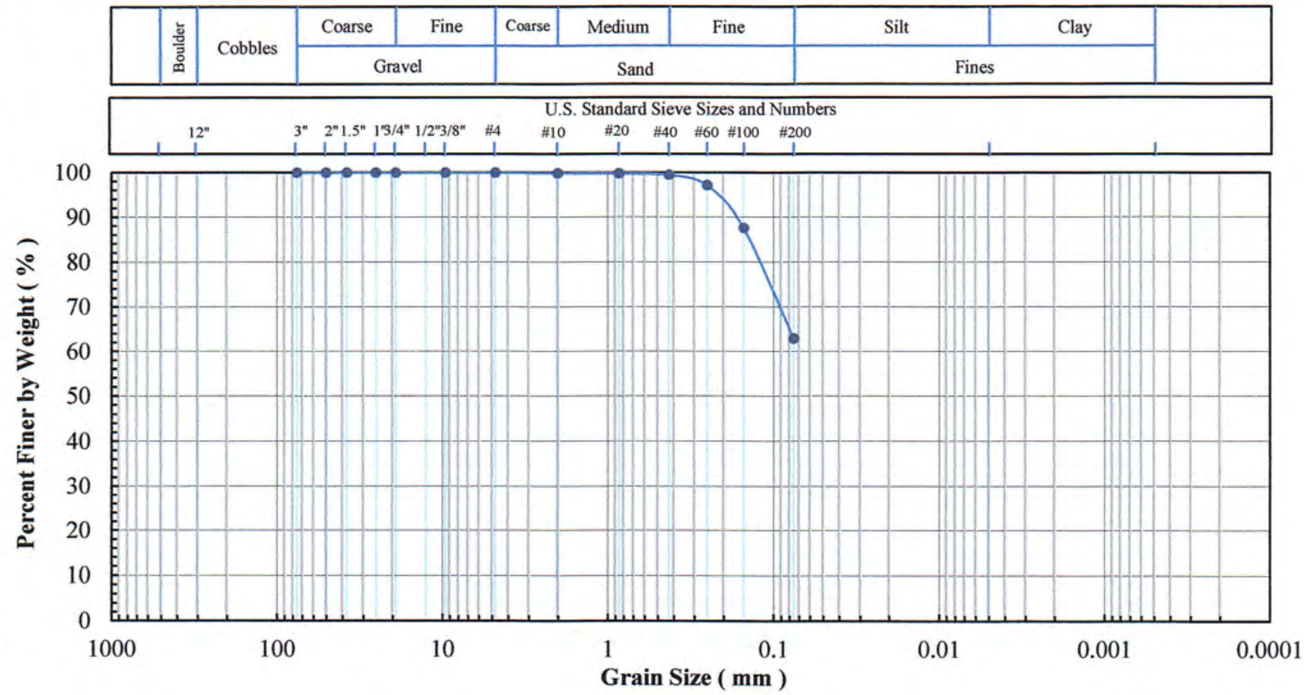
Excel Geotechnical Testing, Inc.
"Excellence in Testing"
953 Forrest Street, Roswell, Georgia 30075
Tel: (770) 910 7537 Fax: (770) 910 7538

Project Name:	Energy Fuels - Cell 5A and 5B
Project No:	574
Client Sample ID:	TP12-4 (1.0')
Lab Sample No:	12K025

ASTM C 136, D 422, D 854, D 1140, D2216, D 2487, D4318

SOIL INDEX PROPERTIES

Grain Size, Spec. Gravity, Moist. Content, Eng. Classification, Atterberg Limits



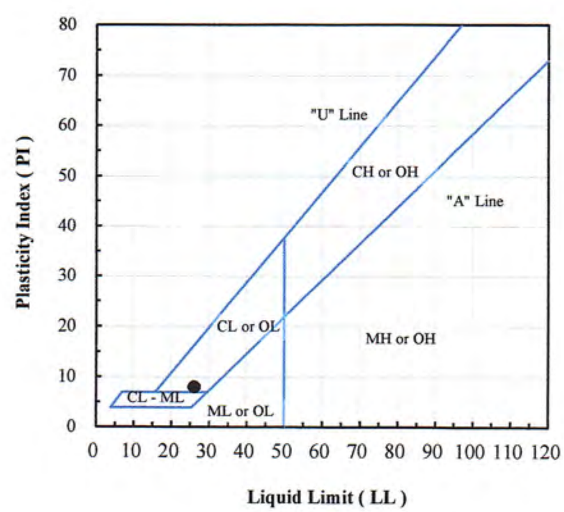
Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2.00	99.9
#20	0.850	99.8
#40	0.425	99.5
#60	0.250	97.2
#100	0.150	87.6
#200	0.075	63.0

Specific Gravity (-):	

Hydrometer Particle Diameter (mm)	% Finer

Gravel (%):	
Sand (%):	37.0
Fines (%):	63.0
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	
Coeff. Curv. (Cc):	



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (-)	PL (-)	PI (-)	Engineering Classification
TP12-4 (1.0')	12K025	4.0	63.0	26	18	8	CL - Sandy lean clay

Note(s):

12-4-12
NSR

Excel Geotechnical Testing, Inc.
"Excellence in Testing"
953 Forrest Street, Roswell, Georgia 30075
Tel: (770) 910 7537 Fax: (770) 910 7538

LAST PAGE

Test Applicability and Limitations:

- The results are applicable only for the materials received at the laboratory and tested which may or may not be representative of the materials at the site.

Storage Policy:

- Uncontaminated Material: All samples (or what is left) will be archived for a period of 3 months from the date received. Thereafter the samples will be discarded unless a written request for extended storage is received. A rate of $1.00 per sample per day will be applied after the initial 3 month storage period.

- Contaminated Material: All samples (or what is left) will be archived for a period of 3 months from the date received. Thereafter, the samples will be returned o the project manager or his/her designated receiver unless a written request for extended storage is received. A rate of $1.30 per sample per day will be applied after the initial 3 months storage.

APPENDIX F

Chemical Resistance Charts

Chemical Resistance Chart

GSE is the world's leading supplier of high quality, polyethylene geomembranes and geonets. GSE polyethylene geomembranes and geonets are resistant to a great number and combinations of chemicals. Note that the effect of chemicals on any material is influenced by a number of variable factors such as temperature, concentration, exposed area and duration. Many tests have been performed that use geomembranes and geonets and certain specific chemical mixtures. Naturally, however, every mixture of chemicals cannot be tested for, and various criteria may be used to judge performance. Reported performance ratings may not apply to all applications of a given material in the same chemical. Therefore, these ratings are offered as a guide only.

Medium	Concentration	Resistance at:	
		20° C (68° F)	60° C (140° F)
A			
Acetic acid	100%	S	L
Acetic acid	10%	S	S
Acetic acid anhydride	100%	S	L
Acetone	100%	L	L
Adipic acid	sat. sol.	S	S
Allyl alcohol	96%	S	S
Aluminum chloride	sat. sol.	S	S
Aluminum fluoride	sat. sol.	S	S
Aluminum sulfate	sat. sol.	S	S
Alum	sol.	S	S
Ammonia, aqueous	dil. sol.	S	S
Ammonia, gaseous dry	100%	S	S
Ammonia, liquid	100%	S	S
Ammonium chloride	sat. sol.	S	S
Ammonium fluoride	sol.	S	S
Ammonium nitratesat. sol.	S	S	
Ammonium sulfate	sat. sol.	S	S
Ammonium sulfide	sol.	S	S
Amyl acetate	100%	S	L
Amyl alcohol	100%	S	L
B			
Barium carbonate	sat. sol.	S	S
Barium chloride	sat. sol.	S	S
Barium hydroxide	sat. sol.	S	S
Barium sulfate	sat. sol.	S	S
Barium sulfide	sol.	S	S
Benzaldehyde	100%	S	L
Benzene	—	L	L
Benzoic acid	sat. sol.	S	S
Beer	—	S	S
Borax (sodium tetraborate)	sat. sol.	S	S
Boric acid	sat. sol.	S	S
Bromine, gaseous dry	100%	U	U
Bromine, liquid	100%	U	U
Butane, gaseous	100%	S	S
1-Butanol	100%	S	S
Butyric acid	100%	S	L
C			
Calcium carbonate	sat. sol.	S	S
Calcium chlorate	sat. sol.	S	S
Calcium chloride	sat. sol.	S	S
Calcium nitrate	sat. sol.	S	S
Calcium sulfate	sat. sol.	S	S
Calcium sulfide	dil. sol.	L	L
Carbon dioxide, gaseous dry	100%	S	S
Carbon disulfide	100%	L	U
Carbon monoxide	100%	S	S
Chloracetic acid	sol.	S	S
Carbon tetrachloride	100%	L	U
Chlorine, aqueous solution	sat. sol.	L	U
Chlorine, gaseous dry	100%	L	U
Chloroform	100%	U	U
Chromic acid	20%	S	L
Chromic acid	50%	S	L
Citric acid	sat. sol.	S	S
Copper chloride	sat. sol.	S	S
Copper nitrate	sat. sol.	S	S
Copper sulfate	sat. sol.	S	S
Cresylic acid	sat. sol.	L	—
Cyclohexanol	100%	S	S
Cyclohexanone	100%	S	L
D			
Decahydronaphthalene	100%	S	L
Dextrine	sol.	S	S
Diethyl ether	100%	L	—
Dioctylphthalate	100%	S	L
Dioxane	100%	S	S
E			
Ethanediol	100%	S	S
Ethanol	40%	S	L
Ethyl acetate	100%	S	U
Ethylene trichloride	100%	U	U
F			
Ferric chloride	sat. sol.	S	S
Ferric nitrate	sol.	S	S
Ferric sulfate	sat. sol.	S	S
Ferrous chloride	sat. sol.	S	S
Ferrous sulfate	sat. sol.	S	S
Fluorine, gaseous	100%	U	U
Fluorosilicic acid	40%	S	S
Formaldehyde	40%	S	S
Formic acid	50%	S	S
Formic acid	98-100%	S	S
Furfuryl alcohol	100%	S	L
G			
Gasoline	—	S	L
Glacial acetic acid	96%	S	L
Glucose	sat. sol.	S	S
Glycerine	100%	S	S
Glycol	sol	S	S
H			
Heptane	100%	S	U
Hydrobromic acid	50%	S	S
Hydrobromic acid	100%	S	S
Hydrochloric acid	10%	S	S
Hydrochloric acid	35%	S	S
Hydrocyanic acid	10%	S	S
Hydrofluoric acid	4%	S	S
Hydrofluoric acid	60%	S	L
Hydrogen	100%	S	S
Hydrogen peroxide	30%	S	L
Hydrogen peroxide	90%	S	U
Hydrogen sulfide, gaseous	100%	S	S
Lactic acid	100%	S	S
Lead acetate	sat. sol.	S	—
Magnesium carbonate	sat. sol.	S	S
Magnesium chloride	sat. sol.	S	S
Magnesium hydroxide	sat. sol.	S	S
Magnesium nitrate	sat. sol.	S	S
Maleic acid	sat. sol.	S	S
Mercuric chloride	sat. sol.	S	S
Mercuric cyanide	sat. sol.	S	S
Mercuric nitrate	sol.	S	S

GSE ENVIRONMENTAL™

Medium	Concentration	Resistance at:	
		20° C (68° F)	60° C (140° F)
Mercury	100%	S	S
Methanol	100%	S	S
Methylene chloride	100%	L	—
Milk	—	S	S
Molasses	—	S	S
N			
Nickel chloride	sat. sol.	S	S
Nickel nitrate	sat. sol.	S	S
Nickel sulfate	sat. sol.	S	S
Nicotinic acid	dil. sol.	S	—
Nitric acid	25%	S	S
Nitric acid	50%	S	U
Nitric acid	75%	U	U
Nitric acid	100%	U	U
O			
Oils and Grease	—	S	L
Oleic acid	100%	S	L
Orthophosphoric acid	50%	S	S
Orthophosphoric acid	95%	S	L
Oxalic acid	sat. sol.	S	S
Oxygen	100%	S	L
Ozone	100%	L	U
P			
Petroleum (kerosene)	—	S	L
Phenol	sol	S	S
Phosphorus trichloride	100%	S	L
Photographic developer	cust. conc.	S	S
Picric acid	sat. sol.	S	—
Potassium bicarbonate	sat. sol.	S	S
Potassium bisulfide	sol.	S	S
Potassium bromate	sat. sol.	S	S
Potassium bromide	sat. sol.	S	S
Potassium carbonate	sat. sol.	S	S
Potassium chlorate	sat. sol.	S	S
Potassium chloride	sat. sol.	S	S
Potassium chromate	sat. sol.	S	S
Potassium cyanide	sol.	S	S
Potassium dichromate	sat. sol.	S	S
Potassium ferricyanide	sat. sol.	S	S
Potassium ferrocyanide	sat. sol.	S	S
Potassium fluorid	sat. sol.	S	S
Potassium hydroxide	10%	S	S
Potassium hydroxide	sol.	S	S
Potassium hypochlorite	sol.	S	L
Potassium nitrate	sat. sol.	S	S
Potassium orthophosphate	sat. sol.	S	S
Potassium perchlorate	sat. sol.	S	S
Potassium permanganate	20%	S	S
Potassium persulfate	sat. sol.	S	S
Potassium sulfate	sat. sol.	S	S
Potassium sulfite	sol.	S	S
Propionic acid	50%	S	S
Propionic acid	100%	S	L
Pyridine	100%	S	L
Q			
Quinol (Hydroquinone)	sat. sol.	S	S
S			
Salicylic acid	sat. sol.	S	S

Medium	Concentration	Resistance at:	
		20° C (68° F)	60° C (140° F)
Silver acetate	sat. sol.	S	S
Silver cyanide	sat. sol.	S	S
Silver nitrate	sat. sol.	S	S
Sodium benzoate	sat. sol.	S	S
Sodium bicarbonate	sat. sol.	S	S
Sodium biphosphate	sat. sol.	S	S
Sodium bisulfite	sol.	S	S
Sodium bromide	sat. sol.	S	S
Sodium carbonate	sat. sol.	S	S
Sodium chlorate	sat. sol.	S	S
Sodium chloride	sat. sol.	S	S
Sodium cyanide	sat. sol.	S	S
Sodium ferricyanide	sat. sol.	S	S
Sodium ferrocyanide	sat. sol.	S	S
Sodium fluoride	sat. sol.	S	S
Sodium hydroxide	40%	S	S
Sodium hydroxide	sat. sol.	S	S
Sodium hypochlorite	15% active chlorine	S	S
Sodium nitrate	sat. sol.	S	S
Sodium nitrite	sat. sol.	S	S
Sodium orthophosphate	sat. sol.	S	S
Sodium sulfate	sat. sol.	S	S
Sodium sulfide	sat. sol.	S	S
Sulfur dioxide, dry	100%	S	S
Sulfur trioxide	100%	U	U
Sulfuric acid	10%	S	S
Sulfuric acid	50%	S	S
Sulfuric acid	98%	S	U
Sulfuric acid	fuming	U	U
Sulfurous acid	30%	S	S
T			
Tannic acid	sol.	S	S
Tartaric acid	sol.	S	S
Thionyl chloride	100%	L	U
Toluene	100%	L	U
Triethylamine	sol.	S	L
U			
Urea	sol.	S	S
Urine	—	S	S
W			
Water	—	S	S
Wine vinegar	—	S	S
Wines and liquors	—	S	S
X			
Xylenes	100%	L	U
Y			
Yeast	sol.	S	S
Z			
Zinc chloride	sat. sol.	S	S
Zinc (II) chloride	sat. sol.	S	S
Zinc (IV) chloride	sat. sol.	S	S
Zinc oxide	sat. sol.	S	S
Zinc sulfate	sat. sol.	S	S

Specific immersion testing should be undertaken to ascertain the suitability
of chemicals not listed above with reference to special requirements.

Notes:
(S) Satisfactory: Liner material is resistant to the given reagent at the given concentration and temperature. No mechanical or chemical degradation is observed.
(L) Limited Application Possible: Liner material may reflect some attack. Factors such as concentration, pressure and temperature directly affect liner performance against the given media. Application, however, is possible under less severe conditions, e.g. lower concentration, secondary containment, additional liner protections, etc.
(U) Unsatisfactory: Liner material is not resistant to the given reagent at the given concentration and temperature. Mechanical and/or chemical degradation is observed.
(–) Not tested
sat. sol. = Saturated aqueous solution, prepared at 20°C (68°F)
sol. = aqueous solution with concentration above 10% but below saturation level
dil. sol. = diluted aqueous solution with concentration below 10%
cust. conc. = customary service concentration

GSE is a leading manufacturer and marketer of geosynthetic lining products and services. We've built a reputation of reliability through our dedication to providing consistency of product, price and protection to our global customers.

Our commitment to innovation, our focus on quality and our industry expertise allow us the flexibility to collaborate with our clients to develop a custom, purpose-fit solution.

GSE ENVIRONMENTAL™

[DURABILITY RUNS DEEP] For more information on this product and others, please visit us at GSEworld.com, call 800.435.2008 or contact your local sales office.

North America 800.435.2008 | Europe & Africa 49.40.767420 | Asia Pacific 66.2.937.0091 | South America 56.2.595.4200 | Middle East 20.23828.8888

CHEMICAL RESISTANCE LIST

GENERAL INFORMATION

Concerning the expected lifetime the data in the chemical resistance table are referring to the information on the expected lifetime (depending on the temperature) specified in the standards DIN8074, DIN8075, DIN8077, DIN8078, ISO10931 and the standard DVS2205. For chemical media having an influence (swelling, stress cracking, oxidizing) on the material the expected lifetime can only be reached in case that the correct chemical resistance factors are used for the dimensioning of the components. Concerning special materials (PPs, PPs-el, HDPE-el; PE100 RC) and sealing materials the chemical resistance has to be checked by contacting the technical department of AGRU Kunststofftechnik (Email: anwt@agru.at).

All data in the media list are based on generally available information, experience and information of the raw material suppliers, the data are therefore just indicative for the chemical resistance of AGRU's thermoplastic materials.

Products produced by AGRU Kunststofftechnik GmbH have not been tested on the resistance against the media, described in the chemical resistance list, so the information in the chemical resistance list is based on analog circuits.

A legal guarantee of certain properties, nor the suitability for the individual case cannot be derived from this chemical resistance list due to the possible influence of many factors that may affect processing and the application and do not relieve users from their responsibility of carrying out their own tests and experiments.

For chemical inquiries we kindly ask to send the following questionnaire with all information to anwt@agru.at respectively to wi@agru.at.

For return shipments of products, which have been in contact with chemical media, it is kindly requested to fill out the following blank.

CLASSIFICATION

+: Chemically resistant

-: Not resistant

+/-(q): Swelling effect (diffusion and permeation): a chemical reduction factor of 1.1-1.6 has to be considered for the dimensioning of the components (according to the standards DVS, DIBt and based on statements / recommendations of the raw material suppliers)

+/-(s): Stress cracking property: a chemical reduction factor of 1.1-2.0 has to be considered for the dimensioning of the components (according to the standards DVS, DIBt and based on statements / recommendations of the raw material suppliers)

+/-(o): Oxidizing influence: a chemical reduction factor of 1.1-2.0 has to be considered for the dimensioning of the components (according to the standards DVS, DIBt and based on statements / recommendations of the raw material suppliers)

CONCENTRATION

TR: Technically pure
GL: Saturated solution
H: Commercial composition
S: Suspension
VL: Diluted solution

CHEMISCHE BESTÄNDIGKEITSLISTE

GENERELL INFORMATION

Bezüglich der zu erwartenden Lebensdauer beziehen sich die Aussagen in der chemischen Beständigkeitsliste auf die Lebensdauerangaben in Abhängigkeit von der Temperatur, festgelegt in den Normen DIN8074, DIN8075, DIN8077, DIN8078 und ISO10931 sowie der DVS Richtlinie 2205. Bei Medien, die einen chemischen Einfluss (quellend, spannungsrissauslösend, oxidierend) auf die Werkstoffe haben, kann die zu erwartende Lebensdauer nur dann erreicht werden, wenn die entsprechenden chemischen Abminderungsfaktoren für die Bauteildimensionierung korrekt berücksichtigt werden. Für Sonderwerkstoffe (PPs, PPs-el, PEHD-el, PE100 RC) und Dichtungswerkstoffe ist die chemische Beständigkeit mit der Anwendungstechnik der Firma AGRU Kunststofftechnik (Email: anwt@agru.at) abzuklären.

Alle Angaben in der Medienliste beruhen auf allgemein erhältlichen Informationen, Erfahrungen und Informationen der Rohstofflieferanten und sind somit Richtwerte zur Einschätzung der chemischen Beständigkeit.

Produkte von AGRU Kunststofftechnik GmbH wurden nicht auf Beständigkeit gegen diese Medien geprüft; es handelt sich daher um Analogschlüsse.

Eine rechtliche verbindliche Zusicherung bestimmter Eigenschaften oder die Eignung im Einzelfall kann aufgrund der Fülle möglicher Einflüsse bei der Verarbeitung und Anwendung nicht abgeleitet werden und befreien den Anwender nicht von eigenen Prüfungen und Versuchen.

Für chemische Anfragen bitten wir, das nachstehende Formular auszufüllen und an anwt@agru.at bzw. wi@agru.at zu senden.

Für Rücksendungen von Produkten, die mit chemischen Medien in Berührung waren, wird gebeten, folgendes Formular auszufüllen.

KLASSIFIZIERUNG

+: Chemisch beständig

-: Nicht beständig

+/-(q): Bedingt beständig - Quellende Wirkung (Diffusion und Permeation): ist bei der Bauteildimensionierung mit chemischen Abminderungsfaktoren von 1,1-1,6 zu berücksichtigen (gemäß den DVS, DIBt Richtlinien und basierend auf Stellungnahmen / Empfehlungen der Rohstofflieferanten)

+/-(s): Bedingt beständig - Spannungsrissauslösende Wirkung: ist bei der Bauteildimensionierung mit chemischen Abminderungsfaktoren von 1,1-2,0 zu berücksichtigen (gemäß den DVS, DIBt Richtlinien und basierend auf Stellungnahmen / Empfehlungen der Rohstofflieferanten)

+/-(o): Bedingt beständig - Oxidierende Wirkung: ist bei der Bauteildimensionierung mit chemischen Abminderungsfaktoren von 1,1-2,0 zu berücksichtigen (gemäß den DVS, DIBt Richtlinien und basierend auf Stellungnahmen / Empfehlungen der Rohstofflieferanten)

KONZENTRATION

TR: Technisch rein
GL: Gesättigte Lösung
H: Handelsübliche Zusammensetzung
S: Suspension
VL: Verdünnte Lösung

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
3-Aminopropyltriethoxysilan	3-Aminopropyltriethoxysilan	$C_9H_{23}NO_3Si$	TR	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	+/-(o)	+/-(o)	+	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Acetaldehyde	Acetaldehyd	CH_3CHO	40%	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Acetaldehyde	Acetaldehyd	CH_3CHO	TR	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Acetaldehyde + Acetic acid	Acetaldehyd + Essigsäure	$CH_3CHO + CH_3COOH$	all	20	+	+	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Acetamide	Acetamid	CO_3CONH_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetanilide	Acetanilid	$C_6H_5NHCOCH_3$	TR	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	+	+	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	+/-(q)
Acetate (Ester of acetic acid)	Essigsäureester	$CH_3COOC_2H_5$, $-OC_4H_9$, …	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetic acid	Essigsäure	CH_3COOH	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Acetic acid	Essigsäure	CH_3COOH	96%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Acetic acid	Essigsäure	CH_3COOH	80%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetic acid	Essigsäure	CH_3COOH	60%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Acetic acid	Essigsäure	CH_3COOH	50%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetic acid	Essigsäure	CH_3COOH	10%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetic anhydride	Essigsäureanhydrid	$(CH_3CO)_2O$	TR	20	+	+	+	+
	(Acetanhydrid)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetone	Aceton	CH_3COCH_3	≤ 1%	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Acetone	Aceton	CH_3COCH_3	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Acetonitrile	Essigsäurenitril	CH_3CN	TR	20	+	+	+	+
	(Acetonnitril)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetophenone	Acetophenon	$C_6H_5COCH_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	-
				120	-	-	-	-
Acetyl acetone	Acetylaceton	$CH_3COCH_2COCH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Acetyl bromide	Acetylbromid	CH_3COBr	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Acetyl chloride	Acetylchlorid	CH_3COCl	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Acetylene	Acetylen	CHCH	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Acrylate	Acrylsäureester	$CH_2=CHCOOR$	60%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Acrylic acid	Acrylsäure	$CH_2=CHCOOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Acrylic acid butyl ester	Acrylsäurebutylester	$CH_2CHCOOC_4H_9$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Acrylonitrile	Acrylnitril	$CH_2=CHCN$	TR	20	+	+	+	+
				40	+	+	+/-(s)	+
				60	+/-(q)	+/-(q)	+/-(s)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Adipic acid	Adipinsäure	$HOOC(CH_2)_4COOH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Adipic acid dinonester	Adipinsäuredinonester	$(CH_2)_4(COOC_9H_{17})_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Adipic acid dioctyl ester	Adipinsäuredioctylester	$(CH_2)_4(COOC_8H_{15})_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Air	Luft	N_2, O_2…	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Alanindiacetic acid	Alanindiessigsäure		40%	20	+	+	+	+
+ Trisodium salt	+ Trinatriumsalz			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Alcalic clay	Alkalische Tonerde	Al_2O_3 x Na_2O	H	20	+	+	-	+
				40	+	+	-	+
				60	+	+/-(s)	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Alcoholic spirits	Spirituosen			20	+/-(q)	+	+	+
(Gin, Whiskey, etc.)	ca. 40% Ethylalkohol			40	+/-(q)	+/-(q)	+	+
approx. 40% ethyl alcohol				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Aliphatic hydrocarbons	Aliphatische Kohlenwasserstoffe	C_nH_{2n}	100-200ppm	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Alkylarylpolyglycolether	Alkylarylpolyglycolether		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Allyl acetate	Essigsaureallylester (Allylacetat)	$CH_3COOCH_2CHCH_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Allyl alcohol	Allylalkohol	$CH_2=CHCH_2OH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	-
				120	-	-	-	-
Allyl chloride (3-Chloropropene)	Allylchlorid (3-Chlorpropen)	CH_2CHCH_2Cl	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Aluminium acetate	Aluminiumacetat	$Al(CH_3COO)_2OH$	all	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Aluminium ammonium sulfate	Aluminiumammoniumsulfat	$AlNH_4(SO_4)_2 \times 12H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Aluminium chlorate	Aluminiumchlorat	$Al(ClO_3)_3$	≤ GL	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Aluminium chloride	Aluminiumchlorid	$AlCl_3$	10%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium chloride	Aluminiumchlorid	$AlCl_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium chloride sulfate	Aluminiumchloridsulfat	$AlClSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Aluminium fluoride	Aluminiumfluorid	AlF_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium hexafluorosilicate	Aluminiumhexafluorsilicat	$Al_2(SiF_6)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium hydroxide	Aluminiumhydroxid	$Al(OH)_3$	≤ GL	20	+	+	-	+
				40	+	+	-	+
				60	+	+/-(s)	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Aluminium iron(II) sulfate	Aluminiumeisen(II)sulfat	$Al_2Fe(SO_4)_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium metaphosphate	Aluminiummetaphosphat	$Al(PO_3)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium nitrate	Aluminiumnitrat	$Al(NO_3)_3 \times 9H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium oxide	Aluminiumoxid (Korund)	Al_2O_3	≤ GL	20	+	+	-	+
				40	+	+	-	+
				60	-	+/-(o)	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Aluminium oxychloride	Aluminiumoxychlorid	$AlOCl$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Aluminium polyhydroxychloro-sulfate	Aluminiumpolyhydroxychlorsulfat		≤ GL	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+
				120	-	-	-	-
Aluminium potassium sulfate	Aluminiumkaliumsulfat	$Al_2(SO_4)_3 \times K_2SO_4 \times 24H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium sulfate	Aluminiumsulfat	$Al_2(SO_4)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Amino acids	Aminosäuren	$RCHNH_2COOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	-
				120	-	-	-	-
Aminobenzoic acid	Aminobenzoesäure	$NH_2C_6H_4COOH$	10%	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Aminoethoxyethanol	Aminoethoxyethanol	$C_4H_{11}NO_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Aminonaphthalinsulfonic acid	Aminonaphthalinsulfonsäure	$C_{10}H_6NH_2SO_3H$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Aminotrimethylenphosphoric acid	Aminotrimethylenphosphorsäure		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Ammoniac	Ammoniak	NH_3	TR	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Ammonium acetate	Ammoniumacetat	CH_3COONH_4	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Ammonium aluminium sulfate	Ammoniumaluminiumsulfat	$NH_4Al(SO_4)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium bromide	Ammoniumbromid	NH_4Br	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium carbonate	Ammoniumcarbonat	$(NH_4)_2CO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium chloride	Ammoniumchlorid	NH_4Cl	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ammonium citrate	Ammoniumcitrat	$(NH_4)_2C_6H_6O_7$	VL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Ammonium dichromate	Ammoniumdichromat	$(NH_4)_2Cr_2O_7$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	+/-(o)	+/-(o)
				120	-	-	-	-
Ammonium dihydrogen-phosphate	Ammoniumdihydrogenphosphat	$NH_4H_2PO_4$	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium fluoride	Ammoniumfluorid	NH_4F	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium fluoroborate	Ammoniumfluorborat	NH_4BF_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium formiate	Ammoniumformiat	NH_4COOH	≤ GL	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ammonium hexafluorosilicate	Ammoniumhexafluorsilicat	$(NH_4)_2SiF_6$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium hydrogenfluoride	Ammoniumhydrogenfluorid	NH_4HF_2	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium hydrogensulfide	Ammoniumhydrogensulfid	NH_4HS	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium hydrogensulfite	Ammoniumhydrogensulfit	NH_4HSO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium hydrogenphosphate	Ammoniumhydrogenphosphat	$(NH_4)_2HPO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ammonium hydroxide	Ammoniumhydroxid	NH_4OH	≤ GL	20	+	+	-	+
	(Salmiakgeist)			40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Ammonium hydroxide	Ammoniumhydroxid	NH_4OH	30%	20	+	+	-	+
	(Salmiakgeist)			40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Ammonium iron(II) sulfate	Ammoniumeisen(II)sulfat	$(NH_4)_2Fe(SO_4)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium metaphosphate	Ammoniummetaphosphat	NH_4PO_3	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium molybdate	Ammoniummolybdat	NH_4MoO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium nitrate	Ammoniumnitrat	NH_4NO_3	10%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium nitrate	Ammoniumnitrat	NH_4NO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium orthophosphate	Ammoniumorthophosphat	$(NH_4)PO_4$ x $3H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium oxalate	Ammoniumoxalat	$(NH_4OOC)_2$	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ammonium persulfate	Ammoniumperoxodisulfat	$(NH_4)_2S_2O_8$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(o)	+/-(o)	+	+
				80	-	+/-(o)	+	+
				100	-	-	+	-
				120	-	-	-	-
Ammonium phosphate	Ammoniumphosphat	$(NH_4)_3PO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ammonium sulfamate	Ammoniumsulfamat	$NH_4OSO_2NH_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium sulfate	Ammoniumsulfat	$(NH_4)_2SO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium sulfide	Ammoniumsulfid	$(NH_4)_2S$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium sulfite	Ammoniumsulfit	$(NH_4)_2SO_3$ x H_2O	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium tetrafluoroborate	Ammoniumtetrafluorborat	NH_4BF_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium thiocyanate	Ammoniumthiocyanat	NH_4SCN	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Ammonium tungstate	Ammoniumwolframat	$(NH_4)_2WO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Amyl acetate	Amylacetat	$CH_3(CH_2)_4OOCCH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Amyl alcohol (1-Pentanol)	Amylalkohol (1-Pentanol)	$CH_3(CH_2)_4OH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Amyl chloride	Pentylchlorid (1-Chlorpentan)	$C_5H_{11}Cl$	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Amyl sec. alcohol (2-Pentanol)	Amylsekundäralkohol (2-Pentanol)	$CH_3(CH_2)_2CHOHCH_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Aniline	Anilin	$C_6H_5NH_2$	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Aniline hydrochloride	Anilinchlorhydrat	$C_6H_5NH_3Cl$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Anisole	Anisol (Methoxybenzol, Methylphenylether)	$C_6H_5OCH_3$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Anthrachinone-2-sulfonic acid	Anthrachinon-2-Sulfonsäure	$C_6H_4(CO)_2C_6H_3SO_3H$	2%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Anthraquinone	Anthrachinon	$C_6H_4(CO)_2C_6H_4$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Antiformin	Antiformin	$NaOCl \times NaOH \times Na_2CO_3$	2%	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Antifreeze agent	Frostschutzmittel		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Antimon oxychloride	Antimonoxychlorid	$SbOCl$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Antimony pentachloride	Antimonpentachlorid	$SbCl_5$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Antimony trichloride	Antimontrichlorid	$SbCl_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Antimony trifluoride	Antimontrifluorid	SbF_3	20%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Apple acid	Apfelsäure	$C_4H_6O_5$	1%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Apple juice	Apfelsaft		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Apple wine	Apfelwein		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Aqua regia	Königswasser	$HNO_3 + HCl$	≤ GL	20	-	-	+	+
(75% hydrochloric acid	(75% Salzsäure			40	-	-	+	+
25% nitric acid)	25% Salpetersäure)			60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Arsenic acid	Arsensäure	H_3AsO_4	80%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Arsenic pentoxide	Arsenpentoxid	As_2O_5	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Arsine	Arsin	AsH_3	TR	20	+	+	+	+
	(Arsenwasserstoff)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ascorbic acid	Ascorbinsäure	$C_6H_8O_6$	TR	20	+	+	+	+
(Vitamin C)	(Vitamin C)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Asphalt	Asphalt		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
2-Butanone	2-Butanon	$CH_3COC_2H_5$	TR	20	+	+	+	+
(Methyl ethyl ketone, MEK)	(Methylethylketon, MEK)		TR	40	+/-(q)	+	+/-(q)	+
			TR	60	+/-(q)	+/-(q)	-	+
			TR	80	-	-	-	+/-(q)
			TR	100	-	-	-	-
			TR	120	-	-	-	-
2-Butenal	2-Butenal	$CH_3CH{=}CHCHO$	TR	20	+	+	+	+
(Crotonic aldehyde)	(Crotonaldehyde)		TR	40	+/-(q)	+	+	+
			TR	60	+/-(q)	+/-(q)	+	+
			TR	80	-	+/-(q)	+	+
			TR	100	-	-	+/-(q)	+
			TR	120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
2-Butoxyethanol	2-Butoxyethanol	$C_6H_{14}O_2$	5%	20	+	+	+	+
			5%	40	+/-(q)	+	+	+
			5%	60	+/-(q)	+/-(q)	+	+
			5%	80	-	+/-(q)	+	+
			5%	100	-	-	+/-(q)	+
			5%	120	-	-	-	-
Barium carbonate	Bariumcarbonat	$BaCO_3$	S	20	+	+	+	+
			S	40	+	+	+	+
			S	60	+	+	+	+
			S	80	-	+	+	+
			S	100	-	-	+	+
			S	120	-	-	-	+
Barium chloride	Bariumchlorid	$BaCl_2$	≤ GL	20	+	+	+	+
			≤ GL	40	+	+	+	+
			≤ GL	60	+	+	+	+
			≤ GL	80	-	+	+	+
			≤ GL	100	-	-	+	+
			≤ GL	120	-	-	-	+
Barium cyanide	Bariumcyanid	$Ba(CN)_2$	≤ GL	20	+	+	+	+
			≤ GL	40	+	+	+	+
			≤ GL	60	+	+	+	+
			≤ GL	80	-	+	+	+
			≤ GL	100	-	-	+	+
			≤ GL	120	-	-	-	+
Barium hydroxide	Bariumhydroxid	$Ba(OH)_2$	≤ GL	20	+	+	-	+
			≤ GL	40	+	+	-	+
			≤ GL	60	+	+	-	+
			≤ GL	80	-	+	-	+
			≤ GL	100	-	-	-	+
			≤ GL	120	-	-	-	+
Barium nitrate	Bariumnitrat	$Ba(NO_3)_2$	≤ GL	20	+	+	+	+
			≤ GL	40	+	+	+	+
			≤ GL	60	+	+	+	+
			≤ GL	80	-	+	+	+
			≤ GL	100	-	-	+	+
			≤ GL	120	-	-	-	+
Barium salts (nitrate, sulfate, chloride, phosphate)	Bariumsalze (Nitrate, Sulfate, Chloride, Phosphate)		≤ GL	20	+	+	+	+
			≤ GL	40	+	+	+	+
			≤ GL	60	+	+	+	+
			≤ GL	80	-	+	+	+
			≤ GL	100	-	-	+	+
			≤ GL	120	-	-	-	+
Barium sulfate	Bariumsulfat (Schwerspat)	$BaSO_4$	S	20	+	+	+	+
			S	40	+	+	+	+
			S	60	+	+	+	+
			S	80	-	+	+	+
			S	100	-	-	+	+
			S	120	-	-	-	+
Barium sulfide	Bariumsulfid	BaS	S	20	+	+	+	+
			S	40	+	+	+	+
			S	60	+	+	+	+
			S	80	-	+	+	+
			S	100	-	-	+	+
			S	120	-	-	-	+
Beef tallow emulsion, sulphonated	Rindertalg-Emulsion, sulfoniert		H	20	+/-(q)	+/-(q)	+	+
			H	40	+/-(q)	+/-(q)	+	+
			H	60	+/-(q)	+/-(q)	+	+
			H	80	-	-	+/-(q)	+
			H	100	-	-	-	+/-(q)
			H	120	-	-	-	-
Beer	Bier		H	20	+	+	+	+
			H	40	+	+	+	+
			H	60	+	+	+	+
			H	80	-	+	+	+
			H	100	-	-	+	+
			H	120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Beeswax	Bienenwachs		TR	20	+	+	+	+
			TR	40	+	+	+	+
			TR	60	+/-(q)	+/-(q)	+	+
			TR	80	-	+/-(q)	+	+
			TR	100	-	-	+	+
			TR	120	-	-	-	+
Benzal chloride (Alphadichlorotoluene)	Benzalchlorid	$C_6H_5CHCl_2$	TR	20	+/-(q)	+/-(q)	+	+
			TR	40	-	-	+	+
			TR	60	-	-	+/-(q)	+/-(q)
			TR	80	-	-	+/-(q)	+/-(q)
			TR	100	-	-	-	-
			TR	120	-	-	-	-
Benzaldehyde	Benzaldehyd	C_6H_5CHO	TR	20	+	+	+	+
			TR	40	+	+	+	+
			TR	60	+/-(q)	+/-(q)	+	+
			TR	80	-	-	-	-
			TR	100	-	-	-	-
			TR	120	-	-	-	-
Benzaldehyde in Isopropanol	Benzaldehyd in Isopropanol	C_7H_6O in C_3H_8O	1%	20	+	+	+	+
			1%	40	+	+	+	+
			1%	60	+/-(q)	+/-(q)	+	+
			1%	80	-	-	-	-
			1%	100	-	-	-	-
			1%	120	-	-	-	-
Benzamide	Benzamid	$C_6H_5CONH_2$	TR	20	+	+	+	+
			TR	40	+	+	+/-(q)	+
			TR	60	+/-(q)	+/-(q)	-	+
			TR	80	-	+/-(q)	-	-
			TR	100	-	-	-	-
			TR	120	-	-	-	-
Benzene	Benzen	C_6H_6	TR	20	+/-(q)	+/-(q)	+	+
			TR	40	-	-	+	+
			TR	60	-	-	-	+/-(q)
			TR	80	-	-	-	-
			TR	100	-	-	-	-
			TR	120	-	-	-	-
Benzenesulfonic acid	Benzolsulfonsäure	$C_6H_5SO_3H$	30%	20	+	+	+	+
			30%	40	+/-(q)	+/-(q)	+	+
			30%	60	+/-(q)	+/-(q)	+/-(q)	+
			30%	80	-	-	+/-(q)	+/-(q)
			30%	100	-	-	-	-
			30%	120	-	-	-	-
Benzenesulfonic acid	Benzolsulfonsäure	$C_6H_5SO_3H$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Benzenesulfonyl chloride	Benzolsulfonylchlorid (Benzolsulfochlorid)	$C_6H_5SO_2Cl$	80%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Benzine (Petrol)	Benzin	C_5H_{12} up to $C_{12}H_{26}$	H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Benzine, normal	Benzin, normal		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Benzine, super	Benzin, super		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Benzine, test	Benzin, test		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Benzine-Benzol-Mixture	Benzin-Benzol-Gemisch		all	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Benzoic acid	Benzoesäure	H_5C_6COOH	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Benzoic acid, chlorinated	Benzoesäure, gechlort	H_5C_6COCl	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Benzophenone	Benzophenon	$C_6H_5COC_6H_5$	TR	20	+/-(q)	+/-(q)	+	+
	(Diphenylketon)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Benzoyl chloride	Benzoylchlorid	C_6H_5COCl	3%	20	+	+	+	+
	(Benzolsäurechlorid)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Benzyl alcohol	Benzylalkohol	$C_6H_5CH_2OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Benzyl amine	Benzylamin	$C_6H_5CH_2NH_2$	TR	20	+/-(q)	+/-(q)	+	+
	(alpha-Aminotoluol)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Benzyl chloride	Benzylchlorid	$C_6H_5CH_2Cl$	TR	20	+/-(q)	+/-(q)	+	+
	(Alpha-Chlortoluene)			40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Benzyl ether	Benzylether	$C_6H_5CH_2OCH_2C_6H_5$	TR	20	+/-(q)	+/-(q)	+	+
	(Dibenzylether)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Benzyl ethyl aniline	Benzylethylanilin	$C_6H_5CH_2N(C_6H_5)(C_2H_5)$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Beryllium sulfate	Berylliumsulfat	$BeSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Betaine	Betain (Trimethylammoniaacetat)	$(CH_3)_3NCH_2COO$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Biodiesel	Biodiesel		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Bismuth carbonate	Wismutcarbonat	$BiCO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Bismuth pentafluoride	Wismutpentafluorid	BiF_5	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Bismuth salts (nitrate, sulfate, chloride, phosphate)	Wismutsalze (Nitrate, Sulfate, Chloride, Phosphate)		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Bitumen	Bitumen		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Black liquor	Schwarzlauge		all	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Bone oil	Knochenöl		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)
Borax	Borax	$Na_2B_4O_7$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Boric acid	Borsäure	H_3BO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Boron trifluoride	Bortrifluorid (Trifluorboran)	BF_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Brake fluid	Bremsflüssigkeit		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Brandy	Branntweine		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Brine alcaline	Salzsole alkalisch		all	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Bromid acid	Bromsäure	$HBrO_3$	VL	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Bromine + dibromomethane	Brom + Dibrommethan	$Br_2 + CH_2Br_2$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+
				100	-	-	-	-
				120	-	-	-	-
Bromine + phosphite hydrogen + phosphate hydrogen	Brom + Hydrogenphosphit + Hydrogenphosphat	$Br_2 + H_3PO_3 + H_3PO_4$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Bromine water	Bromwasser	Br_2	2.8%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Bromine, liquid	Brom, flüssig	Br_2	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Bromine, vapours	Bromdämpfe	Br_2	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Bromochloromethane	Bromchlormethan	CH_2BrCl	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Bromochlorotrifluoroethane	Bromchlortrifluorethan (Halothan)	$CF_3CHBrCl$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Bromoform	Bromform (Tribrommethan)	$CHBr_3$	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	+/-(s)	+
				100	-	-	-	+/-(s)
				120	-	-	-	-
Butadiene	Butadien	$H_2C=CHCH=CH_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butane	Butan	C_4H_{10}	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Butane, chlorinated	Butan, gechlort	C_4H_9Cl	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	-
Butanediol	Butandiol	HOC_4H_8OH	10%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Butanediol	Butandiol (2,3-Butylenglykol)	HOC_4H_8OH	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(q)	+	+
				80	-	+/-(q)	+	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Butanetriol	Butantriol	$C_4H_7(OH)_3$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Butanol	Butanol	$C_3H_7CH_2OH$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Butene	Buten (n-Butylen)	$CH_3CH_2CHCH_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Butenediol	Butendiol	$CH_2OHCHCHCH_2OH$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Butinediol	Butindiol	$CH_2OHCCCH_2OH$	TR	20	+	+	+	+
	(Korantin BH flüssig)			40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Butter	Butter		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Buttermilk	Buttermilch		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Butyl acetate	Essigsäurebutylester	$CH_3COOC_4H_9$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Butyl aldehyde	Butylaldehyd	$CH_3CH_2CH_2CHO$	TR	20	+	+	+	+
	(Butanal)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyl benzyl phthalate	Butylbenzylphthalat	$CH_3(CH_2)_3OOCC_6H_4COO$-	TR	20	+	+	+	+
	(Phthalsäurebenzylbutylester)	$CH_2C_6H_5$		40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyl bromide	Butylbromid	C_4H_9Br	TR	20	+/-(q)	+/-(q)	+	+
	(1-Brombutan)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Butyl chloride	Butylchlorid	C_4H_9Cl	TR	20	+/-(q)	+/-(q)	+	+
	(1-Chlorbutan)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Butyl cyclohexyl ester	Butylcyclohexylester	$ClCOOC_{10}H_{19}$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyl diglykol	Butyldiglykol	$C_8H_{18}O_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Butyl ether	Butylether	$C_4H_9OC_4H_9$	TR	20	+/-(s)	+/-(s)	+	+
	(n-Dibutylether)			40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Butyl glycol	Butylglykol	$HOCH_2CH_2O(CH_2)_3CH_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyl glycolate	Butylglykolat	$HOCH_2COO(CH_2)_3CH_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyl phenol	Butylphenol	$C_{10}H_{14}O$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyl phenone	Butylphenon	$C_6H_5CO(CH_2)_2CH_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butylcyclohexylchloroformiate	Butylcyclohexylchlorformiat	$ClCOOC_6H_{10}C_4H_9$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butylene, liquid	Butylen, flüssig	C_4H_8	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyleneglycol	Butylenglykol	$HOCH_2CH{=}CHCH_2OH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyric acid	Buttersäure	$CH_3CH_2CH_2COOH$	TR	20	+	+	+	+
	(Butansäure)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyrolacetone	Butyrolaceton	OC_4H_6O	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
1-Chloro-1,2,2-trifluoroethylene	Chlortrifluorethylen	$CClFCF_2$	TR	20	+/-(o)	+/-(o)	+/-(o)	+
	(Trifluorvinylchlorid)			40	-	-	+/-(o)	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
1-Chloro-2,3-epoxypropane	Epichlorhydrin	CH_2OCHCH_2Cl	TR	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
1-Cyclohexyl-2-pyrrolidone	1-Cyclohexyl-2-pyrrolidon	$C_{10}H_{17}NO$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
2-4-Chloro-2-methylphenoxy-propionic acid	Chlormethylphenoxypropion-säure (MECOPROP)	$ClCH_3C_6H_3OCH(CH_2)_2$-COOH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
2-Chloro-1-bromoethane	Chlorbrommethan (1-Brom-2-Chlormethan)	$BrCH_2CH_2Cl$	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
2-Chlorobenzoyl chloride	Chlorbenzoylchlorid	ClC_6H_4COCl	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
2-Chloromethyltriethylammonium chloride	2-Chlormethyltriethylammonium-chlorid		TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
2-Chlorophenol	Chlorphenol	ClC_6H_4OH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
3-Chloro-2-hydroxypropyl-ammonium chloride	3-Chlor-2-hydroxypropyl-ammoniumchlorid		TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
4-Chloro-2-methylphenoxyacetic acid	Chlormethylphenoxyessigsäure (MCPA)	$ClCH_3C_6H_3OCH_2CH_2$-COOH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
4-Chloro-2-nitrophenol	Chlornitrophenol	$ClC_6H_3NO_2OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
4-Chlorotoluene	Chlortoluol (4-Chlor-1-methylbenzol, 4-Chlortoluol)	$ClC_6H_4CH_3$	TR	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Cadmium chloride	Cadmiumchlorid	$CdCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Cadmium cyanide	Cadmiumcyanid	$Cd(CN)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Cadmium sulfate	Cadmiumsulfat	$CdSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium acetate	Calciumacetat	$Ca(CH_3COO)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Calcium bromide	Calciumbromid	$CaBr_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium carbide	Calciumcarbid	CaC_2	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium carbonate	Calciumcarbonat	$CaCO_3$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium chlorate	Calciumchlorat	$Ca(ClO_3)_2$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	+/-(o)	+/-(o)
				120	-	-	-	-
Calcium chloride	Calciumchlorid	$CaCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium fluoride	Calciumfluorid	CaF_2	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium hydrogencarbonate	Calciumhydrogencarbonat (Calciumbicarbonat)	$Ca(HCO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Calcium hydrogensulfide	Calciumhydrogensulfid	$Ca(HS)_2$	≤ GL	20	+	+	+	+
	(Calciumbisulfid)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium hydrogensulfite	Calciumhydrogensulfit	$Ca(HSO_3)_2$	≤ GL	20	+	+	+	+
	(Calciumbisulfit)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium hydroxide	Calciumhydroxid	$Ca(OH)_2$	S	20	+	+	-	+
	(gelöschter Kalk, Kalkhydrat)			40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Calcium hypochlorite	Calciumhypochlorit	$Ca(OCl)_2$	≤ GL	20	-	-	-	+
(chloride of lime)	(Chlorkalk)			40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Calcium lactate	Calciumlactat	$Ca(C_3H_5O_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Calcium nitrate	Calciumnitrat	$Ca(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium oxide	Calciumoxid	CaO	S	20	+	+	-	+
				40	+	+	-	+
				60	+/-(o)	+/-(o)	-	+
				80	-	+/-(o)	-	+
				100	-	-	-	+
				120	-	-	-	+
Calcium phosphate	Calciumphosphat	$Ca_3(PO_4)_2$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium sulfate	Calciumsulfat	$CaSO_4$	S	20	+	+	+	+
	(Gips)			40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium sulfide	Calciumsulfid	CaS	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium sulfide	Calciumsulfid	CaS	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Calcium sulfite	Calciumsulfit	$CaSO_3$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Camphor	Campher	$C_{10}H_{16}O$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Camphor oil	Campheröl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Cane sugar	Rohrzucker	$C_{12}H_{22}O$	H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Caprylic acid	Caprylsäure	$CH_3(CH_2)_6COOH$	TR	20	+	+	+	+
	(Octansäure)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Carbazole	Carbazol	$C_6H_4NHC_6H_4$	TR	20	+	+	+	+
	(Dibenzopyrrol)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Carbon dioxide, anhydrous	Kohlendioxid, trocken	CO_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Carbon dioxide, gaseous	Kohlendioxid, gasförmig	CO_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Carbon dioxide, moist	Kohlendioxid, feucht	CO_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Carbon disulfide, gaseous	Schwefelkohlenstoff, gasförmig	CS_2	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Carbon disulfide, liquid	Schwefelkohlenstoff, flüssig	CS_2	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Carbon monoxide	Kohlenmonoxid	CO	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Carbon tetrachloride	Kohlenstofftetrachlorid	CCl_4	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Carbonic acid	Kohlensäure	H_2CO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Carbonileum	Carbonileum		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Carbontetrabromide	Tetrabromkohlenstoff	CBr_4	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Carbontetrachloride	Tetrachlorkohlenstoff	CCl_4	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Carbontetrachloride	Tetrachlorkohlenstoff	CCl_4	5%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Carbontetrafluoride	Tetrafluorkohlenstoff (Tetrafluoromethan)	CF_4	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Carbonyl sulfide	Carbonylsulfid	O=C=S	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Casein	Casein (Calciumcaseinat)		TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Castor oil	Rizinusöl (Kastoröl)		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Cedar oil	Zedernöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	-
Cellosolve acetate	Cellosolvacetat	$CH_3COOCH_2CH_2OC_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cetyl alkohol	Cetylalkohol	$C_{16}H_{33}OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	-
				120	-	-	-	-
Chinin hydrochloride	Chininhydrochlorid	$C_{20}H_{24}O_2N_2$ x HCl	TR	20	+	+	+	+
	(Chininchlorhydrat)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Chinin monosulfate	Chininmonosulfat	$C_{20}H_{24}O_2N_2$ x H_2SO_4	TR	20	+/-(q)	+/-(q)	+	+
	(Schwefelsäurechininester)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Chloral	Chloral	CCl_3CHO	TR	20	+	+	+/-(q)	+
(Trichloroaldeyhde)	(Trichloroaldeyhd)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chloral hydrate	Chloralhydrat	$CCl_3CH(OH)_2$	TR	20	+	+/-(o)	+/-(o)	+
	(2,2,2 Trichlor-1,1-ethandiol)			40	+/-(o)	-	-	+
				60	-	-	-	+/-(o)
				80	-	-	-	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Chloramine	Chloramin	RNHCl, $RNCl_2$	1%	20	+	+	+/-(q)	+
	(Aktivin)			40	+/-(q)	+/-(q)	-	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chloric acid	Chlorsäure	$HClO_3$	1%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chloric acid	Chlorsäure	$HClO_3$	10%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chloric acid	Chlorsäure	$HClO_3$	20%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Chloric acid	Chlorsäure	$HClO_3$	38%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chlorid salt	Chloridsalze		TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Chlorinated lime	Chlorkalk (Blechkalk, Calciumchloridhypochlorit)	$CaCl(OCl) + Ca(OH)_2 + CaCl_2$	≤ GL	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Chlorine dioxide, aqueous solution	Chlordioxid, wässrige Lösung	ClO_2	0.2%	20	-	-	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Chlorine dioxide, aqueous solution	Chlordioxid, wässrige Lösung	ClO_2	1%	20	-	-	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Chlorine dioxide, gaseous	Chlordioxid, gasförmig	ClO_2	60%	20	-	-	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Chlorine water	Chlorwasser	$Cl_2 + HCl + HOCl$	≤ GL	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Chlorine, anhydrous	Chlor, trocken	Cl_2	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	-
Chlorine, atomic, chlorine radical, gaseous, moist	Chlor, atomar, Chlorradikal, gasförmig, feucht	Cl▪	all	20	-	-	-	-
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chlorine, gaseous, anhydrous	Chlor, gasförmig, trocken	Cl_2	10%	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Chlorine, gaseous, moist	Chlor, gasförmig, feucht	Cl_2	0.5%	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Chlorine, gaseous, moist	Chlor, gasförmig, feucht	Cl_2	0.8%	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Chlorine, gaseous, moist	Chlor, gasförmig, feucht	Cl_2	1%	20	-	-	+	+
				40	-	-	+	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Chlorine, gaseous, moist	Chlor, gasförmig, feucht	Cl_2	5%	20	-	-	+	+
				40	-	-	+	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Chloroacetyl chloride	Chloracetylchlorid	$C_2H_2Cl_2O$	TR	20	+/-(o)	+/-(o)	+/-(o)	+
	(Chloressigsäurechlorid,			40	-	-	+/-(o)	+/-(o)
	Monochloracetylchlorid)			60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chloroacetyl chloride	Chloressigsäurechlorid	$ClCH_2COCl$	98%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chlorobenzene	Chlorbenzen	C_6H_5Cl	TR	20	+/-(q)	+/-(q)	+	+
	(Phenylchlorid)			40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chlorobenzenosulfon acid	Chlorbenzensulfonsäure	$ClC_6H_4SO_3H$	80%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Chlorobutane	Chlorbutan	C_4H_9Cl	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chlorocresoles	Chlorkresole	$CH_3C_6H_3ClOH$	TR	20	-	-	+	+
	(Chlorhydroxytoluole,			40	-	-	+/-(q)	+
	Chlormethylphenole)			60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chlorodifluoromethane	Chlordifluormethan	$ClCHF_2$	TR	20	+/-(q)	+/-(q)	+	+
	(Freon 22)			40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chlorodimethyl ether	Chlormethylmethylether	$ClCH_2OCH_3$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
	(Chlordimethylether)			40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Chloroethanol	Chlorethanol (Ethylenchlorhydrin)	$ClCH_2CH_2OH$	TR	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Chloroethyl acetate	Essigsäurechlorethylester	$CH_3COOCH_2CH_2Cl$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Chloroform	Chlorform (Trichlormethan)	$CHCl_3$	TR	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Chloroformic acid ethyl ester	Ameisensäureethylester, chloriert	$ClCOOC_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chloroformic acid methyl ester	Ameisensäuremethylester, chloriert	$HCOOCH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chlorohexanol	Chlorhexanol	$HO(CH_2)_6Cl$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Chloromethyl acetate	Essigsäurechlormethylester	CH_3COOCH_2Cl	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Chloromethyloximether	Chlormethyloximether		TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Chloronaphthalene	Chlornaphtalin (Naphthylchlorid)	$C_6H_4C_4H_3Cl$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chloropicric	Chlorpikrin (Nitrochlorform, Trichlornitromethan)	Cl_3CNO_2	TR	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Chloropropyltriethoxysilan	Chlorpropyltriethoxysilan	$C_3H_7ClSi(OC_2H_5)_3$	TR	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Chlorosulfonic acid	Chlorsulfonsäure	$ClSO_2OH$	TR	20	+/-(o)	+/-(o)	+/-(o)	+
	(Chlorschwefelsäure)			40	-	-	+/-(o)	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chlorotoluensulfonic acid	Chlortoluolsulfonsäure	$ClC_6H_3CH_3SO_3H$	TR	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chlorotrifluoromethane	Chlortrifluormethan	CClF3	TR	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chloroxylene	Chlorxylole	$CH_3C_6H_3CH_3Cl$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Choline	Cholinchlorid	$C_5H_{14}ClNO$	75%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Chrome alum	Chromalaun	$KCr(SO_4)_2$ x $12H_2O$	≤ GL	20	+	+	+	+
(Chromium(III) potassium	(Chromkaliumsulfat)			40	+/-(o)	+/-(o)	+	+
sulfate)				60	-	-	+	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Chromesalts (2- and 3-valent)	Chromsalze (2- und 3-wertig)	Cr^{2+}, Cr^{3+}	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80		+	+	+
				100	-	-	+	+
				120	-	-	-	+
Chromic acid	Chromsäure	H_2CrO_4	50%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Chromic acid	Chromsäure	H_2CrO_4	40%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Chromic acid	Chromsäure	H_2CrO_4	30%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Chromic acid	Chromsäure	H_2CrO_4	20%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Chromic acid	Chromsäure	H_2CrO_4	10%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Chromic acid	Chromsäure	H_2CrO_4	1%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Chromium(II) chloride	Chromchlorid (II)	$CrCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Chromium(III) chloride	Chromchlorid (III)	$CrCl_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Chromium(III) nitrate	Chrom(III)nitrat	$Cr(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Chromium(III) sulfate	Chrom(III)sulfat	$Cr_2(SO_4)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Chromosulfuric acid	Chromschwefelsäure	$CrO_3 + H_2SO_4 + H_2O$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Cider	Obstwein		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Cinnamon oil	Zimtöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	-
Citric acid	Citronensäure	$C_3H_4OH(COOH)_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Citric acid	Citronensäure (2-Hydroxy-1,2,3-propancarbon-säure)	$C_3H_4OH(COOH)_3$	< 10%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Citrus oil	Zitrusöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Clove oil	Nelkenöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Coal gas, benzene free	Leuchtgas, benzolfrei		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Cobalt(II) chloride	Cobalt(II)chlorid	$CoCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Cocofat acid diethanolamide	Kokosfettsäurediethanolamid		49%	20	+	+	+	+
				40	+	+/-(q)	+/-(q)	+
				60	+/-(q)	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Coconut fat alcohol	Kokosfettalkohol		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Coconut oil	Kokosnussöl		H	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Cod liver oil	Lebertran		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Coffee-extracts	Kaffee-Extrakt		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Coke gas (61% hydrogen, 26% methane, 4% carbon monoxide, nitrogen 8%)	Kokereigas (61% Wasserstoff, 26% Methan, 4% Kohlenstoffmonoxid, 8% Stickstoff)	$H_2 + CH_4 + CO + N_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Cola concentrates	Cola-Konzentrate		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Compressed air, containing oil	Pressluft, ölhaltig		H	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Cooking oil	Speiseöl		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Cooking salt	Kochsalz		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper carbonate	Kupfercarbonat	$CuCO_3$ x $Cu(OH)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper salts	Kupfersalze		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper tetrafluoroborate	Kupfertetrafluorborat	$Cu(BF_4)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(I) chloride	Kupfer(I)chlorid	CuCl	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(I) cyanide	Kupfer(I)cyanid	CuCN	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(II) chloride	Kupfer(II)chlorid	$CuCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(II) chloride	Kupfer(II)chlorid	$CuCl_2$	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(II) cyanide	Kupfer(II)cyanid	$Cu(CN)_2$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Copper(II) fluoride	Kupfer(II)fluorid	CuF_2	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(II) nitrate	Kupfer(II)nitrat	$Cu(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(II) sulfate	Kupfer(II)sulfat	$CuSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Corn oil	Maiskeimöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Cotton seed oil	Baumwollsamenöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Cresol	Kresole	$HOC_6H_4CH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cresol carbonic acid	Kresolcarbonsäure	$HOCH_3C_6H_3COOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cresolsulfonic acid	Kresolsulfonsäure	$HOCH_3C_6H_3SO_3H$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	+/-(s)	+/-(s)	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	-
Cresolsulfonic acid	Kresolsulfonsäure	$HOCH_3C_6H_3SO_3H$	80%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	+/-(s)	+/-(s)	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	-
Cresolsulfonic acid	Kresolsulfonsäure	$HOCH_3C_6H_3SO_3H$	50%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	+/-(s)	+/-(s)	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	-
Crotonic acid	Crotonsäure (2-Butensäure)	$CH_3CHCHCOOH$	VL	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Crotonic aldehyde	Crotonaldehyd	C_4H_6O	TR	20	+/-(q)	+/-(q)	+/-(q)	+
	(2-Butenal)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cumol	Cumol	$C_6H_5CH(CH_3)_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
	(2-Phenylpropan,			40	+/-(q)	+/-(q)	+/-(q)	+
	Isopropylbenzol)			60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cyanamide	Cyanamid	H_2NCN	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Cyanide-sulfuric chloride-salts	Zyanid-Schwefelchlorid-Salze		TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Cyclohexane	Cyclohexan	C_6H_{12}	TR	20	+/-(q)	+/-(q)	+	+
	(Hexahydrobenzol)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cyclohexanol	Cyclohexanol	$C_6H_{12}O$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Cyclohexanone	Cyclohexanon	$C_6H_{10}O$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	-	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cyclohexene	Cyclohexen	C_6H_{10}	TR	20	+/-(q)	+/-(q)	+	+
	(Tetrahydrobenzol)			40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Cyclohexyl acetate	Essigsäurecyclohexylester	$CH_3COOC_6H_{11}$	TR	20	+	+	+	+
	(Cyclohexylacetat)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Cyclohexylamine	Cyclohexylamin	$C_6H_{11}NH_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
	(Aminocyclohexan)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cyclopentane	Cyclopentan	C_5H_{10}	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
1,1-Dichloro-1-fluoroethane	1,1-Dichlor-1-fluorethan (Freon 141b)	FCl_2CCH_3	TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
1,1-Dichloro-1-fluoromethane	1,1-Dichlor-1-fluormethan (Freon 12)	CCl_2F_2	TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
1,1-Difluoro-1-chloroethane	1,1-Difluor-1-chlorethan (Freon 142b)	F_2ClCCH_3	TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
1,1-Difluoroethane	1,1-Difluorethan (Freon 152a)	F_2CHCH_3	TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
1,2-Diaminoethane	1,2-Diaminethan	$NH_2CH_2CH_2NH_2$	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
1,2-Dibromobenzene	Dibrombenzen	$C_6H_4Br_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+/-(s)
				80	-	-	+	-
				100	-	-	+/-(s)	-
				120	-	-	-	-
1,2-Dibromoethane	Dibromethan (Ethylenbromid)	$BrCH_2CH_2Br$	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	
3,4-Dichlorotoluene	Dichlortoluol (1-Methyl-3,4-dichlortoluol)	$CH_3C_6H_3Cl_2$	TR	20	+	+	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Decan	Dekan	$C_{10}H_{22}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Dekahydronaphtalene	Decalin (Perhydronaphthalin)	$C_{10}H_{18}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Diacetone alcohol	Diacetonalkohol (4-Hydroxy-4-Methyl-2-Pentanon, Diaceton)	$(CH_3)_2C(OH)CH_2COCH_3$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
DIALA oil	DIALA öl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Dibutyl sebazate	Sebazinsäuredibutylester (Dibutylsebazat)	$H_9C_4OCO(CH_2)_8COO-C_4H_9$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Dibutylglykolphtalate	Dibutylglykolphtalat		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Dibutylphthalate	Dibutylphthalat	$(C_4H_9)_2(COO)_2C_6H_4$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Dibutylsebacate	Dibutylsebazat	$C_8H_{16}(COOC_4H_9)_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Dibutylthiourea	Dibutylthioharnstoff	$H_9C_4NHSCNHC_4H_9$	TR	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	+	+	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	+
Dibutyltinmercaptide	Dibutylzinnmercaptid (Dibutylmercaptostaanan)	$(C_4H_9)_2SSn$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Dichloroacetic acid	Dichloressigsäure	$Cl_2CHCOOH$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dichloroacetic acid methyl ester	Dichloressigsäuremthylester	$Cl_2CHCOOCH_3$	TR	20	+	+	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	-	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dichlorobenzene	Dichlorbenzen	$C_6H_4Cl_2$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichlorodimethylsilane	Dichlordimethylsilan	$(CH_3)_2SiCl_2$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Dichlorodiphenyldichloroethane	Dichlordiphenyldichlorethan (DDD)	$ClC_6H_4CH(CHCl_2)C_6H_4$-Cl	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichlorodiphenyltrichloroethane	Dichlordiphenyltrichlorethan (DDT)	$ClC_6H_4CH(CCl_3)C_6H_4Cl$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichloroethane	Dichlorethan (Ethylendichlorid)	$C_2H_4Cl_2$	35%	20	+	+	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	-	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dichloroethylene	Dichlorethylen (1,1 Dichlorethylen, 1,2 Dichlorethylen)	ClCHCHCl	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichlorofluoromethane	Dichlorfluormethan (Freon 21)	$CHCl_2F$	TR	20	+	+	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichlorohydrin	Dichlorhydrin	$C_3H_6Cl_2O$	5%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dichloroisopropylether	Dichlorisopropylether	$C_5H_{10}ClOC_5H_{10}Cl$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichloromethane (methylene chloride)	Dichlormethan (Methylenchlorid)	CH_2Cl_2	TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichloropropane	Dichlorpropan (1,2-Dichlorpropan, Propylendichlorid)	$ClCH_2CHClCH_3$	TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichloropropanol	Dichlorpropanol (1,3 Dichlor-2-propanol)	$C_3H_6Cl_2O$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Dichloropropene (1,3)	Dichlorpropen (1,3)	$ClCH_2CHCHCl$	TR	20	+	+	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Dichlorotetrafluoroethan	Dichlortetrafluorethan	$CClF_2CClF_2$	TR	20	+	+	+/-(s)	+
	(Cyrofluoran)			40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dicyclohexylcarbodiimid	Dicyclohexylcarbodiimid	$C_{13}N_2H_{22}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Diesel oil	Dieselkraftstoff		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Diethanolamine	Diethanolamin	$(HOCH_2CH_2)_2NH$	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Diethyl carbonate	Diethylcarbonat	$C_5H_{10}O_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Diethyl ether	Diethylether	$CH_3CH_2OCH_2CH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	-	+	+	+
				60	-	+	+/-(q)	+
				80	-	+	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	+
Diethyl ketone	Diethylketon	$C_2H_5COC_2H_5$	TR	20	+	+	+	+
	(3-Pentanon)			40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Diethyl-2,2'-hydroxyamine	Diethyl-2,2'-hydroxyamin	$(HOCH_2CH_2)_2NH$	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Diethylamine	Diethylamin	$(H_5C_2)_2NH$	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Diethylaminoethyl chloride	Diethylaminethylchlorid	$(C_2H_5)_2NCH_2CH_2Cl$	TR	20	+	+	+	+
	(Chlorethyldiethylamin)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Diethylenediamine	Diethylendiamin	$(CH_2CH_2NH)_2$	50%	20	+	+	+/-(q)	+
(Piperazine)	(Hexahydropyrazin, Piperazin)			40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Diethyleneglykol	Diethylenglykol	$C_4H_{10}O_3$	5%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Diethylenetriamine	Diethylentriamin (2,2 Iminodiethylamin)	$NH_2C_2H_4NHC_2H_4NH_2$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Diethylentriaminopentaacetic acid	Diethylentriaminpentässigsäure (DTPA)	$(HOOH_2C)N((CH)_2N-(COOH)_2)_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Diethylmalonate	Malonsäurediethylester	$H_2C(COOC_2H_5)_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Diglycolic acid	Diglykolsäure	$(COOH)_2(CH_2)_2O$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Diglycolic acid	Diglykolsäure	$(COOH)_2(CH_2)_2O$	30%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Dihexyl ether	Dihexylether	$H_{13}C_6OC_6H_{13}$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Dihydroxydimethylsilane	Dihydroxydimethylsilan	$(CH_3)_2Si(OH)_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Diisoamyl ether	Diisoamylether (Diisopentylether)	$H_{11}C_5OC_5H_{11}$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Diisobuten	Diisobuten	$(CH_3)_3CCH_2(CH_3)CCH_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Diisobutyl ketone (2,6-Dimethyl-4-heptanone-Isovalerone)	Diisobytylketon	$((CH_3)_2CHCH_2)_2CO$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Diisocyanate	Diisocyanate		TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Diisopropyl ether	Diisopropylether	$(CH_3)_2CHOCH(CH_3)_2$	TR	20	+	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Diisopropyl ketone A	Diisopropylketon A	$(CH_3)_2CHCOCH(CH_3)_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dimethoxyethane	Dimethoxyethan	$C_4H_{10}O_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(o)	+/-(o)	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	+
				120	-	-	-	+
Dimethyl ether	Dimethylether	C_2H_6O	5%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(s)	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dimethyl sulfate	Dimethylsulfat (Schwefelsäuredimethylester)	$(CH_3)_2SO_4$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Dimethyl sulfoxide	Dimethylsulfoxide	$(CH_3)_2SO$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(o)	+/-(o)	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	+
				120	-	-	-	-
Dimethylacetamide	Dimethylacetamid (N,N-Dimethylacetamid, DMAc)	$CH_3CON(CH_3)_2$	TR	20	+	+	+/-(s)	+
				40	+	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Dimethylamine	Dimethylamin	$(CH_3)_2NH$	TR	20	+	+	+/-(s)	+
				40	+	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Dimethylaniline	Dimethylanilin	$C_6H_5N(CH_3)_2$	TR	20	+	+	+/-(s)	+
				40	+	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Dimethyldichlorosilane	Dimethyldichlorsilizium	$(CH_3)_2SiCl_2$	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+
				100	-	-	-	+/-(s)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Dimethyldodecylamine	Dimethyldodecylamin	$(CH_3)_2NC_{12}H_{23}$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Dimethylen chloride	Dimethylenchlorid		5%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Dimethyleneglykol	Dimethylenglykol		5%	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Dimethylformamide	Dimethylformamid	C_3H_7NO	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Dimethylheptanol	Dimethylheptanol	$CH_3CH(CH_3)(CH_2)_3CH$-$(CH_3)CHOH$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Dimethylhexadien	Dimethylhexadien	$CH_2C(CH_3)CH_2CH_2C$-$(CH_3)CH_2$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Dimethylhydrazine	Dimethylhydrazin	$NN_2N(CH_3)_2$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Dimethylphtalate	Dimethylphtalat	$C_6H_4(COOH_3)_2$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Dimethylpolysiloxan	Dimethylpolysiloxan (Polymer FD 80)	$HO((CH_3)_2SiO)_nH$	H	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Dimethylpropionyl chloride	Dimethylpropionylchlorid (Pivaloylchlorid)	$(CH_3)_3CCOCl$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Di-n-amyl ester	Di-n-amylether (Pentylether)	$H_{11}C_5OC_5H_{11}$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Dioctylphthalate	Dioctylphthalat	$COOC_8H_{17}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Dioxane	Dioxan	$O(C_2H_4)_2O$	TR	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	+	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Diphenyl ether	Diphenylether	$C_6H_5OC_6H_5$	TR	20	+	+	+	+
				40	+/-(q)	+	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Diphenylamine	Diphenylamin	$C_6H_5NHC_6H_5$	TR	20	+	+	+	+
				40	+/-(q)	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Diphenylethylene	Diphenylethylen (Stilben)	$C_6H_5CHCHC_6H_5$	6%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Diphenylglykolic acid	Diphenylglykolsäure	$(C_6H_5)_2C(OH)COOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Diphenyloxide	Diphenyloxid (Diphenylether, Phenylether)	$C_6H_5OC_6H_5$	TR	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Diphosphoric acid	Diphosphorsäure	$H_4P_2O_7$	15%	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Dipotassium hydrogen-phosphate	Dikaliumhydrogenphosphat	K_2HPO_4	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Disodium phosphate	Dinatriumphosphat	Na_2HPO_4 x $2H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Disodium tetraborate	Dinatriumtetraborat (Borax)	Na_2BO_7 x $10H_2O$	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Disulfuric acid	Dischwefelsäure	$H_2S_2O_7$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Divinylbenzene	Divinylbenzen	$CH_2CHC_6H_4CHCH_2$	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dodecanoic acid chloride	Dodecansäurechlorid	$C_{11}H_{23}COCl$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Dodecylbenzensulfonic acid	Dodecylbenzensulfonsäure	$C_{12}H_{25}C_6H_4SO_3H$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Dodecylbenzensulfonic acid	Dodecylbenzensulfonsäure	$C_{12}H_{25}C_6H_4SO_3H$	60%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
2,3-Epoxypropyltrimethyl-ammonium chloride	2,3-Epoxypropyltrimethyl-ammoniumchlorid	$C_6H_{14}ClNO$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
2-Ethylhexanolyl chloride	2-Ethylhexanolylchlorid		TR	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Elektrolyte bath (Sulfuric acid + Cresol sulfone acid)	Elektrolytbad (Schwefelsäure + Kresolsulfonsäure)	$H_2SO_4 + CH_3C_6H_3(OH)$-(SO3H)	all	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	+/-(q)
Ethan, gaseous	Ethan, gasförmig	CH_3CH_3	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	-
Ethanethiol	Ethanthiol (Ethylmercaptan)	C_2H_5SH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Ethanol	Ethanol	$C_2H_5OH + H_2O$	TR	20	+/-(q)	+/-(q)	+	+
				40	-	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ethanol	Ethanol	$C_2H_5OH + H_2O$	96%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Ethanol	Ethanol	$C_2H_5OH + H_2O$	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Ethanol	Ethanol	$C_2H_5OH + H_2O$	10%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Ethanol / acetic acid (fermentation mixture)	Ethanol / Essigsäure (Gärungsgemisch)		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Ethanolamine	Ethanolamin	$H_2NC_2H_4OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				60	-	-	-	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ethen	Ethen (Ethylen)	CH_2CH_2	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Ethyl acetate	Ethylacetat	$CH_3COOCH_2CH_3$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	-	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ethyl acrylate	Acrylsäureethylester	CH_2=$CHCCOCH_2CH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	-	+/-(q)	-
				100	-	-	-	-
				120	-	-	-	-
Ethyl alcohol, denatured	Ethylalkohol, vergällt	C_2H_5OH + 2% $C_6H_5CH_3$	96%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Ethyl benzoate	Benzoesäureethylester (Ethylbenzoat)	$C_6H_5COOC_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ethyl bromide	Ethylbromid (Bromethan)	CH_3CH_2Br	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ethyl butyrate	Buttersäureethylester (Ethylbutyrat)	$CH_3CH_2CH_2COOC_2H_5$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Ethyl chloride	Ethylchlorid	CH_3CH_2Cl	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Ethylacetoacetate	Acetessigester	$CH_3COCHCOOC_2H_5$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Ethylbenzene	Ethylbenzen	$C_6H_5C_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ethylchloroformiate	Chlorameisensäureethylester	$ClCOOC_2H_5$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ethylcyanoacetate	Cyanessigsäureethylester (Ethylcyanoacetat)	$CH_2CNCOOC_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Ethylenbenzene	Ethylenbenzen (Phenylethan)	C_8H_{10}	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Ethylenbutyrate	Ethylenbutyrat	$C_6H_{12}O_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Ethylene chloride (1,2-Dichloroethane)	Ethylenchlorid (1,2-Dichlorethan)	$ClCH_2CH_2Cl$	TR	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Ethylenediamine	Ethylendiamin (1,2-Diaminoethan, 1,2-Ethandiamin)	$H_2NCH_2CH_2NH_2$	TR	20	+	+	+/-(s)	+
				40	+	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	+
Ethylenediaminetetraacetic acid	Ethylendiamintetraessigsäure (EDTA)	$C_2H_4N_2(CH_2COOH)_4$	TR	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+/-(q)	+/-(q)	+/-(s)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ethyleneglykol	Ethylenglykol	$(CH_2OH)_2$	TR	20	+	+	+	+
	(1,2-Ethandiol, Glykol)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Ethyleneglykoldiethylether	Ethylenglykoldiethylether	$CH_3CH_2OCH_2CH_2O$-	TR	20	+	+	+	+
	(Diethylglykolether)	CH_2CH_3		40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Ethyleneglykolmonomethylether	Ethylenglykolmonomethylether	$CH_3OCH_2CH_2OH$	TR	20	+	+	+	+
	(2-Methoxyethanol, Methylglykol)			40	+	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	-	+/-(s)	+
				100	-	-	-	-
				120	-	-	-	-
Ethyleneoxide	Ethylenoxid	CH_2CH_2O	TR	20	-	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	+
Ethylether	Ethylether	$H_5C_2OC_2H_5$	TR	20	+/-(o)	+/-(o)	+	+
	(Diethylether)			40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ethylformalat	Ethylformalat	$C_3H_6O_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Ethylhexanol	Ethylhexanol	$(C_4H_9)(C_2H_5)CHCH_2OH$	TR	20	+	+	+	+
	(Isooctanol)			40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80		+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Ethylpropionate	Ethylpropionat	$C_2H_5CHOOC_2H_5$	TR	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Fatty acid amides	Fettsäurenamide	$RCONH_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Fatty acids	Fettsäuren		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Fatty alcohol alkoxylate	Fettalkoholalkoxylat		20%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Fatty alcohol ethoxylate	Fettalkoholethoxylat	$R(OC_2H_4)_nOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Fatty alcohol ethylether sulfate	Fettalkoholethersulfat	$R(OC_2H_4)_nSO_3Na$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Fatty alcohol sulphonate	Fettalkoholsulfonate		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Fatty alcohols	Fettalkohole	C_8 up to C_{18}	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Fenarimol	Fenarimol	$C_{17}H_{12}Cl_2N_2O$	12%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Fermentation mash	Gärungsmaische	$C_2H_5OH + CH_3COOH$	all	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Fertilizer salts	Düngesalze		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Fire extinguishing form	Feuerlöschschaum		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Fish oil, sulfited (Licrol 3235)	Fischöl, sulfitiert (Licrol 3235)		H	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Fluoboric acid	Fluorborsäure	HBF_4	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Fluorine, liquid	Fluor, flüssig	F_2	≤ GL	20	-	-	-	+/-(s)
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Fluorine, gaseous	Fluor, gasförmig	F_2	TR	20	-	-	-	+/-(s)
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Fluoroboric acid	Borfluorwasserstoffsäure	HBF_4	50%	20	+	+	+	+
	(Tetrafluorborsäure)			40	+	+	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Fluorosilic acid	Fluorsiliziumsäure	H_2SiF_6	50%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Fluorosulfuric acid	Fluorschwefelsäure	HSO_3F	≤ GL	20	+	+	+	+
	(Fluorosulfonsäure)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Fluorotrichloromethane	Fluortrichlormethan	CCl_3F	TR	20	+/-(s)	+/-(s)	+	+
	(Trichlorfluormethan, Frigen 11)			40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Fluosilicic acid	Kieselfluorwasserstoffsäure	H_2SiF_6	50%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Fluosilicic acid	Kieselfluorwasserstoffsäure	H_2SiF_6	32%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Fluosilicic acid	Kieselfluorwasserstoffsäure	H_2SiF_6	10%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Formaldehyde	Formaldehyd	CH_2O	40%	20	+/-(q)	+/-(q)	+/-(q)	+
	(Formalin)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Formaldehyde	Formaldehyd	CH_2O	10%	20	+/-(q)	+/-(q)	+/-(q)	+
	(Formalin)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Formamide	Formamid	CH_3NO	TR	20	+/-(s)	+/-(s)	+/-(q)	+
	(Ameisensäureamid)			40	+/-(s)	+/-(s)	+/-(q)	+
				60	+/-(s)	+/-(s)	+/-(q)	+
				80	-	+/-(s)	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Formic acid	Ameisensäure	HCOOH	< 60%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Formic acid	Ameisensäure	HCOOH	< 85%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Formic acid	Ameisensäure	HCOOH	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Formic acid ethyl ester	Ameisensäureethylester	$HCOOC_2H_5$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Formic acid methyl ester	Ameisensäuremethylester	$HCOOCH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Fructose	Fructose (Fruchtzucker)	$C_6H_{12}O_6$	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Fruit juices	Fruchtsäfte		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Fruit juices, unfermented	Obstsäfte		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Fruit pulp	Obstpulp		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Fuel	Kraftstoffe		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)
Fuel oil	Heizöl		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Fumaric acid	Fumarsäure	$C_2H_2(COOH)_2$	TR	20	+	+	+	+
	(1,4 Butendisäure)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Furan	Furan	C_4H_4O	TR	20	-	-	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Furfural	Furfural	OCH=CHCH=CCHO	TR	20	-	-	+/-(o)	+
	(Furfuran)			40	-	-	-	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Furfurylalcohol	Furfurylalkohol	$OH_3C_4CH_2OH$	TR	20	+	+	+	+
	(2-Furanylmethanol)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Gallic acid	Gallussäure	$C_6H_2(OH)_3COOH$	TR	20	+	+	+	+
	(3,4,5-Trihydroxybenzolsäure)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	-
				120	-	-	-	-
Gallium chloride	Galliumchlorid	$GaCl_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Gelatine	Gelatine		all	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Gipssupsension	Gipssupsension		S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Gluconic acid	Gluconsäure	$C_6H_{12}O_7$	TR	20	+	+	+	+
	(D-Gluconsäure)			40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)
Glucose	Dextrose	$C_6H_{12}O_6$	TR	20	+	+	+	+
	(D-Glucose)			40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Glucose	Dextrose	$C_6H_{12}O_6$	20%	20	+	+	+	+
	(D-Glucose)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Glucose	Glucose	$O(CHOH)_4CHCH_2OH$	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Glue	Leim		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Glutamic acid	Glutaminsäure	$HOOCCH_2CH_2CH(NH_2)$-COOH	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Glutaraldeyde	Glutaraldeyd	$C_5H_8O_2$	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Glutaric acid	Glutarsäure (Pentandisäure)	$HOOC(CH_2)_3COOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Glycerine	Glycerin	$C_3H_5(OH)_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Glycerinechlorohydrine	Glycerinchlorhydrin (3-Chlor-1,2-Propandiol)	$CH_2ClCHOHCH_2OH$	TR	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	-	-	+	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Glycerinemonolaurate	Glycerinmonolaurat (Monolaurinsäureglycerinester)	$CH_3(CH_2)_{10}COOC_3H_5$-$(OH)_2$	H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Glycerinetriacetate	Glycerintriacetat (Triessigsäureglycerinester)		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Glycerintriacetate	Triacetin (Glycerintriacetat)	$(CH_3COO)_3C_3H_5$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Glycerol	Glycerol	$(HOCH_2)_2CHOH$	VL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Glycerol	Glycerol	$(HOCH_2)_2CHOH$	10%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	-
Glycocol	Glykokol	NH_2CH_2COOH	10%	20	+	+	+	+
(glycin)	(Glycin)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Glycolic acid	Glykolsäure	$HOCH_2COOH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Glycolic acid	Glykolsäure	$HOCH_2COOH$	70%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Glycolic acid	Glykolsäure	$HOCH_2COOH$	37%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Glycolic acid	Glykolsäure	$HOCH_2COOH$	30%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Glyoxylic acid	Glyoxylsäure	OHCCOOH	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Glyoxylic acid	Glyoxylsäure	OHCCOOH	10%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Guanidinehydrochloride	Guanidinhydrochlorid	CH_5N_3 x HCl	all	20	+	+	+	+
	(Guanidiumchlorid)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
2-Hydroxyethyl hydrazine	2-Hydroxyethylhydrazin	$C_2H_8N_2O$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Hard coal tar oil	Steinkohlenteeröl		TR	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Heptane	Heptan (n-Heptan)	C_7H_{16}	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Heptanol	Heptanol (2,6-Dimethyl-4-heptanol)	$((CH_3)_2CHCH_2)_2CHOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Heptanone (2,6-Dimethyl-4-heptanone)	Heptanon (Isovalerone)	$((CH_3)_2CHCH_2)_2CO$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Hexachlorobutadiene	Hexachlorbuta-1,3-dien (Perchlorbutadien)	C_4Cl_6	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Hexachlorocyclohexane	Hexachlorcyclohexan (Lindan, Gammahexan)	$C_6H_6Cl_6$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Hexachloroethane	Hexachlorethan (Perchlorethan)	CCl_3CCl_3	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hexadiene (2,5-Dimethyl-1,5-hexadiene)	Hexadien	$CH_2C(CH_3)CH_2CH_2C$-$(CH_3)CH_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Hexafluoroethane	Hexafluorethan	C_2F_6	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Hexafluorosilicic acid	Hexafluorkieselsäure	H_2SiF_6	< 50%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Hexamethyldisilazane	Hexamethyldisilazane (HMDS)	$(CH_3)_3SiNHSi(CH_3)_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hexamethylenediamine	Hexamethylendiamin	$C_6H_{16}N_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Hexamethylenetetramine	Hexamethylentetramin	$(NCH_2)_3N(CH_2)_3$	TR	20	+	+	+	+
	(Urotropin)			40	+	+	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Hexamethylphosphamide	Hexamethylphosphamid	$((CH_3)_2N)_3PO$	TR	20	+	+	+	+
	(HMPT)			40	+	+	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hexamethylphosphotriamide	Hexamethylphosphotriamide	$((CH_3)_2N)_3PO$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Hexane, liquid	Hexan, flüssig	C_6H_{14}	TR	20	+	+	+	+
	(n-Hexan)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Hexanetriole	Hexantriol	$C_6H_{11}(OH)_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Hexanol	Hexanol	$CH_3(CH_2)_4CH_2OH$	TR	20	+	+	+	+
	(Hexylalkohol)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hexanon	Hexanon	$CH_3CO(CH_2)_3CH_3$	TR	20	+/-(q)	+/-(q)	+/-(s)	+
	(Methylbutylketon)			40	+/-(q)	+/-(q)	+/-(s)	+
				60	+/-(q)	+/-(q)	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Hexene	Hexen	C_6H_{12}	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Honey	Honig		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrazine	Hydrazin	N_2H_4	10%	20	+	+	+/-(s)	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Hydrazine	Hydrazin	N_2H_4	15%	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Hydrazine	Hydrazin	N_2H_4	40%	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Hydrazine	Hydrazin	N_2H_4	70%	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Hydrazine	Hydrazin	N_2H_4	TR	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Hydrazine hydrate	Hydrazinhydrat	N_2H_4 x H_2O	< 24%	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Hydrazine hydrochloride	Hydrazinhydrochlorid (Hydraziniumdihydrochlorid)	$NH_3NH_3Cl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrobromic acid (Hydrogen bromide)	Bromwasserstoffsäure	HBr	66%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Hydrochinone	Hydrochinon (1,4-Dihydroxybenzol)	HOC_6H_4OH	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydrochloric acid	Salzsäure	HCl	39%	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	+/-(s)	+
				100	-	-	-	-
				120	-	-	-	-
Hydrochloric acid	Salzsäure	HCl	36%	20	+/-(s)	-	+	+
				40	+/-(s)	-	+	+
				60	+/-(s)	-	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrochloric acid	Salzsäure	HCl	30%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrochloric acid	Salzsäure	HCl	20%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Hydrochloric acid	Salzsäure	HCl	10%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrochloric acid	Salzsäure	HCl	5%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrocyanic acid	Cyanwasserstoffsäure (Blausäure)	HCN	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrocyanic acid, gaseous	Cyanwasserstoffsäure, gasförmig (Blausäure)	HCN	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrofluoric acid	Flusssäure (Fluorwasserstoffsäure)	HF	TR	20	-	-	+/-(q)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	+/-(q)
Hydrofluoric acid	Flusssäure (Fluorwasserstoffsäure)	HF	85%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Hydrofluoric acid	Flusssäure (Fluorwasserstoffsäure)	HF	70%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Hydrofluoric acid	Flusssäure (Fluorwasserstoffsäure)	HF	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Hydrofluoric acid	Flusssäure (Fluorwasserstoffsäure)	HF	≤ 40%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(s)	+/-(q)
				100	-	-	+/-(s)	+/-(q)
				120	-	-	-	+/-(q)
Hydrofluoric acid	Flusssäure (Fluorwasserstoffsäure)	HF	10%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Hydrogen	Wasserstoff	H_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Hydrogen chloride, gaseous	Chlorwasserstoff, gasförmig	HCl	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Hydrogen peroxide	Wasserstoffperoxid	H_2O_2	10%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydrogen peroxide	Wasserstoffperoxid	H_2O_2	30%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydrogen peroxide	Wasserstoffperoxid	H_2O_2	50%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydrogen peroxide	Wasserstoffperoxid	H_2O_2	70%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydrogen peroxide	Wasserstoffperoxid	H_2O_2	90%	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydrogen sulfide	Schwefelwasserstoff	H_2S	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrogen sulfide	Schwefelwasserstoff	H_2S	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydroiodic acid	Iodwasserstoffsäure	HI	≤ GL	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Hydroiodic acid	Iodwasserstoffsäure	HI	57%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Hydroxyacetic acid	Hydroxyessigsäure	HOCCOOH	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Hydroxyethylethylene diamin triacetatacid	Hydroxyethylethylendiamin-triessigsäure, z.B. Trilon D		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Hydroxylamine sulfate	Hydroxylaminsulfat	$(H_2NOH)_2H_2SO_4$	all	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	+	+	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydroxylamine sulfate	Hydroxylammoniumsulfat	$(H_2NOH)_2H_2SO_4$	< 12%	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	+	+	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hypochlorous acid	Hypochlorige Säure (Unterchlorige Säure)	HOCl	33%	20	-	-	+	+
				40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	-	+
				100	-	-	-	+/-(o)
				120	-	-	-	+/-(o)
Ink	Tinte		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Iodine	Iod	I_2	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+
				120	-	-	-	-
Iodine solution (Iodine in ethanol)	Jodtinktur (Iod in Ethanol)	I_2 in C_2H_6O	6.5%	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Iodine, anhydrous, gaseous	Iod, trocken, gasförmig	I_2	all	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+
				120	-	-	-	-
Iodoform	Iodoform (Triiodmethan)	CHI_3	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Iprodione	Iprodion (Glycophen, Promodion)	$C_{13}H_{13}Cl_2N_3O_3$	13 mg/l	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Iron salts	Eisensalze		all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Iron(II) chloride	Eisen(II)chlorid	$FeCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(II) nitrate	Eisen(II)nitrat	$Fe(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(II) sulfate	Eisen(II)sulfat	$FeSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(II) sulfide	Eisen(II)sulfid	FeS	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(III) aluminium chloride mixture	Eisen(III)-Aluminiumchlorid-mischung (Flockungsmittel) wie z.B. Südflock K2		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(III) chloride	Eisen(III)chlorid	$FeCl_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(III) chloride sulfate	Eisen(III)chloridsulfat	$FeClSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(III) hydroxide	Eisen(III)hydroxid	$(CH_3)_2CHCH_2CHOHCH_3$	TR	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Iron(III) nitrate	Eisen(III)nitrat	$Fe(NO_3)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(III) sulfate	Eisen(III)sulfat	$Fe_2(SO_4)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Isobutan	Isobutan	C_4H_{10}	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Isobutylamine	Isobutylamin	$CH_3CH(CH_3)CH_2NH_2$	TR	20	+	+	+	+
	(1-Amino-2-methylpropan)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Isononanic acid chloride	Isononansäurechlorid	$C_9H_{17}ClO$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Isooctane	Isooctan	C_8H_{18}	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Isopentanol	Isopentanol	$(CH_3)_2CHCH_2CH_2OH$	TR	20	+	+	+	+
	(Isoamylalkohol)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Isophorone	Isophoron	$C_9H_{14}O$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Isopropanol	Isopropanol	$(CH_3)_2CHOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Isopropyl acetate	Essigsäureisopropylester	$CH_3COOCH(CH_3)_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Isopropyl ether	Isopropylether	$C_6H_{14}O$	TR	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Isopropylamine	Isopropylamin	C_3H_9N	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+
				100	-	-	-	-
				120	-	-	-	-
Isothiazolone	Isothiazolone		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Isovalerone	Isovaleron	$((CH_3)_2CHCH_2)_2CO$	TR	20	+/-(q)	+/-(q)	+	+
(2,6-Dimethyl-4-heptanone)	(Diisobutylketone)			40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Jet petrol	Kerosin		H	20	+/-(q)	+/-(q)	+	+
	(Flugzeugkraftstoff)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Lactic acid	Milchsäure	$CH_3CHOHCOOH$	TR	20	+/-(q)	+/-(q)	+	+
(2-Hydroxypropanoic acid)	(2-Hydroxypropansäure)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Lactic acid	Milchsäure	$CH_3CHOHCOOH$	90%	20	+/-(q)	+/-(q)	+	+
(2-Hydroxypropanoic acid)	(2-Hydroxypropansäure)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Lactic acid	Milchsäure	$CH_3CHOHCOOH$	75%	20	+/-(q)	+/-(q)	+	+
(2-Hydroxypropanoic acid)	(2-Hydroxypropansäure)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Lactic acid	Milchsäure	$CH_3CHOHCOOH$	50%	20	+/-(q)	+/-(q)	+	+
(2-Hydroxypropanoic acid)	(2-Hydroxypropansäure)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Lactic acid	Milchsäure	$CH_3CHOHCOOH$	10%	20	+/-(q)	+/-(q)	+	+
(2-Hydroxypropanoic acid)	(2-Hydroxypropansäure)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Lactose	Lactose	$C_{12}H_{22}O_{11}$	TR	20	+	+	+	+
	(Milchzucker)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Lanoline	Lanolin		H	20	+	+	+	+
	(Wollfett, Wollwachs)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	-	+
				120	-	-	-	-
Lauric acid	Laurinsäure	$C_{12}H_{24}O_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Lauric acid chloride	Laurylsäurechlorid	$CH_3(CH_2)_{10}COCl$	TR	20	+	+	+	+
	(Lauroylchlorid)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Lauryl alcohol	Laurylalkohol	$C_{12}H_{25}OH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Lauryl chloride	Laurylchlorid (Dodecylchlorid)	$C_{11}H_{23}COCl$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Lauryl mercaptane	Laurylmercaptan	$C_{12}H_{25}SH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Lauryl sulfate	Laurylsulfat (Schwefelsäurediarylester)	$(C_{12}H_{25}O)_2SO_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Laurylmercaptan	Dodecanethiol	$C_{12}H_{25}SH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Lead acetate	Bleiactetat	$Pb(CH_3COO)_2$	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Lead chloride	Bleichlorid	$PbCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Lead nitrate	Bleinitrat	$Pb(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Lead sulfate	Bleisulfat (Bleivitriol)	$PbSO_4$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Lead tetrafluoroborate	Bleitetrafluorborat (Bleifluorborat)	$Pb(BF_4)_2$	< 50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Light oil	Leichtöl		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Linoleic acid	Linolsäure (Octadecadiensäure)	$C_{17}H_{31}COOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Linseed oil	Leinöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Liqueurs	Liköre		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Liquid fertiliser	Flüssigdünger		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Liquid manure	Jauche		TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	-	+
				120	-	-	-	+
Lithium bromide	Lithiumbromid	LiBr	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Lithium chloride	Lithiumchlorid	LiCl	40%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Lithium chromate	Lithiumchromat	LiCr	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	+/-(o)
				120	-	-	-	-
Lithium hydroxide	Lithiumhydroxid	LiOH	≤ GL	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Lithium sulfate	Lithiumsulfat	Li_2SO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Lubricating oils	Schmieröle		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
1-Methyl-2-pyrrolidone	1-Methyl-2-pyrrolidon	C_5H_9NO	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	-	-	-	+/-(q)
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
2-Mercaptobenzothiazole	2-Mercaptobenzothiazol	$C_7H_5NS_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
2-Mercaptoethanol	Mercaptoethanol (Thioglykol)	$HSCH_2CH_2OH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
2-Methylbutane	2-Methylbutan	C_5H_{12}	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Machine oil	Maschinenöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Magnesium carbonate	Magnesiumcarbonat	$MgCO_3$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium chloride	Magnesiumchlorid	$MgCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium chloride hexahydrate	Magnesiumchloridhexahydrat	$MgCl_2$ x $6H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium citrate	Magnesiumcitrat	$C_3H_4OHCOOH(COO)_2Mg$ x $5H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium hydrogen carbonate	Magnesiumhydrogencarbonat	$Mg(HCO_3)_2$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium hydroxide	Magnesiumhydroxid	$Mg(OH)_2$	≤ GL	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Magnesium hydroxide carbonate	Magnesiumhydroxidcarbonat	$MgCO_3$ x $Mg(OH)_2$ x H_2O	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Magnesium nitrate	Magnesiumnitrat	$Mg(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium nitrate	Magnesiumnitrat	$Mg(NO_3)_2$	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium salts	Magnesiumsalze		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium sulfate	Magnesiumsulfat	$MgSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Maleic acid	Maleinsäure	$(CHCOO)_2$	TR	20	+/-(q)	+/-(q)	+	+
(cis-butenedioic acid)	(cis-Butendisäure)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Maleic anhydride	Maleinsäureanhydrid	$C_2H_2(CO)_2O$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Malonic acid	Malonsäure	$HOOCCH_2COOH$	TR	20	+/-(q)	+/-(q)	+	+
	(Propandisäure)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Manganese sulfate	Mangansulfat	$MnSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Marmalade	Marmelade		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mayonnaise	Mayonnaise		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Menthol	Menthol	$(CH_3)_2CHC_6H_3CH_3OH$	TR	20	+	+	+	+
	(3-p-Methanol)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Mercury salts	Quecksilbersalze		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mercury(I) nitrate	Quecksilber(I)nitrat	$HgNO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mercury(II) chloride	Quecksilber(II)chlorid	$HgCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mercury(II) cyanide	Quecksilber(II)cyanid	$Hg(CN)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mercury(II) nitrate	Quecksilber(II)nitrat	$Hg(NO_3)_2$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mercury(II) sulfate	Quecksilber(II)sulfat	$HgSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mercury, liquid	Quecksilber, flüssig	Hg		20	-	-	-	-
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Mesitylen (Trimethylbenzol)	Mesitylen (Trimethylbenzol)		TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Metal pickle	Metallbeize		VL	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Metal soap	Metallseife			20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Methacrylic acid	Methacrylsäure (2-Methylpropensäure, Isobutensäure)	$C_4H_6O_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Methane	Methan	CH_4	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methanesulfonic acid	Methansulfonsäure (Methylschwefelsäure)	CH_3SO_3H	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Methanesulfonic acid	Methansulfonsäure (Methylschwefelsäure)	CH_3SO_3H	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methanesulfonyl chloride	Methansulfonylchlorid (Mesylchlorid)	CH_3SO_2Cl	TR	20	+/-(s)	+/-(s)	-	+
				40	-	-	-	+
				60	-	-	-	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methanol	Methanol (Methylalkohol)	CH_3OH	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methanol	Methanol (Methylalkohol)	CH_3OH	50%	20	+	+	+/-(q)	+
				40	+/-(q)	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methanol	Methanol (Methylalkohol)	CH_3OH	20%	20	+	+	+	+
				40	+/-(q)	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methanthiol	Methanthiol (Methylmercaptan, Methylsulfhydrat)	CH_4S	5%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Methoxybutanol	Methoxybutanol	$CH_3CH(OCH_3)(CH_2CH_2$-OH)	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methoxybutyl acetate	Essigsäuremethoxybutylester (Butoxyl)	$CH_3COOCH_2CH_2CH$-$(OCH_3)(CH_3)$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Methoxyethyloleate	Ölsäuremethoxyethylester (Methoxyethyloleat)		TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Methoxypropanol	Methoxypropanol	$CH_3CH(OCH_3)(CH_2OH)$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methoxypropylamine	Methoxypropylamin	$CH_3O(CH_2)_3NH_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methyl acetate	Methylacetat	CH_3COOCH_3	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methyl acrylate	Acrylsäuremethylester	$CH_2CHCOOCH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Methyl acrylate (Propenoic acid methyl ester)	Methylacrylat	$CH_2{=}CHCOOCH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methyl amine	Methylamin (Aminethan)	CH_3NH_2	TR	20	+/-(q)	+/-(q)	-	+
				40	+/-(q)	+/-(q)	-	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl amine	Methylamin (Aminethan)	CH_3NH_2	32%	20	+/-(q)	+/-(q)	-	+
				40	+/-(q)	+/-(q)	-	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl benzoate	Benzoesäuremethylester (Methylbenzoat)	$C_6H_5COOC_2H_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl bromide	Methylbromid	CH_3Br	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Methyl butyrate	Methylbutyrat (Buttersäuremethylester, Methylbutanoat)	$CH_3CH_2CH_2COOCH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Methyl chloride	Methylchlorid	CH_3Cl	TR	20	-	-	+	+
				40	-	-	+/-(s)	+/-(s)
				60	-	-	-	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Methyl ethyl ether	Methylethylether	$H_3COC_2H_5$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl ethyl ketone	Methylethylketon	$CH_3COC_2H_5$	TR	20	+/-(q)	+	-	+
				40	+/-(q)	+	-	+
				60	-	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methyl formiate	Methylformiat (Ameisensäuremethylester, Methansäuremethylester, Methylmethanat)	$C_2H_4O_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl isobutyl ketone	Methylisobutylketon (4-Methyl-2-pentanon)	$CH_3COCH_2CH(CH_3)_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl isobutyl ketone	Methylisobutylketon (4-Methyl-2-pentanon)	$CH_3COCH_2CH(CH_3)_2$	1%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl sulfate	Methylsulfat	CH_3OSO_3H	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methyl sulfate	Methylsulfat	CH_3OSO_3H	50%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methyl tert-butyl ether	Methyl-tertiär-butylether	$C_5H_{12}O$	TR	20	+/-(s)	+/-(s)	+/-(s)	+/-(s)
				40	-	-	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methylchloroformiate	Chlorameisensäuremethylester	$ClCOOCH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methylchlorophenoxyacetic acid	Methylchlorphenoxyessigsäure	$Cl(CH_3)C_6H_3OCH_2COOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Methylchlorophenoxypropanoic acid	Methylchlorphenoxypropionsäure	$Cl(CH_3)C_6H_3OCH(CH_3)$-COOH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Methylcyclohexane	Methylcyclohexan	$H_3CC_6H_{11}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Methylene bromide	Dibrommethan (Methylenbromid)	CH_2Br_2	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Methylene chloride	Methylenchlorid (Dichlormethan)	CH_2Cl_2	TR	20	-	-	+/-(s)	+/-(s)
				40	-	-	+/-(s)	+/-(s)
				60	-	-	-	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyleneiodide	Diiodmethan (Methylenjodid)	CH_2I_2	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methylmethacryalate (2-Methylpropenoic acid methyl ester)	Methylmethacryalat	$CH_2{=}C(CH_3)COOCH_3$	50%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methylmethacrylate	Methacrylsäuremethylester (MMA)	$CH_2C(CH_3)(COOCH_3)$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Methylpropionate	Methylpropionat	$CH_3CH_2COOH_3$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methylstyrol	Methylstyrol (4-Vinyltoluol)	$CH_3C_6H_4CHCH_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	-	-	-	+/-(q)
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyltrichlorosilan	Methyltrichlorsilan	CH_3SiCl_3	TR	20	+/-(s)	+/-(s)	+/-(s)	+/-(s)
				40	-	-	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Milk	Milch		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mineral oil, no aromatic	Mineralöl, aromatenfrei	$CH_3CHOHCOOH$	H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+	+/-(q)
				120	-	-	-	+/-(q)

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Mineral water	Mineralwasser			20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Molasses	Melasse		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Molasses flavor	Melassewürze		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Monobromicacetic acid	Monobromessigsäure	$C_2H_3BrCO_2$	80%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Monochloroacetic acid	Chloressigsäure (MONO)	$ClCH_2COOH$	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Monochloroacetic acid	Chloressigsäure (MONO)	$ClCH_2COOH$	85%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Monochloroacetic acid	Chloressigsäure (MONO)	$ClCH_2COOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Monochloroacetic acid ethyl ester	Monochloressigsäureethylester	$ClCH_2COOC_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Monochloroacetic acid methyl ester	Monochloressigsäuremethyl-ester	$ClCH_2COOCH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Monoethanolamine	Monoethanolamin (2-Aminoethanol, Ethanolamin, Aminoethylalkohol)	C_2H_7NO	30%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	-	+/-(q)	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Mononitrochlorobenzene	Mononitrochlorbenzol		TR	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Monophosphane	Monophosphan (Phosphan, Phosphorwasserstoff)	PH_3	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Monophosphane	Monophosphan (Phosphan, Phosphorwasserstoff)	PH_3	4%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Monopropylene glykol	Monopropylenglykol (1,2-Propandiol, Propylenglykol)	$C_3H_8O_2$	6%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Morpholine	Morpholin	$HNCH_2CH_2OCH_2CH_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Motor oil	Motorenöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Mustard	Senf		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Nail polish remover	Nagellackentferner		H	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Naphtha	Naphta		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Naphthalene	Naphthalin	$C_{10}H_8$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Naphthalenesulfonic acid	Naphtalinsulfonsäure	$C_{10}H_7SO_3H$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Naphtylbenzothiazylolethene	Naphtylbenzothiazylolethen		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Natrium aluminium sulfate	Natriumaluminiumsulfat	$NaAl(SO_4)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Natural gas, gaseous	Erdgas, gasförmig		TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Natural gas, liquid	Erdgas, flüssig		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
n-Butylmercaptan	Butylmercaptan	C_4H_9SH	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
n-Heptan	n-Heptan	$(C_7H_{16})_n$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
n-Hexan	n-Hexan	$(C_6H_{14})_n$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
NDM (n-Dodecylmercaptan)	NDM (n-Dodecylmercaptan)		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+
				120	-	-	-	-
Nickel acetate	Nickelacetat	$Ni(CH_3COO)_2$	≤ GL	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Nickel nitrate	Nickelnitrat (Nickeldinitrat)	$Ni(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Nickel salts	Nickelsalze		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Nickel sulfamate	Nickelsulfamat		55%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Nickel sulfate	Nickelsulfat	$NiSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Nickel(II) chloride	Nickel(II)chlorid	$NiCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Nicotine	Nikotin	$C_5H_4NC_4H_7NCH_3$	VL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Nicotinic acid	Nicotinsäure	$(NC_5H_4)COOH$	VL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	98%	20	-	-	-	+/-(q)
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	90%	20	-	-	-	+/-(q)
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	65%	20	-	-	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	53%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	40%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	30%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	20%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Nitric acid	Salpetersäure	HNO_3	10%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	6.3%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid glycerinester	Salpetersäureglycerinester		TR	20	-	-	+/-(o)	+
	(Nitroglycerin)			40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Nitric oxide	Stickoxide		TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Nitrilotriacetatacid	Nitrilotriessigsäure	$N(CH_2COOH)_3$	H	20	+/-(q)	+/-(q)	+/-(q)	+
	(Trilon AS)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Nitrobenzene	Nitrobenzen	$C_6H_5NO_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Nitrobenzoic acid	Nitrobenzoesäure	$C_6H_4NO_2COOH$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Nitrocellulose	Nitrocellulose		TR	20	+	+	+	+
	(Cellulosenitrat)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Nitroethane	Nitroethan	$CH_3CH_2NO_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Nitrogen	Stickstoff	N_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Nitrogen fluoride	Stickstofffluorid	NF_3	TR	20	+	+	+	+
	(Trifluoramin)			40	+	+	+	+
				60	+	+	+/-(q)	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Nitroglykol	Nitroglykol	$O_2NOCH_2CH_2ONO_2$	VL	20	+/-(q)	+/-(q)	+/-(q)	+
	(Ethylenglykoldinitrat)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Nitromethane	Nitromethan	CH_3NO_2	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Nitropropane	Nitropropan	$CH_3CH_2CH_2NO_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Nitrotoluene (o-,m-,p-)	Nitrotoluole (o-,m-,p-)	$C_7H_7NO_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Nitrous acid	Salpetrige Säure	HNO_2	VL	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Nitrous gases	Nitrose Gase	NO_x	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Nonylalcohol	Nonylalkohol	$CH_3(CH_2)_7CH_2OH$	TR	20	+/-(q)	+/-(q)	+	+
	(1-Nonanol)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Nonylphenylpolyglykolether	Nonylphenylpolyglykolether	$C_9H_{19}C_6H_4(OC_2H_4)_nOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Nonylphenylpolyglykolether	Nonylphenylpolyglykolether	$C_9H_{19}C_6H_4(OC_2H_4)_nOH$	20%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Nonylphenylpolyglykolether	Nonylphenylpolyglykolether	$C_9H_{19}C_6H_4(OC_2H_4)_nOH$	5%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Nonylphenylpolyglykolether	Nonylphenylpolyglykolether	$C_9H_{19}C_6H_4(OC_2H_4)_nOH$	2%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Nut oil	Nussöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
oCresol	oCresol	$C_6H_4CH_3OH$	TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Octane	Octan	$CH_3(CH_2)_6CH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Octanol	Octanol (Octylalkohol)	$C_8H_{17}OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Octene	Octen	$CH_3(CH_2)_4CHCHCH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Octylcresol	Octylcresol	$CH_3(CH_2)_7C_6H_3OHCH_3$	TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Oils (animal)	Öle, tierische		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Oils (etherel)	Öle, etherische		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Oleic acid	Ölsäure	$C_{17}H_{33}COOH$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Oleum	Oleum	$H_2SO_4 + SO_3$		20	-	-	-	+
(sulfuric acid	(Schwefelsäure			40	-	-	-	-
+ sulfur trioxide 10%)	+ Schwefeltrioxid 10%)			60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Oleum	Oleum	$H_2SO_4 + SO_3$		20	-	-	-	+
(sulfuric acid	(Schwefelsäure			40	-	-	-	-
+ sulfur trioxide 30%)	+ Schwefeltrioxid 30%)			60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Oleum vapours	Oleumdämpfe		traces	20	-	-	-	+
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Olive oil	Olivenöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Optical brightener	Optische Aufheller		H	20	+	+	+	+
				40	+	+	+	+
				60	-	+	+	+
				80	-	-	+	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Orange peel oil	Apfelsinenschalenöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Oxalic acid	Oxalsäure	HOOCCOOH	TR	20	+/-(q)	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Oxalic acid	Oxalsäure	HOOCCOOH	VL	20	+/-(q)	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Oxalic acid	Oxalsäure	HOOCCOOH	50%	20	+/-(q)	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Oxygen	Sauerstoff	O_2	all	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Ozone	Ozon	O_3	≤ GL	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, aqueous	Ozon, wässrig	O_3	1 ppm	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, aqueous	Ozon, wässrig	O_3	2.5 ppm	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ozone, aqueous	Ozon, wässrig	O_3	30 ppm	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, aqueous	Ozon, wässrig	O_3	100 ppm	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, aqueous	Ozon, wässrig	O_3	700 ppm	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, gaseous	Ozon, gasförmig	O_3	0.5 ppm	20	+/-(s)	+/-(s)	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, gaseous	Ozon, gasförmig	O_3	0.15%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, gaseous	Ozon, gasförmig	O_3	1%	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, gaseous	Ozon, gasförmig	O_3	up to 2%	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, gaseous	Ozon, gasförmig	O_3	6%	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Palm oil, palm nut oil	Palmöl, Palmkernöl		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Palmitic acid	Palmitinsäure	$C_{15}H_{31}COOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
p-Aminoazobenzene	Aminoazobenzen	$NH_2C_6H_4NNC_6H_5$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Paraffin emulsion	Paraffinemulsion		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Paraffin oil	Paraffinöl		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Paraffine	Paraffine		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Paraldehyde	Paraldehyd (Paracetylaldehyd)	$(OCHCH_3)_3$	TR	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Patassium aluminium fluoride	Kaliumaluminiumfluorid	$KAlF_4$	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
p-dibromobenzene	p-dibrombenzen	$C_6H_4Br_2$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Peanut butter	Erdnussbutter		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Peanut oil	Erdnussöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Pectin	Pektin (Polygalactaronsäuremethylerster)		TR	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Pentachlorofluoroethane, aqueous	Pentachlorfluorethan, wässrig	CCl_3CCl_2F	12%	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Pentan, liquid	Pentan (n-Pentan, Amylhydrid), flüssig	C_5H_{12}	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Pentanol	Pentanol	$C_5H_{11}OH$	TR	20	+/-(q)	+/-(q)	+	+
	(Amylalkohol)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Pentyl laurate	Laurylsäureamylester	$CH_3(CH_2)_{10}COOC_5H_{11}$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Peppermint oil	Pfefferminzöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Peracetic acid	Peroxyessigsäure	$C_2H_4O_3$	40%	20	+/-(q)	+/-(q)	+/-(q)	+
	(Ethanperoxysäure,			40	+/-(q)	+/-(q)	+/-(q)	+
	Peressigsäure)			60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Peracetic acid	Peroxyessigsäure	$C_2H_4O_3$	15%	20	+/-(q)	+/-(q)	+/-(q)	+
	(Ethanperoxysäure,			40	+/-(q)	+/-(q)	+/-(q)	+
	Peressigsäure)			60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Peracetic acid	Peroxyessigsäure	$C_2H_4O_3$	1%	20	+/-(q)	+/-(q)	+/-(q)	+
	(Ethanperoxysäure,			40	+/-(q)	+/-(q)	+/-(q)	+
	Peressigsäure)			60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Perchloric acid	Perchlorsäure	$HClO_4$	70%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Perchloric acid	Perchlorsäure	$HClO_4$	50%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Perchloric acid	Perchlorsäure	$HClO_4$	20%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Perchloric acid	Perchlorsäure	$HClO_4$	10%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Perchloroethylene	Perchlorethylen	$Cl_2C=CCl_2$	TR	20	-	-	+	+
	(Tetrachlorethylen)			40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Petrol of airplane	Flugzeugbenzin		H	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Petroleum	Erdöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Petroleum	Petroleum		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Petroleumether	Petrolether	C_5H_{12} or C_6H_{14}	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Phenol	Phenol	C_6H_5OH	≤ 5%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phenol	Phenol	C_6H_5OH	≤ 10%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Phenol	Phenol	C_6H_5OH	≤ 90%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phenol	Phenol	C_6H_5OH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phenol resin	Phenolharz-Formmassen		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phenolsulfon acid	Phenolsulfonsäure (Paraphenolsulfonsäure, p-Phenolsulfonsäure)	$C_6H_6O_4S$	≤ 2%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Phenolsulfon acid	Phenolsulfonsäure (Paraphenolsulfonsäure, p-Phenolsulfonsäure)	$C_6H_6O_4S$	65%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Phenolsulfon acid	Phenolsulfonsäure	$C_6H_6O_4S$	70%	20	+/-(q)	+/-(q)	+	+
	(Paraphenolsulfonsäure,			40	+/-(q)	+/-(q)	+	+
	p-Phenolsulfonsäure)			60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Phenyl bromide	Phenylbromid	C_6H_5Br	TR	20	-	-	+/-(s)	+
	(Brombenzol)			40	-	-	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Phenyl hydrazine	Phenylhydrazin	$C_6H_5NHNH_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Phenylhydrazine hydrochloride	Phenylhydrazinchlorhydrat	$C_6H_5NHNH_3Cl$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Phenylphenol	Phenylphenol	$C_6H_5C_6H_4OH$	TR	20	+/-(q)	+/-(q)	+	+
	(2-Hydroxybiphenyl)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Phenylsulfone	Phenylsulfon		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Phosgene, gaseous	Phosgen, gasförmig	$COCl_2$	TR	20	-	-	+/-(o)	+
				40	-	-	+/-(o)	+/-(o)
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Phosgene, liquid	Phosgen, flüssig	$COCl_2$	TR	20	-	-	+/-(o)	+
				40	-	-	+/-(o)	+/-(o)
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Phosphane, gaseous	Phosphorwasserstoff, gasförmig	PH_3	TR	20	+	+	+	+
	(Phosphan)			40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	-
Phosphoric acid	Phosphorsäure	H_3PO_4	30%	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Phosphoric acid	Phosphorsäure	H_3PO_4	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Phosphoric acid	Phosphorsäure	H_3PO_4	85%	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Phosphoric acid	Phosphorsäure	H_3PO_4	95%	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Phosphoric acid	Phosphorsäure	H_3PO_4	98%	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Phosphoric acid diethyl ester	Phosphorsäurediethylester		40%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Phosphoric acid tri-2-chloroethyl ester	Phosphorsäuretri-2-chlorethyl-erster	$(Cl_3CCH_2O)_3PO$	TR	20	+	+	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Phosphoric acid tri-2-kresyl ester	Phosphorsäuretri-2-kresylester	$OP(OC_6H_4CH_3)_3$	TR	20	+	+	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Phosphoric acid tributyl ester	Phosphorsäuretributylester (Tributylphosphat)	$(C_4H_9)_3PO_4$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Phosphoric acid triethyl ester	Phosphorsäuretriethylester (Triethylphosphat)	$(C_2H_5O)_3PO$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Phosphoric acid trioctyl ester	Phosphorsäuretrioctylester (Trioctylphosphat)	$(C_8H_{14})_3PO_4$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Phosphorus	Phosphor	$(P_4)_n$	TR	20	-	-	-	-
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Phosphorus chloride	Phosphortrichlorid	PCl_3	TR	20	+	+/-(o)	+/-(o)	+
				40	+/-(o)	-	+/-(o)	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Phosphorus oxychloride	Phosphoroxychlorid	$POCl_3$	TR	20	+/-(o)	+/-(o)	+/-(o)	+/-(o)
				40	-	-	-	+/-(o)
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Phosphorus pentachloride	Phosphorpentachlorid	PCl_5	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Phosphorus pentoxide	Phosphorpentoxyd	P_2O_5	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	-
Phtalic acid butyl benzyl ester	Phthalsäurebutylbenzylester		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid	Phthalsäure	$HOOCC_6H_4COOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid diamyl ester	Phthalsäurediamylester	$H_{11}C_5COOC_6H_4COOC_5H_{11}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid dibutyl ester	Phthalsäuredibutylester	$C_{16}H_{22}O_4$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid diethyl ester	Phthalsäurediethylester	$H_{17}C_8COOC_6H_4COOC_8H_{17}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid dihexyl ester	Phthalsäuredihexylester (Dihexylphtalat)	$H_{13}C_6COOC_6H_4COOC_6H_{13}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid diisooctyl ester	Phthalsäurediisooctylester (Diisooctylphtalat)	$H_{17}C_8COOC_6H_4COOC_8H_{17}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid dimethyl ester	Phthalsäuredimethylester	$C_6H_4(COOCH_3)_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Phthalic acid dinonyl ester	Phthalsäuredinonylester	$H_{19}C_9COOC_6H_4COOC_9H_{19}$	TR	20	+/-(q)	+/-(q)	+	+
	(Dinonylphtalat)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid dioctyl ester	Phthalsäuredioctylester	$C_{24}H_{38}O_4$	TR	20	+/-(q)	+/-(q)	+	+
	(DOP)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic anhydride	Phthalsäureanhydrid	$C_6H_4(CO)_2O$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Picric acid	Pikrinsäure	$C_6H_2(OH)(NO_2)_3$	1%	20	+/-(q)	+/-(q)	+	+
	(2,4,6-Trinitrophenol)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Picric acid	Pikrinsäure	$C_6H_2(OH)(NO_2)_3$	50%	20	+/-(q)	+/-(q)	+	+
	(2,4,6-Trinitrophenol)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Picric acid	Pikrinsäure	$C_6H_2(OH)(NO_2)_3$	TR	20	+/-(q)	+/-(q)	+	+
	(2,4,6-Trinitrophenol)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Pine needle oil	Fichtennadelöl		H	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Pine oil	Kiefernadelöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Piperazine	Piperazine	$NHCH_2CH_2NHCH_2CH_2$	50%	20	+/-(q)	+/-(q)	+	+
	(Diethylendiamin)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Pivalic acid chloride	Pivalinsäurechlorid		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Polyacryl amide	Polyacrylamid		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Polyacryl chloride	Polyacrylchlorid	$(C_3H_5ClO)_n$	H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Polyaluminium chloride	Polyaluminiumchlorid	$Al_n(OH)_mCl_{3n-m}$	40%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Polyester resin	Polyesterharz		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Polyglykol	Polyglykol (Polyethylenglykol)		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Polyole	Polyole		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Polyvinyl acetate, solid	Polyvinylacetat, fest	$H(CH_2CHOOCCH_3)_nH$	H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	-
				120	-	-	-	-
Polyvinyl alcohol, solid	Polyvinylalkohol, fest	$H(CH_2CHO)_nH$	H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	-
				120	-	-	-	-
Potassium	Kalium	K		20	-	-	-	-
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Potassium acetate	Kaliumacetat	CH_3COOK	≤ GL	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Potassium aluminium sulfate (alum)	Kalium-Aluminiumsulfat (Alaun)	$Al_2(SO_4)_3 \times K_2SO_4 \times 24H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium aluminium sulfate (alum)	Kalium-Aluminiumsulfat (Alaun)	$Al_2(SO_4)_3 \times K_2SO_4 \times 24H_2O$	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Potassium bichromate	Kaliumbichromat	$K_2Cr_2O_7$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium borate	Kaliumborat	K_3BO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium bromate	Kaliumbromat	$KBrO_3$	≤ GL	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	+/-(o)	+/-(o)	+	+
				80	-	+/-(o)	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium bromate	Kaliumbromat	$KBrO_3$	10%	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	+/-(o)	+/-(o)	+	+
				80	-	+/-(o)	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium bromide	Kaliumbromid	KBr	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium bromide	Kaliumbromid	KBr	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium carbonate	Kaliumcarbonat	K_2CO_3	50%	40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
				20	+	+	+	+
Potassium carbonate (Potash)	Kaliumcarbonat (Pottasche)	K_2CO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium carbonate (Potash)	Kaliumcarbonat (Pottasche)	K_2CO_3	30%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium chlorate	Kaliumchlorat	$KClO_3$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	+	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium chlorate	Kaliumchlorat	$KClO_3$	VL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	+	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Potassium chloride	Kaliumchlorid	KCl	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium chloride	Kaliumchlorid	KCl	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium chlorite	Kaliumchlorit	$KClO_2$	5%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium chlorite	Kaliumchlorit	$KClO_2$	50%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium chromate	Kaliumchromat	K_2CrO_4	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium cyanide	Kaliumcyanid	KCN	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium dichromate	Kaliumdichromat	$K_2Cr_2O_7$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium dichromate	Kaliumdichromat	$K_2Cr_2O_7$	VL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	+	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium ferricyanide	Ferricyankalium (Kaliumhexacyaonaferrat)	$K_3[Fe(CN)_6]$	VL	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Potassium ferrocyanide	Kaliumeisencyanid	$K_4[Fe(CN)_6]$ x $3H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium ferrocyanide (II)	Kaliumhexacyanoferrat(II) (gelbes Blutlaugensalz)	$K_4[Fe(CN)_6]$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Potassium ferrocyanide (III)	Kaliumhexacyanoferrat(III)	$K_3[Fe(CN)_6]$	≤ GL	20	+	+	+	+
	(rotes Blutlaugensalz)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium fluoride	Kaliumfluorid	KF	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium formate	Kaliumformiat	KCOOH	55%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Potassium hydrogen carbonate	Kaliumhydrogencarbonat	$KHCO_3$	≤ GL	20	+	+	+	+
	(Kaliumbicarbonat)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium hydrogen phosphate	Kaliumdihydrogenphosphat	KH_2PO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium hydrogen sulfate	Kaliumhydrogensulfat	$KHSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium hydrogen sulfite	Kaliumhydrogensulfit	$KHSO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium hydroxide	Kalilauge	KOH	50%	20	+	+	-	+
	(Kaliumhydroxid)			40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium hydroxide	Kalilauge	KOH	30%	20	+	+	-	+
	(Kaliumhydroxid)			40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium hydroxide	Kalilauge	KOH	5%	20	+	+	-	+
	(Kaliumhydroxid)			40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium hydroxide	Kalilauge	KOH	4%	20	+	+	-	+
	(Kaliumhydroxid)			40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Potassium hydroxide	Kalilauge (Kaliumhydroxid)	KOH	2%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium hydroxide	Kalilauge (Kaliumhydroxid)	KOH	<1%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium hypochlorite	Kaliumhypochlorit	KClO	≤ GL	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium hypochlorite	Kaliumhypochlorit	KClO	VL	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium iodate	Kaliumiodat	KIO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium iodate	Kaliumiodat	KIO_3	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium iodide	Kaliumiodid	KI	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium Iodine (Lugol's-solution)	Iod-Iodkalium (Lugols-Lösung)	$KI + I_2$	< 3%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+/-(q)	+
				80	-	+/-(s)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Potassium metaborate	Kaliummetaborat	KBO_2	1%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium nitrate	Kaliumnitrat	KNO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium nitrite	Kaliumnitrit	KNO_2	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Potassium perborate	Kaliumperborat	$K_2B_2O_6$ x H_2O	≤ GL	20	+	+	+	+
	(Kaliumperoxoborat)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium perchlorate	Kaliumperchlorat	$KClO_4$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium permanganate	Kaliumpermanganat	$KMnO_4$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium permanganate	Kaliumpermanganat	$KMnO_4$	6%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium permanganate	Kaliumpermanganat	$KMnO_4$	10%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium permanganate	Kaliumpermanganat	$KMnO_4$	18%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium permanganate	Kaliumpermanganat	$KMnO_4$	20%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium permanganate	Kaliumpermanganat	$KMnO_4$	50%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium persulfate	Kaliumpersulfat	$K_2S_2O_8$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium phosphate	Kaliumphosphat	K_3PO_4	VL	20	+	+	+	+
	(Trikaliumphosphat)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium sulfate	Kaliumsulfat	K_2SO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Potassium sulfite	Kaliumsulfit	K_2SO_3 x H_2O	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium tatrate	Kaliumtartrat	$K_2(CHOHCOO)_2$ x $2H_2O$	≤ GL	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)
Potassium tetracyanocuprate	Kaliumtetracyanocuprat	$K_3[Cu(CN)_4]$	≤ GL	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)
Potassium tripolyphosphate	Kaliumtripolyphosphat	$K_5P_3O_{10}$	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Propane, gaseous	Propan, gasförmig	C_3H_8	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propane, liquid	Propan, flüssig	C_3H_8	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propanol	Propanol	C_3H_7OH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propargyl alcohol	Propargylalkohol	$CH{=}CCH_2OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propargyl alcohol	Propargylalkohol	$CH{=}CCH_2OH$	7%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propionic acid	Propionsäure	CH_3CH_2COOH	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propionic acid	Propionsäure	CH_3CH_2COOH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Propionic acid ethyl ester	Propionsäureethylester (Ethylpropionat)	$CH_3CH_2COOC_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propionic acid methyl ester	Propionsäuremethylester (Methylpropionat)	$CH_3CH_2COOCH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propyl acetate	Essigsäurepropylester (Propylacetat)	$CH_3COOCH_2CH_2CH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Propyl chloride	Propylchlorid (Isopropylchlorid)	$CH_3CHClCH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propylamine	Propylamin (Aminopropan)	$CH_3CH_2CH_2NH_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+
				120	-	-	-	-
Propylene carbonate	Propylencarbonat	$OCH(CH_3)CH_2OCO$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propylene dibromide	Dibrompropan (1,2 Propylendibromid)	$CH_3CHBrCH_2Br$	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Propylene glycol	Propylenglykol (1,2-Propandiol)	$HOCH_2CH_2CH_2OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propylene oxide	Propylenoxyd (1,2-Epoxypropan)	C_3H_6O	TR	20	+/-(o)	+/-(o)	+/-(o)	+/-(o)
				40	-	-	-	+/-(o)
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Prussic acid	Blausäure (Cyanhydroxyde)	HCN	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	+	+	+
				120	-	-	-	-
Pseudocumene	Pseudocumen	$C_6H_3(CH_3)_3$	TR	20	+/-(o)	+/-(o)	+/-(o)	+/-(o)
				40	-	-	+/-(o)	+/-(o)
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	+/-(o)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
p-Toluenesulfonic acid	p-Toluolsulfonsäure	$C_7H_8O_3S$ x H_2O	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Pyridine	Pyridin	C_5H_5N	TR	20	+	+/-(q)	-	+/-(q)
				40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Pyridine	Pyridin	C_5H_5N	5%	20	+	+/-(q)	-	+/-(q)
				40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Pyrogallol	Pyrogallol (1,2,3-Trihydroxybenzen)	$C_6H_3(OH)_3$	< 50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+	+/-(q)
				120	-	-	-	-
Quinine	Chinin (6-Methoxycinchonan, Palmitylalkohol)	$C_{20}H_{24}O_2N_2$ x H_2O	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Rapsmethyl ester	Rapsmethylester (Biodiesel)		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Raw oil	Rohöl		H	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Resin dispersion	Kunstharzdispersion		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Resorcin	Resorcin	$C_6H_6O_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Rubber dispersion	Kautschukdispersionen		TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Salicylic acid	Salicylsäure	HOC_6H_4COOH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+/-(q)
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Salicylic acid methyl ester	Salicylsäuremethylester	$HOC_6H_4COOCH_3$	TR	20	+/-(q)	+/-(q)	+	+
	(Methylsalicylat)			40	+/-(q)	+/-(q)	+	+/-(q)
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Salicylic aldehyde	Salicylaldehyd	$HOCC_6H_4OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+/-(q)
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Sea water	Meerwasser		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Selenium acid	Selensäure	H_2SeO_4	30%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	-
Selenium acid	Selensäure	H_2SeO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	-
Silane	Silan	Si_nH_{2n+2}	TR	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Silicic acid	Kieselsäure	$SiO_2(H_2O)_n$	≤ GL	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Silicon oil	Siliconöl		TR	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Silicon oil	Siliconöl		VL	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Silicon tetrachloride	Siliziumtetrachlorid	$SiCl_4$	TR	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Silver acetate	Silberacetat	CH_3COOAg	≤ GL	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Silver cyanide	Silbercyanid	AgCN	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Silver nitrate	Silbernitrat	$AgNO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Silver nitrate	Silbernitrat	$AgNO_3$	8%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Silver salts	Silbersalze		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Silver sulfate	Silbersulfat	$AgSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Soap solution	Seifenlösung		all	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium	Natrium	Na		20	-	-	-	-
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Sodium acetate	Natriumacetat	CH_3COONa	≤ GL	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Sodium benzoate	Natriumbenzoat	C_6H_5COONa	≤ GL	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Sodium bicarbonate	Natriumbicarbonat	$NaHCO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium bisulfate	Natriumbisulfat	$NaHSO_4$	10%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sodium bisulfite	Natriumbisulfit	$NaHSO_3$	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium borate	Natriumborat	Na_3BO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium bromate	Natriumbromat	$NaBrO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(o)	+/-(o)	+	+
				80	-	-	+/-(o)	+
				100	-	-	+/-(o)	+
				120	-	-	-	-
Sodium bromide	Natriumbromid	NaBr	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium carbonate	Natriumcarbonat	Na_2CO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium carbonate	Natriumcarbonat	Na_2CO_3	15%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium carbonate	Natriumcarbonat	Na_2CO_3	10%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium chlorate	Natriumchlorat	$NaClO_3$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium chlorate	Natriumchlorat	$NaClO_3$	33%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium chloride	Natriumchlorid	NaCl	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium chlorite	Natriumchlorit	$NaClO_2$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sodium chromate	Natriumchromat	Na_2CrO_4	VL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium cyanide	Natriumcyanid	$NaCN$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium dichloroisocyanurate	Natriumdichlorisocyanurat	$C_3HCl_2N_3O_3Na$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium dichromate	Natriumdichromat	$Na_2Cr_2O_7$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium dihydrogenphosphate	Natriumdihydrogenphosphat	NaH_2PO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium disulfite	Natriumdisulfit	$Na_2S_2O_5$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium dithionite	Natriumdithionit	$Na_2S_2O_4$	≤ GL	20	+	+	+	+
(Hydrosulfite)	(Hydrosulfite)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium dodecylbenzene-	Natriumdodecylbenzolsulfonat	$H_{25}C_{12}C_6H_{14}SO_3Na$	≤ GL	20	+	+	+	+
sulfonate	(Lutensit, Phenylsulfonat)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	-
				120	-	-	-	-
Sodium fluoride	Natriumfluorid	NaF	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium fluorosilicate	Natriumfluorsilikat	Na_2SiF_6	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium hexafluorosilicate	Natriumhexafluorsilikat	Na_2SiF_6	3%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sodium hydrogencarbonate	Natriumhydrogencarbonat	$NaHCO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium hydrogensulfate	Natriumhydrogensulfat	$NaHSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium hydrogensulfide	Natriumhydrogensulfid	NaHS	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Sodium hydrogensulfide	Natriumhydrogensulfid	NaHS	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium hydrogensulfide	Natriumhydrogensulfid	NaHS	20%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium hydrogensulfite	Natriumhydrogensulfit	$NaHSO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium hydroxide	Natronlauge	NaOH	50%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hydroxide	Natronlauge	NaOH	45%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hydroxide	Natronlauge	NaOH	up to 40%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hydroxide	Natronlauge	NaOH	30%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hydroxide	Natronlauge	NaOH	up to 10%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sodium hydroxide	Natronlauge	NaOH	4%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hypochlorite (active chlorine 12.5%)	Natriumhypochlorit (aktives Chlor 12,5%)	NaOCl		20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hypochlorite (active chlorine 12.5%)	Natriumhypochlorit (aktives Chlor 12,5%)	NaOCl		20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hypochlorite (active chlorine 12.5%)	Natriumhypochlorit (aktives Chlor 12,5%)	NaOCl		20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hypochlorite (active chlorine 12.5%)	Natriumhypochlorit (aktives Chlor 12,5%)	NaOCl		20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium iodide	Natriumiodid	NaI	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium lactate	Natriumlactat	$CH_3CHOHCOONa$	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Sodium nitrate	Natriumnitrat	$NaNO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium nitrite	Natriumnitrit	$NaNO_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium oxalate	Natriumoxalat	$Na_2C_2O_4$	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Sodium palmitic	Natriumpalmitat	$CH_3(CH_2)_{14}COONa$	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sodium perborate	Natriumperborat	$Na_2B_2O_6 \times 3H_2O$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium perchlorate	Natriumperchlorat (Irenat)	$NaClO_4$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium peroxide	Natriumperoxid	Na_2O_2	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium peroxide	Natriumperoxid	Na_2O_2	10%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium persulfate	Natriumpersulfat	$Na_2S_2O_8$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium phosphate	Natriumphosphat	Na_3PO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium silicate	Natriumsilikat (Wasserglas)	Na_2SiO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium sulfate	Natriumsulfat	Na_2SO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium sulfide	Natriumsulfid	Na_2S	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium sulfide	Natriumsulfid	Na_2S	10%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium sulfide	Natriumsulfid	Na_2S	5%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sodium sulfite	Natriumsulfit	Na_2SO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium tartrate	Natriumtartrat	$Na_2C_4H_4O_6 \times 2H_2O$	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80		+/-(q)	+/-(q)	+
				100			+/-(q)	+
				120	-	-	-	-
Sodium tetraborate	Natriumtetraborat	$Na_2B_4O_7$	≤ GL	20	+	+	+	+
	(Borax)			40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium thiocyanate	Natriumthiocyanat	NaSCN	≤ GL	20	+	+	+	+
	(Natriumrhodanid)			40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium thiosulfate	Natriumthiosulfat	$Na_2S_2O_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Soja bean oil	Sojabohnenöl		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Spindle oil	Spindelöl		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Starch glue	Stärkekleber		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Starch solution	Stärkelösung		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Starch syrup	Stärkesirup		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Stauffer fat	Staufferfett		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Stearic acid	Stearinsäure	$C_{17}H_{35}COOH$	TR	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Stearic acid butyl ester	Stearinsäurebutylester	$C_{17}H_{35}COOC_4H_9$	TR	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Stearoyl chloride	Stearoylchlorid	$(CH_3)(CH_2)_{16}COCl$	TR	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Stilbene	Stilben	$C_6H_5CH{=}CHC_6H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Styrene	Styren	$C_6H_5CH{=}CH_2$	TR	20	-	-	+	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Succinic acid	Bernsteinsäure	$COOHCH_2CH_2COOH$	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Sugar acid	Zuckersäure	$HOOC(CHOH)_4COOH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Sugar beet juice	Zuckerrübensaft		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Sugar syrup	Zuckersirup		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Sulfamic acid	Amidoschwefelsäure (Amidosulfonsäure)	NH_2SO_3H	18%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Sulfamic acid	Amidoschwefelsäure (Amidosulfonsäure)	NH_2SO_3H	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sulfaminic acid	Sulfaminsäure (Amidoschwefelsäure, Sulfamidsäure)	H_3SO_3N	≤ GL	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	-	+/-(s)
				120	-	-	-	-
Sulfochromic acid	Schwefelchromsäure	$CrO_3 + H_2SO_4 + H_2O$	40%	20	-	-	+/-(s)	+/-(s)
				40	-	-	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Sulfoethylmethacryalate	Sulfoethylmethacryalat (SEM)		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Sulfonic acid	Sulfonsäure	$R\text{-}SO_2\text{-}OH$	60%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Sulfonic acid	Sulfonsäure	$R\text{-}SO_2\text{-}OH$	VL	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Sulfur	Schwefel	S		20	-	-	-	-
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Sulfur dichloride	Schwefelchlorid (Schwefeldichlorid)	SCl_2	≤ GL	20	-	-	+/-(q)	+
				40	-	-	-	+
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Sulfur dioxide, anhydrous	Schwefeldioxid, trocken	SO_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Sulfur dioxide, aqueous	Schwefeldioxid, feucht	SO_2	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Sulfur dioxide, liquid	Schwefeldioxid, flüssig	SO_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Sulfur trioxide	Schwefeltrioxid	SO_3	TR	20	-	-	-	+/-(s)
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sulfuric acid	Schwefelsäure	H_2SO_4	3%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	10%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	40%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	60%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	78%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	85%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	90%	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	96%	20	-	-	+/-(s)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	98%	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sulfurous acid	Schwefelige Säure	H_2SO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Sulfuryl chloride	Sulfurylchlorid	SO_2Cl_2	≤ GL	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sulfuryl fluoride	Sulfuryldifluorid	SO_2F_2	≤ GL	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Surfactants	Netzmittel		up to 5%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	-	+/-(s)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
1,1,1,2-Tetrafluoroethane	1,1,1,2-Tetrafluorethan (Freon 134a)	F_3CCH_2F	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
1,2,3-Trichloropropane	Trichlorpropan (Trichlorhydrin)	$CH_2ClCHClCH_2Cl$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
1,2,3-Trihydroxybenzene	1,2,3-Trihydroxybenzen	$C_6H_3(OH)_3$	50%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
1-Tetradecanamine	1-Tetradecanamin	$C_{14}H_{31}N$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
4-Toluene sulfonyl chloride	Toluol-4-sulfonylchlorid	$CH_3C_6H_4SO_2Cl$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
4-Toluensulfonic acid	Toluolsulfonsäure	$C_7H_8O_3S$	70%	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
4-Toluensulfonic acid	Toluolsulfonsäure	$C_7H_8O_3S$	30%	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
4-Toluensulfonic acid	Toluolsulfonsäure	$C_7H_8O_3S$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Tall oil	Tallöl		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Tallow	Talg			20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Talpa oil	Talpaöl		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Tannic acid	Tanninsäure	$C_{76}H_{52}O_{46}$	TR	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Tanning extracts from plants	Gerbextrakte, pflanzliche		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Tar	Teer		H	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Tartaric acid (2,3-Dihydroxybutanedioc acid)	Weinsäure (2,3-Dihydroxybutandisäure)	$(CHOH)_2(COOH)_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	-
t-Butanol, 2-Methyl-2-propanol (tert. Butylalkohol)	t-Butanol, 2-Methyl-2-propanol (tert. Butylalkohol)	$(CH_3)_3COH$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
t-Butylmethether SP UV	t-Butylmethether SP UV		TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Tellus oils	Tellusöle		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Tenside	Tenside		H	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Tert-butyl alcohol	Tert-butylalkohol (2-methyl-2-propanol)	$(CH_3)_3COH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Tert-butylcyclohexyl acetate	Essigsäurebutylcyclohexylester	$CH_3COOC_6H_{10}C(CH_3)_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Tetrabromethane	Tetrabromethan	$Br_2CHCHBr_2$	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetrachlorodifluoroethane	Tetrachlordifluorethan	CCl_3CClF_2	18%	20	-	-	+	+
	(Freon R 113)			40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetrachloroethane	Tetrachlorethan	$Cl_2CHCHCl_2$	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetrachlorophenole	Tetrachlorphenol	C_6HCl_4OH	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetraethyl lead	Bleitetraethyl	$(CH_3CH_2)_4Pb$	TR	20	+/-(q)	+/-(q)	+	+
	(Tetraetylblei)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Tetrafluoroboric acid	Tetrafluorborsäure	HBF_4	< 50%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetrahydrofurane	Tetrahydrofuran	C_4H_8O	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetrahydronaphthalene	Tetrahydronaphthalin	$C_{10}H_{12}$	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetrahydronaphthalene	Tetrahydronaphthalin	$C_{10}H_{12}$	90%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetramethylammoniumhydroxide	Tetramethylammoniumhydroxid	$C_4H_{13}NO$	50%	20	+	+	-	+
	(TMAH)			40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Tetramethylammoniumhydroxide	Tetramethylammoniumhydroxid (TMAH)	$C_4H_{13}NO$	28%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Tetramethylammoniumhydroxide	Tetramethylammoniumhydroxid (TMAH)	$C_4H_{13}NO$	10%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Tetramethylthiourea	Tetramethylthioharnstoff	$(CH_3)_2NCSN(CH_3)_2$	TR	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Tetramethylurea	Tetramethylharnstoff	$(CH_3)_2NCON(CH_3)_2$	TR	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Thioglycolic acid	Thioglykolsäure	$HSCH_2COOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Thioglycolic acid	Thioglykolsäure	$HSCH_2COOH$	80%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Thioglycolic acid	Thioglykolsäure	$HSCH_2COOH$	40%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Thionyl chloride	Thionylchlorid	$SOCl_2$	TR	20	-	-	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Thiophen	Thiophen	C_4H_4S	TR	20	-	-	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Thiophosphoric chloride	Thiophosphorylchlorid	$PSCl_3$	TR	20	-	-	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Thioureadioxide	Formamidinsäure (Thioharnstoffdioxid)		TR	20	+/-(q)	+/-(q)	+	+
				40	-	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Tin(II) chloride	Zinnchlorid (II)	$SnCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Tin(IV) chloride	Zinnchlorid (IV)	$SnCl_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Titanium sulfate	Titansulfat	$Ti_2(SO_4)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Titanium tetrachloride	Titaniumtetrachlorid	$TiCl_4$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Toloyl bromide	Toloylbromid	$C_6H_4CH_3Br$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Toluendiisocyanate	Toluoldiisocyanat	$C_9H_6N_2O_2$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	-
				100	-	-	-	-
				120	-	-	-	-
Toluene	Toluol	$C_6H_5CH_3$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	-
				100	-	-	-	-
				120	-	-	-	-
Tomato juice	Tomatensaft		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Transformer oil	Transformatorenöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Tributhyl amine	Tributylamin	$(CH_3)_3CNH_2$	TR	20	+	+	+	+
	(2-Amino-2-methylpropan)			40	+	+	+/-(q)	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Tributyl ester	Tributylester		TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Tributyl phosphate	Tributylphosphat (Phosphorsäuretributylester)	$(C_4H_9)_3PO_4$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Trichloroacetalaldehyde	Trichloracetalaldehyd (Chloral)	CCl_3CHO	TR	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichloroacetic acid	Chloressigsäure (TRI)	Cl_3CCOOH	10%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Trichloroacetic acid	Chloressigsäure (TRI)	Cl_3CCOOH	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Trichloroacetic acid	Chloressigsäure (TRI)	Cl_3CCOOH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Trichloroacetyl chloride	Trichloressigsäurechlorid	CCl_3COCl	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichlorobenzene	Trichlorbenzol	$C_6H_3Cl_3$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichlorobutane	Trichlorbutan	$C_4H_7Cl_3$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichloroethane (1,1,1)	Trichlorethan (1,1,1) (Methylchloroform)	CH_3CCl_3	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichloroethane (1,1,2)	Trichlorethan (1,1,2) (Methylchloroform)	$CHCl_2CHCl_2$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichloroethylene	Trichlorethylen (Ethylentrichlorid, Acetylentrichlorid)	$Cl_2C=CHCl$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Trichloroisocyanuric acid	Trichlorisocyanursäure	$C_3Cl_3N_3O_3$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichloromethansulfonyl chloride	Trichlormethansulfonylchlorid (Perchlormethylmercaptan)	Cl_3CSCl_2	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichlorophenole	Trichlorphenol	$C_6H_2Cl_3OH$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichlorosilane	Trichlorsilan (Siliconchloroform)	$SiHCl_3$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Tricresyl phosphate	Trikresylphosphat	$(H_3CC_6H_5O)_3PO_4$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Triethanolamine	Triethanolamin	$C_6H_{15}NO_3$	5%	20	+	+	-	+
				40	+/-(q)	+/-(q)	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Triethanolamine	Triethanolamin	$N(CH_2CH_2OH)_3$	TR	20	+	+	-	+
				40	+/-(q)	+/-(q)	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Triethyl amide	Triethylamid		TR	20	+	+	+/-(q)	+
				40	+	+	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Triethyl amine	Triethylamin	$N(CH_2CH_3)_3$	TR	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Triethylenglykol	Triethylenglycol (Triglykol)	$C_6H_{14}O_4$	5%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Triethylentetramine	Triethylentetramin		TR	20	+	+	+/-(q)	+
				40	+	+	-	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Trifluoroacetic acid	Trifluoressigsäure	CF_3COOH	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trifluoroacetic acid	Trifluoressigsäure	CF_3COOH	80%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trifluoroacetic acid	Trifluoressigsäure	CF_3COOH	50%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Triiodinemethane in methanol	Triiodmethan in Methanol	CHI_3	50%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Triisopropanolamine	Triisopropanolamin	$((CH_3)_2COH)_3N$	10%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Trimethyl borate	Borsäuremethylester	$B(OCH_3)_3$	TR	20	+/-(q)	+/-(q)	+	+
	(Trimethoxyboran,			40	+/-(q)	+/-(q)	+	+
	Trimethylborat)			60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Trimethyl phosphate	Trimethylphosphat	$(CH_3)_3PO_4$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Trimethylacetyl chloride	Trimethylacetylchlorid	$(CH_3)_3CCOCl$	TR	20	-	-	+/-(q)	+
	(Pivaloylchlorid)			40	-	-	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trimethylammonium chloride	Trimethylammoniumchlorid		TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Trimethylpropane	Trimethylpropan	C_6H_{14}	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Trioctyl phosphate	Trioctylphosphat	$(C_8H_{17})_3PO_4$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Triphenyl borate	Borsäurepenthylester	$(C_5H_{11}O)_3B$	TR	20	+/-(q)	+/-(q)	+	+
	(Triamylborat, Triphenylborat)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Triphenyl phosphite	Triphenylphosphit	$(C_6H_5O)_3P$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Trishydroxymethylpropane	Trishydroxymethylpropan	$CH_3CH_2C(CH_2OH)_3$	10%	20	+	+/-(q)	+	+
	(Trimethylolpropan)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Turpentine	Terpentin		H	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Turpentine oil	Terpentinöl		H	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Two stroke oil	Zweitaktöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Uranyl nitrate	Uranylnitrat	$UO_2(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Urea	Harnstoff	H_2NCONH_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Uric acid	Harnsäure	$C_5H_4O_3N_4$	TR	20	+	+	+	+
	(2,6,8-Trihydroxypurin)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Vaseline	Vaseline	$C_{22}H_{46}$ / $C_{23}H_{48}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Vaseline oil	Vaselineöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Vegetable oils and fats	Öle und Fette, vegetabil		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Vinegar	Essig		H	20	+	+	+	+
	(Weinessig)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Vinyl acetate	Vinylacetat	CH_2=$CHOOCCH_3$	TR	20	+/-(q)	+/-(q)	+	+
	(Ethenylester)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Vinyl chloride	Vinylchlorid	CH_2=CHCl	TR	20	-	-	+	+
				40	-	-	+/-(q)	+/-(q)
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Vinylidene bromide	Ethylendibromid	CH_2CBr_2	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Viscose spinning solution	Viscose-Spinnlösung		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Vitamin preparations	Vitaminpräparate		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Vitrea oil	Vitrea öl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Voluta oil	Voluta öl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Washing agents, synthetic	Waschmittel, synthetische		H	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(q)	+
				80	-	+/-(s)	-	+
				100	-	-	-	-
				120	-	-	-	-
Washing liquids	Spülmittel		H	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Waste gases containing bromine	Abgase bromhaltig	Br_2	all	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Waste gases containing carbon dioxide	Abgase kohlenstoffdioxidhaltig	CO_2	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Waste gases containing carbon monoxide	Abgase kohlenstoffmonoxidhaltig	CO	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Waste gases containing cyanur chloride	Abgase cyanurchloridhaltig	$C_3N_3Cl_3$	traces	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Waste gases containing hydrogen chloride	Abgase chlorwasserstoffhaltig	HCl	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Waste gases containing hydrogen fluoride	Abgase fluorwasserstoffhaltig	HF	traces	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)
Waste gases containing nitrous gases	Abgase nitrosehaltig	NO_x	traces	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Waste gases containing sulfur dioxide	Abgase schwefeldioxidhaltig	SO2	traces	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Waste gases containing sulfuric acid	Abgase schwefelsäurehaltig	H_2SO_4	traces	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Waste gases containing sulfuric trioxide	Abgase schwefeltrioxidhaltig	SO3	traces	20	-	-	+/-(s)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Waste water, traces of ethanol + butanol	Abwasser, Spuren von Ethanol + Butanol		traces	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Waste water, without organic solvent	Abwasser, ohne organische Lösungsmittel		traces	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Water destilled	Wasser destilliertes entionisiertes und vollentsalztes			20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Water waste water without organic solvent	Wasser, Abwasser ohne organische Lösungsmittel			20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Water, condensed	Wasser, Kondensatwasser			20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Wax alcohol	Wachsalkohol	$C_{31}H_{63}OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Whey	Molke		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Wine vinegar	Weinessig		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Wines, red and white	Weine, rot und weiß		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Wolframhexafluoride	Wolframhexafluorid (Wolfram(VI)fluorid)	WF_6	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Xylene	Xylol (Dimethylbenzen)	$C_6H_4(CH_3)_2$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Yeast	Hefe		all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Yeast wort	Stellhefenwürze		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc acetate	Zinkacetat	$(CH_3COO)_2Zn \times 2H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	-
Zinc bromide	Zinkbromid	$ZnBr_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc carbonate	Zinkcarbonat	$ZnCO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc chloride	Zinkchlorid	$ZnCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc chromate	Zinkchromat	$ZnCrO_4$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Zinc cyanide	Zinkcyanid	$Zn(CN)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc nitrate	Zinknitrat	$Zn(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc oxide	Zinkoxid	ZnO	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Zinc phosphate	Zinkphosphat	$Zn_3(PO_4)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc salts	Zinksalze		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Zinc stearate	Zinkstearat	$Zn(C_{17}H_{35}COO)_2$	≤ GL	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Zinc sulfate	Zinksulfat	$ZnSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

APPENDIX E

LINER COMPATIBILITY

July 11, 2018

Technical Memorandum

To
Scott Bakken,
David Frydenlund

From
Jo Ann Tischler

CC
Harold Roberts
Kathy Weinel

Re
Suitability of HDPE Cell Liner Material

Introduction

This technical memorandum was prepared in support of Energy Fuels Resources (USA) Inc.'s (EFRI's), license amendment request for construction of two additional cells, Cells 5A and 5B, in the tailings management system at White Mesa Mill. EFRI requested that Tischler Consulting Services (TCS) evaluate the high density polyethylene (HDPE) liner material proposed for construction of the cells. This technical memorandum demonstrates that for the proposed liner construction materials, there are no anticipated compatibility or degradation issues with regard to exposure to UV radiation, chemicals, process solutions, or tailings, from processing of ores or alternate feeds.

Evaluation and Findings

The new Cells 5A and 5B will both have high-density polyethylene ("HDPE") liners. EFRI provided copies of chemical resistance tables from two prospective liner suppliers, AGRU, and GSE. As described in the Environmental Report accompanying the license amendment request, over the life of these two cells, each will receive a combination of acidic tailings solutions and solids, from both conventional ores and alternate feeds.

According to Gulec, et al. (2005), a study on the degradation of HDPE liners under acidic conditions (synthetic acid mine drainage), HDPE was found to be chemically resistant to solutions similar to the tailings solutions at the Mill. Mitchell (1985) studied the chemical resistivity of HDPE at a pH range of 1.5 to 2.5 standard units using sulfuric acid. This study concluded that HDPE performed well and was stable under acidic conditions. Chemical resistance charts provided by AGRU and GSE, manufacturers of HDPE liner material, indicate that HDPE material is resistant to sulfuric and other mineral acids even at high concentrations.

It is expected that most of the inorganic metal and non-metal impurities entering the leach system from processing ores or alternate feeds will be converted to sulfate or other ionic salt forms, precipitated, and eventually discharged to the tailings system. Chemical resistance charts provided by AGRU and GSE, manufacturers of HDPE liner material, indicate that HDPE material is resistant to inorganic salt forms in nearly all proportions, including those proportions that will be contained in the solutions from processing of ores or alternate feeds.

The constituents in the tailings sands and liquids resulting from the processing of alternate feeds are not expected to be significantly different from those resulting from processing of conventional ores either in composition or in concentration of constituents. Residuals from alternate feed processing has historically contained additional organic solutes (such as phthalates) and additional anions in solutions or salt form including halides, nitrates, and amines. Per the AGRU and GSE resistance charts, the HDPE material is resistant to these constituents in a wide range of concentrations and conditions, including those concentrations and conditions that will be contained in the solutions from processing of ores or alternate feeds.

In summary, the HDPE liner material is expected to be sufficient for all the components of tailings solutions and solids, under all the conditions they are anticipated to be discharged from the Mill.

Sincerely,

Jo Ann Tischler
Tischler Consulting Services, LLC

References

- AGRU "Chemische Bestandigkeitsliste" ("Chemical Resistance Chart") AGRU Kunststofftechnik GMBH, Bad Hall, Austria, provided June 2018

- GSE, 2015 GSE "Chemical Resistance Chart" GSE Environmental March 5, 2015

- Gulec, S.B., C.H. Benson, and T. B. Edil, 2005. "Effect of Acid Mine Drainage on the Mechanical and Hydraulic Properties of Three Geosynthetics", Journal of Geotechnical and Geoenvironmental Engineering Vol. 131, No. 8, ASCE, pp. 937-950.

- Mitchell, D.H., 1985. "Geomembrane Compatibility Tests Using Uranium Acid Leachate", Journal of Geotextiles and Geomembranes, Vol. 2, No. 2, Elsevier Publishing Co., pp. 111-128.

APPENDIX F

[RESERVED]

APPENDIX G

REVIEW OF ENVIRONMENTAL RADIOLOGICAL MONITORING PROGRAM

ARCADIS Design & Consultancy for natural and built assets

Mr. Scott Bakken
Director, Regulatory Affairs
Energy Fuels Resources (USA) Inc.
225 Union Blvd., Suite 600
Lakewood, CO 80228

Arcadis Canada Inc.
121 Granton Drive, Suite 12
Richmond Hill, ON L4B 3N4
Tel 905.764.9380
Fax 905.764.9386
www.arcadis.com

Subject:

Review of Environmental Radiological Monitoring Program for the White Mesa Uranium Mill

Rad and Risk

Date:
July 11, 2018

Contact:
Doug Chambers

Phone:
905.764.9380

Email:
Doug.Chambers@arcadis.com

Our ref:
351418

Dear Mr. Bakken,

This letter report provides a review of the environmental radiological monitoring program at Energy Fuels Resources (USA) Inc.'s (EFR) White Mesa Uranium Mill (the "Mill") in San Juan County, Utah, in support of an application by EFR to support the addition of two (2) new cells 5A and 5B to the existing tailings management system. Specifically, this letter report addresses the question of whether or not any changes to the current environmental radiation monitoring program at the Mill site are warranted by the addition of the new cells 5A and 5B.

In preparing this report, we directly reference and use information from the Semi-Annual Effluent Monitoring Reports for the White Mesa Mill for the period 2014 through 2017 and the Semi-Annual and Annual Monitoring Summary Meteorological Station reports provided to us by EFR.

1.0 Current Environmental Radiological Monitoring Program

Annual meteorological data collected from the Mill's meteorological station show that the predominant wind directions during the past four years (2014-2017) were blowing from the north-north-easterly (NNE) and from the south-southwesterly (SSW).

The 2017 annual frequency distribution is presented graphically in Attachment A. The wind blows from the NNE (at an average speed of 2.9 m/s, 13.1% of the time) and from the SSW (at an average speed of 4.1 m/s, 8.9% of the time) (McVehil-Monnett 2017b).

The locations of the current and proposed air monitoring stations are shown on Attachment B. Data from these stations are considered to represent long term wind patterns at the Mill. Air monitoring stations BHV-1, BHV-2 and BHV-8 will detect radiological characteristics of winds from the south and station BHV-4 and BHV-6 will detect radiological characteristics of winds from the north.

The current radiological monitoring program at the Mill has the following environmental media and conditions (EFR 2017a-b):

1. Air particulate radionuclide concentrations from the following sampling stations (see Attachment B):
   - North, East, and South of the Mill site: BHV-1, BHV-2 and BHV-8 (north), BHV-5 and BHV-7 (east) and BHV-4 (south). BHV-1 and BHV-8 serve as surrogates for concentration at the nearest resident.
   - BHV-3 (a background station west of the Mill) was used to monitor airborne particulate until November 1995 and subsequently decommissioned with the approval of the United States Nuclear Regulatory Commission (NRC).
   - BHV-6 (station specifically requested by the White Mesa Ute Community south of the Mill site).
2. External (direct) gamma radiation is measured at all air monitoring stations (BHV-1, BHV-2, BHV-3 and BHV-4 through BHV-8).
3. Radon-222 is measured at all air monitoring stations (BHV-1, BHV-2, BHV-3 and BHV-4 through BHV-8).
4. Vegetative uptake of radionuclides at three periphery locations.
5. Stack releases from the facility's air emissions sources.
6. Annual Surface water samples from within the Westwater Canyon drainage, when flowing and quarterly surface water samples from Cottonwood Creek, when flowing both located west of the Mill.
7. Annual Soil radionuclide activity obtained during the third quarter of each year near the air monitoring stations and along the perimeter of the Mill property boundary.
8. Groundwater at the Mill facility, up gradient and down gradient.
9. Radon flux of Cell 2 cover, as requested by the Division of Waste Management and Radiation Control (DWMRC) in correspondence dated July 23, 2014 and as required by NESHAPs for Cell 3.
10. Meteorological conditions.
11. Seeps and springs in the vicinity of the Mill.

2.0 Review of Existing Environmental Radiological Monitoring Program

In order to review the adequacy of the environmental radiological monitoring program in light of the addition of cells 5A and 5B, some general observations from the semi-annual effluent reports for 2017 (EFR 2017a-b), meteorological data, and other reports are provided:

- The current BHV stations cover the predominant wind directions: BHV-1, BHV-2 and BHV-8 cover winds that flow predominantly from the south, BHV-4 and BHV-6 cover the winds predominantly flowing from the north and BHV-5 and BHV-7 cover the winds predominantly flowing from the west and southwest of the Mill.
- The 2017 annual mean wind speed was 3.40 m/s.
- The measured activity of airborne particulate (U-nat, Th-230, Th-232, Ra-226 and Pb-210) at all monitoring stations shown in Attachment B were well below regulatory Effluent Concentration Limits (ECLs) and the Mill's "As Low As Reasonably Achievable" (ALARA) goals (i.e., 25% of the ECL).
- Previously, radon monitoring had been carried out but was discontinued with the agreement of the NRC in 1995. However, in 2013 EFR voluntarily began ambient Radon-222 monitoring at some stations and later in 2014 the monitoring program was expanded to include collection of Radon-222 data at all BHV stations. The measured radon-222 concentration values are compared to derived ECLs. It is noted that through the 2013-2017 period, radon-222 results have been consistently below the calculated ECLs and within the range of historic levels.
- Results of the Optically Stimulated Luminescent dosimeters (OSLs) measurements for external gamma radiation indicate that measurements for stations BHV-1, BHV-2, BHV-4, BHV-5, BHV-6, BHV-7 and BHV-8 are within regulatory limits.
- 2017 data compared to previous years indicate no increase in uptake of Ra-226, Th-232, U-nat or Pb-210 in vegetation and are within the range of previous sampling episodes.
- Stack releases were reported but these are direct stack measurements and are not comparable to ECLs, which for regulatory compliance purposes are site boundary standards.
- The results of the sampling indicate that soil activity levels at the air monitoring stations and along the perimeter of the Mill property remain low and within the range of historic levels.
- Groundwater and seeps and springs are listed in the semi-annual effluent report, but the data are reported separately pursuant to the Mill's Groundwater Discharge Permit and the monitoring program is not included as part of this evaluation.
- At Cottonwood Creek, surface water samples were collected only in the third quarter of 2017. Westwater Canyon was not able to be sampled because the Creek was dry for the sampling events. A sediment sample was collected instead and included in the soil data analysis. The results of the radionuclide data remain low and within the range of a typical surface water, thus no influences from the Mill operations has been identified.
- Sampling results of Cell 2 indicate that 2017 average radon flux was 0.7 pCi/m^2-sec which is well below the 20 pCi/m^2-sec standard. Further, during the 2014-2017 period, values have been

measured within a range of 0.7-18.1 pCi/m^2-sec. Higher results were reported for earlier years, before the radon barrier was completed for Cell 2 in 2016.

The results from the Semi-Annual Effluent Monitoring Report (2017) did not show any anomalies from the historical data, which indicates the Mill's ALARA practices are adequately protecting the public and the environment. Nonetheless, in view of the proposed development of the cells 5A and 5B, we propose the following modification to the current environmental monitoring program:

- The existing Hi-Vol station BHV-4 be relocated to the south-south west of the new cells, to cover the winds flowing predominantly from the NNE of the Mill. The proposed new location is presented in Attachment B.

3.0 Evaluation

In our opinion, the current environmental radiological monitoring program and the suggested modifications will offer a comprehensive analysis and adequate measurements to provide assurance that the proposed activities at the Mill will not adversely affect the local environment.

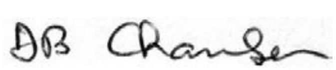
Further, given our understanding of the existing monitoring data and the low doses to public who live or undertake recreational activities such as hiking or hunting near the Mill, our opinion is that the current environmental radiological monitoring and the proposed modifications to Hi-Vol stations as outlined above are adequate and consistent with the objectives set out in the NRC's Regulatory Guide 4.14, *Radiological Effluent and Environmental Monitoring at Uranium Mills* (NRC 1980).

In closing, our overall opinion is that the proposed modifications to the radiological monitoring program will adequately monitor the release of radioactive materials to the local environment associated with the current operation and the addition of cells 5A and 5B at the Mill site.

Should you have any questions or comments on this letter, please contact us at your convenience.

Yours very truly,

Arcadis Canada Inc.



Douglas B. Chambers, Ph.D.
Vice president; Senior Scientist Risk and Radioactivity;
Director Technical Knowledge & Innovation – Radiation Services

Cc:
Kathy Weinel, Quality Assurance Manager; and
David Frydenlund, CFO/Secretary/General Counsel

References

EFR 2014-2017a, Energy Fuels Resources (USA) Inc. *White Mesa Uranium Mill Radioactive Materials License UT900479 Semi-Annual Effluent Monitoring Report (January through June, 2014-2017).*

EFR 2014-2017b, Energy Fuels Resources (USA) Inc. *White Mesa Uranium Mill Radioactive Materials License UT900479 Semi-Annual Effluent Monitoring Report (July through December, 2014-2017).*

McVehil-Monnett Associates, Inc 2014-2017a. *Semi-Annual Monitoring Report, January-June 2014-2017 White Mesa Mill Meteorological Station*.

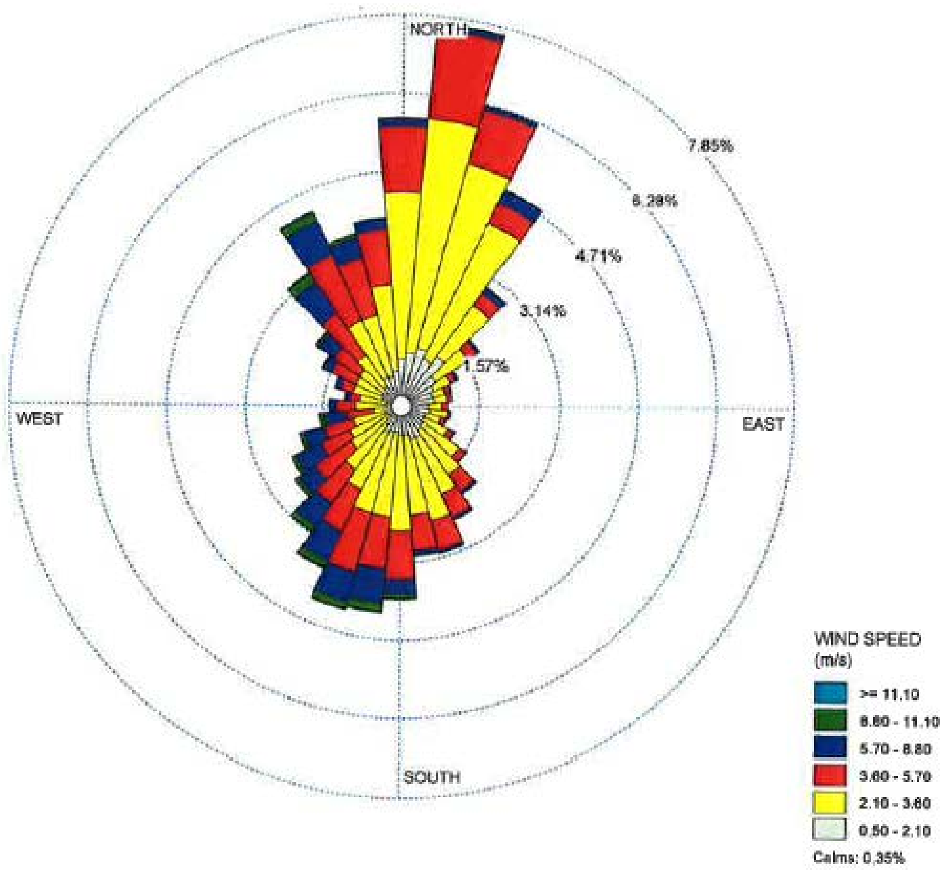
McVehil-Monnett Associates, Inc 2014-2017b. *Semi-Annual Monitoring Report, July-December 2014-2017 and Annual Monitoring Summary White Mesa Mill Meteorological Station.*

United States Nuclear Regulatory Commission (NRC). 1980. Regulatory Guide 4.14, *Radiological Effluent and Environmental Monitoring at Uranium Mills-Rev. 1.*

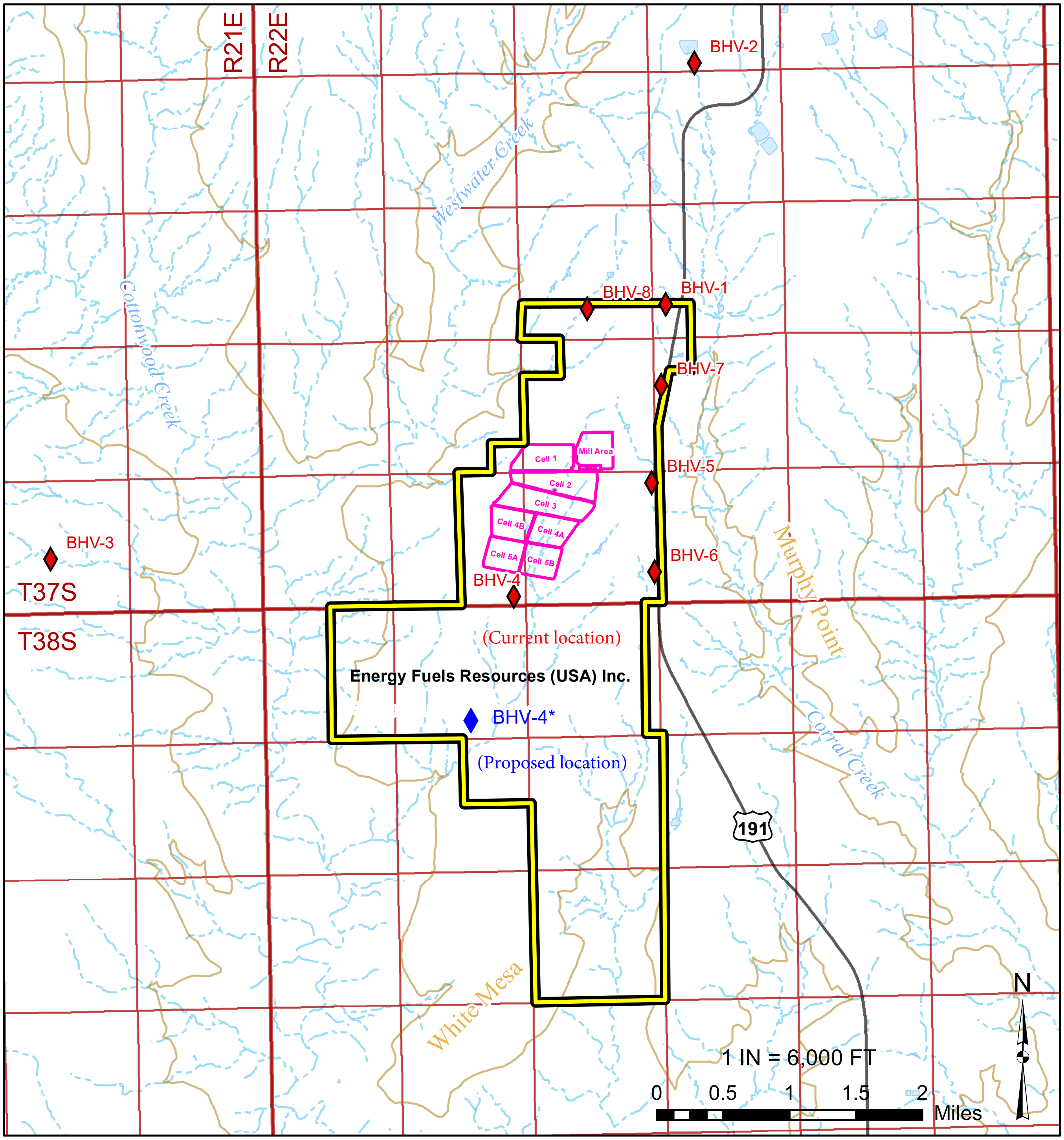
Attachment A - 2017 Wind Rose Plot

WIND ROSE PLOT:
White Mesa Mill
Meteorological Data

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:	DATA PERIOD:	COMPANY NAME:	
	Start Date: 1/1/2017 - 00:00 **End Date: 12/31/2017 - 23:59**	MODELER:	
	CALM WINDS: **0.35%**	TOTAL COUNT: **8756 hrs.**	
	AVG. WIND SPEED: **3.36 m/s**	DATE: **1/4/2018**	PROJECT NO.: :



Legend

- Air Monitoring Station
- Property Boundary
- Tailings Cell
- Road
- Canyon Rim
- Township and Range
- Section
- Pond
- Drainage

*BHV-4: Proposed Location

Coordinate System: NAD 1983 StatePlane Utah South FIPS 4303 Feet

ENERGY FUELS

REVISIONS		Project: WHITE MESA MILL	
Date:	By:	County: San Juan	State: Utah
		Location: -	

ATTACHMENT B

PARTICULATE MONITORING STATIONS

Author: dkapostasy | Date: 7/2/2018 | Drafted By: dkapostasy

C:\Users\dkapostasy\Desktop\Mill_PartMonitoring.mxd / 7/2/2018 11:15:32 AM by dkapostasy

APPENDIX H

ATTACHMENT F TO RECLAMATION PLAN, REVISION 5.1C

JULY 2018

White Mesa Mill, Blanding, Utah

Radioactive Materials License No. UT1900479

Index Sheet for Attachment F to Reclamation Plan, Revision 5.1C, July 2018

Page, Map or Other Entry to be Added as Attachment F	Description of Change
Attachment F - Tab	Add tab after Attachment E
Attachment F – Cover Sheet	Add cover sheet
Title Page, Revision 5.1C Redline	Update revision number to Revision 5.1C and date to July 2018
Page vi, Revision 5.1C Redline	Add references to Drawing TRC-11 – Cover Over Cell 5A and 5B Cross Sections and Attachment F – Revision 5.1C Page Changes to Table of Contents
Page I-1, Revision 5.1C Redline	Update Introduction section to include Cells 5A and 5B and effective date of Stipulation and Consent Agreement
Page I-2, Revision 5.1C Redline	Add reference to Cells 5A and 5B to all cell descriptions in Introduction section
Page I-3, Revision5.1C Redline	Add reference to Attachment F – Revision 5.1C Page Changes to Table I-1
Page 1-1, Revision 5.1C Redline	Update history of reclamation plan revisions in Section 1 Site Characteristics
Page 2-2, Revision 5.1C Redline	Update operating history and processing run dates in Section 2.2.1 Operating Periods
Page 2-3, Revision 5.1C Redline	Update operating history and processing quantities in Section 2.2.2 Mill Circuit
Page 3-1, Revision 5.1C Redline	Add Cells 5A and 5B to all cell descriptions in Section 3 Tailings Reclamation Plan
Page 3-3, Revision 5.1C Redline	Add reference to Cells 5A and 5B to Section 3.2.1 Summary of Facilities to be Reclaimed and Section 3.2.2 Tailings and Evaporative Cells
Pages 3-6 and 3-7, Revision 5.1C Redline	Add new Section 3.2.2.6 Cells 5A and 5B to describe cover design and reclamation procedures for Cells 5A and 5B
Page 3-10, Revision 5.1C Redline	Add dewatering system description for Cells 5A and 5B to Section 3.3.7 Tailings Dewatering
Page 5-1, Revision 5.1C Redline	Update status of Stipulation and Consent Agreement
Page 6-2, Revision 5.1C Redline	Add reference to Cells 5A and 5B as future cells to be used as evaporation cells
Conceptual Cover Design for Proposed Cells 5A and 5B	Letter from Stantec Consulting Services Inc. dated June 15, 2018, Reference: Conceptual Cover Design for White Mesa Uranium Mill Proposed Cells 5A and 5B, including Figure 1 – Plan View of Reclamation Features

ATTACHMENT F

REVISION 5.1C PAGE CHANGES

Reclamation Plan

White Mesa Mill

Blanding, Utah

Radioactive Materials License No. UT1900479

Revision 5.1~~B~~C

~~February 2018~~July 2018

Prepared by:
Energy Fuels Resources (USA) Inc.
225 Union Blvd., Suite 600
Lakewood, CO 80228

LIST OF DRAWINGS

LIST OF ATTACHMENTS

LIST OF APPENDICES

INTRODUCTION

This Reclamation Plan (the "Plan") has been prepared by Energy Fuels Resources (USA) Inc. ("EFRI")[1] for EFRI's White Mesa Uranium Mill (the "Mill"), located approximately six miles south of Blanding, Utah. This Plan presents EFRI's plans and estimated costs for the reclamation of cells for the tailings management system, and for decommissioning of the Mill and Mill site.[2] This Plan is an update to the White Mesa Mill Reclamation Plan Revision 3.2b (Denison, 2011b) approved by the Utah Department of Environmental Quality (UDEQ) Division of Radiation Control (DRC) on January 26, 2011. This Plan is also an update to Plan Revision 5.1B, to include the addition of Cell 5A and Cell 5B.

Summary of Plan

The uranium and vanadium processing areas of the Mill, including equipment, structures and support facilities, will be decommissioned and disposed of in tailings or buried at the Mill site as appropriate. Equipment (including tankage and piping, agitation, process control instrumentation and switchgears, and contaminated structures) will be cut up, removed, and buried in tailings prior to final cover placement. Concrete structures and foundations will be demolished and removed for disposal in tailings or covered in place with soil as appropriate.

The sequence of demolition will proceed so as to allow the maximum use of support areas of the facility, such as the office and shop areas. Uncontaminated or decontaminated equipment to be considered for salvage will be released in accordance with United States Nuclear Regulatory Commission ("NRC") guidance and in compliance with the conditions of the EFRI's State of Utah Radioactive Materials License No. UT1900479 (the "License"). As with the equipment for disposal, contaminated soils from the Mill and surrounding areas and ore or feed materials on the Mill site will be disposed of in the tailings cells in accordance with Attachment A, Technical Specifications. An evapotranspiration cover system is proposed for reclamation of the tailings management system cells.

The estimated reclamation costs for surety are set out in Attachment C. Attachment C will be reviewed and updated in accordance with License requirements. The reclamation costs are based on the approved Reclamation Plan (Denison, 2011b) and incorporate reclamation work completed to date. The reclamation costs will be updated when this Plan is approved and the Cell 2 cover performance test sections (see Sections 3.0, 5.0, and 6.0) are verified based on requirements outlined in thea Stipulation and Consent Agreement (SCA) being developeddated February 23, 2017, between EFRI and UDEQ Division of Waste Management and Radiation Control (DWMRC) (see Sections 5.0 and 6.0).

Plan Organization

General site characteristics pertinent to this Plan are contained in Section 1.0. Descriptions of the facility construction, operations and monitoring are given in Section 2.0. The reclamation plan itself, including descriptions of facilities to be reclaimed and design criteria, is presented in Section 3.0. Section 4.0 provides an overview of the preliminary mill decommissioning plan. Section 5.0 presents how reclamation would proceed if the "Proposed Cover Design" in Appendix A is not approved. Milestones and schedule commitments for reclamation are outlined in Section 6.0. Design drawings ("Drawings") are attached to this plan following the main text. Attachments A through D comprise the Technical Specifications,

[1] Prior July 25, 2012 EFRI was "Denison Mines (USA) Corp." and prior to December 16, 2006, Denison was named "International Uranium (USA) Corporation."
[2] Cell 1 was previously referred to as Cell 1-I. It is now referred to as Cell 1.

Construction Quality Assurance/Quality Control (QA/QC) Plan, Reclamation Cost Estimate, and Radiation Protection Manual for Reclamation Activities. Attachment E provides documents on the approved "Existing Cover Design" including the Titan Environmental 1996 Tailings Cover Design Report (Attachment E.1) and Technical Specifications (Attachment E.2). Both documents were included in the approved Reclamation Plan Revision 3.2b (Denison, 2011b).
Supporting documents include:

- *Updated Tailings Cover Design Report,* December 2016. MWH, Inc. (Appendix A)
- *Preliminary Mill Decommissioning Plan,* August 2016. MWH, Inc. (Appendix B)

As required by Part I.H.11 of previous revisions of the Mill's State of Utah Ground Water Discharge Permit No. UGW370004 (the "GWDP"), and Part I.H.2 of the current revision of the GWDP, EFRI completed an infiltration and contaminant transport model of the final tailings cover system to demonstrate the long-term ability of the cover to protect nearby groundwater quality (MWH, 2010). The model was updated to address DWMRC comments on the ICTM Report (DRC, 2012; 2013) and to incorporate additional geotechnical and hydrologic data collected as part of field investigations conducted in 2010 and 2012 for cover borrow material and in 2013 for in situ tailings. The updated infiltration modeling results were presented in EFRI (2012b) and EFRI (2015c). The updated cover design is included in the Updated Tailings Cover Design Report, included as Appendix A to this Reclamation Plan, and includes a monolithic evapotranspiration (ET) cover for the tailings cells. The revised cover design and basis was used for this version of the Plan.

The Reclamation Plan is written assuming Cells 2, 3, 4A, 4B, 5A and 5~~4~~B of the tailings management system will receive tailings to the maximum permitted tailings elevations. Cell 2 is full and partially reclaimed. Cell 3 was used for tailings storage, but currently only receives mill waste and byproduct material in accordance with License provisions. Cell 3 is partially full, and partially reclaimed. Cell 4A is the only cell currently receiving tailings and is partially full. Cell 4B is used for evaporation of process solutions and has not been used for tailings disposal. The Plan has been written assuming Cell 4B, Cell 5A and Cell 5B will be used in the future for permanent tailings disposal. If Cell 4B, Cell 5A and Cell 5B are~~is~~ not used in the future for tailings disposal, the Cells ~~4B~~ can be reclaimed for clean closure. This design is not presented in this report.

A Cell 1 Disposal Area is included in the reclamation design to provide additional storage for permanent disposal of contaminated materials and debris from the Mill site decommissioning and windblown cleanup. The current design is approved per the existing License, however this additional storage area is not currently needed for reclamation. If the Cell 1 Disposal Area is required for storage at the time of final Mill decommissioning, the liner system design will be updated to be the same basic design as the liner system for Cell 4B, including the same basic leak detection system. The revised design would be submitted to the Director prior to construction. After approval of the design by the Director, the Plan and surety would be updated to reflect the approved design.

Revisions to this Reclamation Plan include information related to the updated tailings cover design, as well as results of data collection and monitoring since Revision 5.0 of this Plan (Denison, 2011c). Revisions to the attachments and appendices of the Reclamation Plan are listed in a tabular format in Table I-1.

Table I-1
Revisions to Attachments and Appendices in Reclamation Plan

Attachments/ Appendices	**Reclamation Plan Revision 5.0 (2011)**	**Reclamation Plan Revision 5.1B (February 2018)***	**Reclamation Plan Revision 5.1C (July 2018)**
Drawings	Included in Attachment A	**Updated and provided as a standalone attachment**	
Attachment A	Plans and Technical Specifications for Reclamation of White Mesa Mill Facility, Blanding, Utah	**Updated -** Technical Specifications for Reclamation of White Mesa Mill Facility, Blanding, Utah	
Attachment B	Construction Quality Assurance/Quality Control Plan for Reclamation of White Mesa Mill Facility, Blanding, Utah	**Updated** - Construction Quality Assurance/Quality Control Plan for Reclamation of White Mesa Mill Facility, Blanding, Utah	
Attachment C	Cost Estimates for Reclamation of White Mesa Facility in Blanding, Utah	**Updated** - Cost Estimates for Reclamation of White Mesa Facility in Blanding, Utah	
Attachment D	Radiation Protection Manual for Reclamation	**Updated -** Radiation Protection Manual for Reclamation Activities	
Attachment E	Not included	**Added** – Existing Cover Design Documents	
Attachment F	Not Included	**Not Included**	**Added – Revision 5.1C Page Changes**
Appendix A	*Semi-Annual Effluent Report* (January through June, 2011), for the Mill	**Deleted to reduce redundancy** (latest report was submitted to DWMRC)	
Appendix B	*Hydrogeology of the Perched Groundwater Zone and Associated Seeps and Springs Near the White Mesa Uranium Mill Site, Blanding, Utah*, November 12, 2010, prepared by Hydro Geo Chem, Inc. (the “2010 HGC Report”)	**Deleted to reduce redundancy** (latest report was submitted to DWMRC)	
Appendix C	The Mill’s *Stormwater Best Management Practices Plan*, Revision 1.3, June 12, 2008, *Emergency Response Plan*, Revision 2.1, August 18, 2009, and Spill Prevention, Control, and Countermeasures Plan, 2011.	**Deleted to reduce redundancy** (latest report was submitted to DWMRC)	
Appendix D	*Updated Tailings Cover Design Report*, White Mesa Mill, September 2011. MWH Americas, Inc.	**Updated and now Appendix A -** *Updated Tailings Cover Design Report*, White Mesa Mill, December 2016. MWH, Inc.	
Appendix E	*National Emission Standards for Hazardous Air Pollutants Radon Flux Measurement Program, White Mesa Mill Site*, 2010, Tellco Environmental	**Deleted to reduce redundancy** (latest report was submitted to DWMRC)	
Appendix F	*Semi-Annual Monitoring Report January 1 - June 30, 2010, White Mesa Mill Meteorological Station*, August 19, 2011, McVehil-Monnett Associates, Inc.	**Deleted to reduce redundancy** (latest report was submitted to DWMRC).	
Appendix G	*Preliminary Mill Decommissioning Plan*, White Mesa Mill, September 2011, MWH Americas, Inc.	**Updated and now Appendix B -** *Preliminary Mill Decommissioning Plan*, White Mesa Mill, August 2016, MWH, Inc.	

*Main Text and Attachment A were updated from Revision 5.1 to 5.1B (see Section 1).

1 SITE CHARACTERISTICS

EFRI operates the Mill, which is located approximately six miles south of Blanding, Utah (see Figures 1-1 and 1-2). The Mill was initially licensed by the NRC in May 1980 under NRC Source Material License No. SUA-1358. Upon the State of Utah becoming an Agreement State for uranium mills in August 2004, the Mill's NRC license was replaced with the Mill's current State of Utah License and the Mill's GWDP.

The License was up for timely renewal on March 31, 2007 in accordance with Utah Administrative Code ("UAC") R313-22-36.[3] In accordance with R313-22-36, EFRI submitted an application to the Director ("Director") of Utah Department of Environmental Quality, Division of Waste Management and Radiation Control ("DWMRC")[4] on February 27, 2007 for renewal of the License under R313-22-37 (the "2007 License Renewal Application"). Similarly, the GWDP was up for timely renewal on March 8, 2010, in accordance with UAC R317-6-6.7. In 2009, 2012, and 2014, EFRI filed an application to the DWMRC for renewal of the GWDP for under R313-6-6.7.

The Mill is also subject to State of Utah Air Quality Approval Order DAQE-AN1205005-06 (the "Air Approval Order") which was re-issued on March 2, 2011 and is not up for renewal at this time.

Revision 3.0 of this Plan was submitted to and approved by NRC in 2000. A copy of Revision 3.0 of this Plan was also submitted to the DWMRC as part of the 2007 License Renewal Application. The most recently approved version of the Reclamation Plan is Revision 3.2b (Denison, 2011a). This version of the Reclamation Plan was approved by DRC under the Mill License on January 26, 2011. A copy of the White Mesa Mill Reclamation Plan, Revision 4.0 was previously submitted to the Director in November 2009 and is on file at the DRC. This version and previous versions of the Reclamation Plan presented design criteria for a multi-layered cover system. Revision 5.0 of this Plan was submitted to the DWMRC in September 2011. EFRI prepared Revision 5.0 of the Plan to incorporate changes since 2009 and to address interrogatories from the DWMRC (DRC, 2010 and 2011). EFRI prepared Revision 5.1 of the Plan to incorporate changes since 2011 and include updates provided in EFRI response to interrogatories and review comments from DWMRC on Reclamation Plan, Revision 5.0 (Denison, 2012; EFRI, 2012a; EFRI, 2015). EFRI prepared this Revision 5.1B to address select public comments on the White Mesa Mill Groundwater Discharge Permit and Radioactive Materials License. EFRI responses to public comments were documented in EFRI (2017) and an updated Section 6 to Revision 5.1 of the Plan was provided as an attachment. Attachment A (Technical Specifications) has also been updated for Revision 5.1B with a minor revision to address public comments. The remaining attachments and appendices do not require revisions and therefore the designation of Revision 5.1 or reference to Revision 5.1 remain to indicate changes have not been made to these components of the Plan. EFRI prepared this Revision 5.1C for approval with the License amendment application to construct Cells 5A and 5B.

This Section 1.0 of the Plan incorporates by reference, updates or supplements, information previously submitted in previous environmental analyses performed at the Mill, as described below.

[3] The License was originally issued by the NRC as a source material license under 10 CFR Part 40 on March 31, 1980. It was renewed by NRC in 1987 and again in 1997. After the State of Utah became an Agreement State for uranium mills in August 2004, the License was re-issued by the DWMRC as a State of Utah Radioactive Materials License on February 16, 2005, but the remaining term of the License did not change.

[4] Prior to 2015, the DWMRC was two separate divisions of UDEQ, the Division of Radiation Control and the Division of Solid and Hazardous Waste.

The Mill was shut down during all of 1984. The Mill operated at least part of each year from 1985 through 1990. Mill operations again ceased during the years of 1991 through 1994. EFN reacquired sole ownership on May 26, 1994, and the Mill operated again during 1995 and 1996. After acquisition of the Mill by Denison and its affiliates several local mines were restarted and the Mill processed conventional ore during 1999 and early 2000. With the resurgence in uranium and vanadium prices in 2003, Denison reopened several area mines and again began processing uranium and vanadium ores in April 2008. Mill operations were suspended in May 2009, and resumed in March 2010. Conventional ore processing was again suspended in July 2011, resumed in November 2011 through March 2012, and suspended in April 2012. Denison became EFRI after July 25, 2012. Conventional ore processing resumed from August 2012 through June 2013, was suspended in July 2013, resumed May 2014 through August 2014, and was suspended again in September 2014. The Mill again processed conventional ore from August thru November 2016, Typical employment figures for the Mill are approximately 110 during uranium-only operations and 150 during uranium/vanadium operations.

Commencing in the early 1990s through today, the Mill has processed alternate feed materials from time to time when the Mill has not been processing conventional ores. Alternate feed materials are uranium-bearing materials other than conventionally mined uranium ores. The Mill installed an alternate feed circuit in 2009 that allows the Mill to process certain alternate feed materials simultaneously with conventional ores.

2.2.2 Mill Circuit

While originally designed for a capacity of 1,500 dry tons per day (dtpd), the Mill capacity was boosted to the present rated design of 1,980 dtpd prior to commissioning.

The Mill uses an atmospheric hot acid leach followed by counter current decantation (CCD). This in turn is followed by a clarification stage which precedes the solvent extraction (SX) circuit. Kerosene containing iso-decanol and tertiary amines extracts the uranium and vanadium from the aqueous solution in the SX circuit. Salt and soda ash are then used to strip the uranium and vanadium from the organic phase.

After extraction of the uranium values from the aqueous solution in SX, uranium is precipitated with anhydrous ammonia, dissolved, and re-precipitated to improve product quality. The resulting precipitate is then washed and dewatered using centrifuges to produce a final product called "yellowcake." The yellowcake is dried in a multiple hearth dryer and packaged in drums weighing approximately 800 to 1,000 lbs. for shipping to converters.

After the uranium values are stripped from the pregnant solution in SX, the vanadium values are transferred to tertiary amines contained in kerosene and concentrated into an intermediate product called vanadium product liquor (VPL). An intermediate product, ammonium metavanadate (AMV), is precipitated from the VPL using ammonium sulfate in batch precipitators. The AMV is then filtered on a belt filter and, if necessary, dried. Normally, the AMV cake is fed to fusion furnaces where it is converted to the Mill's primary vanadium product, V_2O_5 tech flake, commonly called "black flake."

The same basic process steps used for the recovery of uranium from conventional ores are used for the recovery of uranium from alternate feed materials, with some variations depending on the particular alternate feed material.

The Mill processed 1,511,544 tons of conventional ore and other materials from May 6, 1980 to February 4, 1983. During the second operational period from October 1, 1985 through December 7, 1987, 1,023,393 tons of conventional ore were processed. During the third operational period from July 1988 through November 1990, 1,015,032 tons of conventional ore were processed. During the fourth operational period from August 1995 through January 1996, 203,317 tons of conventional ore were processed. In the fifth operational period, from May 1996 through September 1996, the Mill processed 3,868 tons of calcium fluoride alternate feed material. From 1997 to early 1999, the Mill processed 58,403 tons from several additional alternate feed stocks.

With rising uranium prices in the late 1990s, company mines were reopened in 1997, and 87,250 tons of conventional ore were processed in 1999 and early 2000. In 2002 and 2003, the Mill processed 266,690 tons of alternate feed material from government cleanup projects. An additional 40,866 tons of alternate feed materials were processed in 2007. An additional 1,401 tons of alternate feed materials were processed from 2008 through July 2011. From April 2008 through July 2011 the Mill processed an additional 722,843 tons of conventional ore. The Mill processed 340,058 and 24,036 tons of conventional ore and alternate feed materials, respectively, between August 2011 and March 2016. The Mill processed an additional 46,000 tons of conventional ore between August 2016 and November 201.6

Inception to date material processed through ~~March~~December 2016 totals ~~5,298,701~~5,344,701 tons. This total is for all processing periods and feeds combined.

2.2.3 Tailings Management Facilities

Tailings produced by the Mill from conventional ores typically contain 30 percent moisture by weight, have an in-place dry density of 86.3 pounds per cubic foot (calculated from Cell 2 volume and tons placed), have a size distribution with a significant -200 to -325 mesh size fraction, and have a high acid and flocculent content. Tailings from alternate feed materials that are similar physically to conventional ores, which comprise most of the tons of alternate feed materials processed to date at the Mill, are similar to the tailings for conventional ores. Tailings from some of the higher grade, lower volume alternate feed materials may vary somewhat from the tailings from conventional ores, primarily in moisture and density content.

The tailings facilities at the Mill currently consist of five cells as follows:

- Cell 1, constructed with a 30 mil PVC earthen-covered liner, is used for the evaporation of process solutions (Cell 1 was previously referred to as Cell 1-I).
- Cell 2, constructed with a 30 mil PVC earthen-covered liner, is used for the storage of barren tailings sands. This Cell is full and has been partially reclaimed.
- Cell 3, constructed with a 30 mil PVC earthen-covered liner, is used for the storage of barren tailings sands and process solutions, but currently only receives mill waste and byproduct material in accordance with License provisions. This cell is partially filled and has been partially reclaimed.
- Cell 4A, constructed with a geosynthetic clay liner, a 60 mil HDPE liner, a 300 mil HDPE geonet drainage layer, a second 60 mil HDPE liner, and a slimes drain network over the entire cell bottom. This cell was placed into service in October 2008 and is used for storage of barren tailings sands and evaporation of process solutions.
- Cell 4B, constructed with a geosynthetic clay liner, a 60 mil HDPE liner, a 300 mil HDPE geonet drainage layer, a second 60 mil HDPE liner, and a slimes drain network over the entire cell bottom. This cell was placed into service in February 2011, is used for evaporation of process solutions, and has not been used for tailings storage.

Total estimated design capacity of Cells 2, 3, 4A, and 4B is approximately eight million tons. Figures 1.5-4 and 1.5-5 show the locations of the tailings management system cells.

3 TAILINGS RECLAMATION PLAN

This section provides an overview of the Mill location and property; details the facilities to be reclaimed; and describes the design criteria applied in this Plan. Drawings are presented as an attachment to this report. Technical specifications are presented in Attachment A. Attachment B presents the quality assurance and quality control plan for construction activities. Attachment C presents cost estimates for reclamation (based on the Existing Cover Design). Attachment D presents the most current Radiation Protection Manual for Reclamation Activities. Attachment E provides documents on the approved Existing Cover Design that was presented in Reclamation Plan Revision 3.2b (Denison, 2011b).

The Reclamation Plan is written assuming the tailings management system Cells 2, 3, 4A, and 4B, 5A and 5B will receive tailings to the maximum permitted tailings elevations. Cell 4B is currently used for evaporation of process solutions and has not been used for tailings storage. Cells 5A and 5B have not been constructed. The Plan has been written assuming Cells 4B, 5A and 5B will be used in the future for tailings storage.

If Cell 4B is not used in the future for tailings storage, Cell 4B can be reclaimed for clean closure. Any remaining solutions would be pumped to the last active tailings Cell. The liner system would be removed and disposed in the last active tailings cell. The exterior embankments would then be regraded. This design is not presented in this report.

3.1 Location and Property Description

The Mill is located approximately six miles south of Blanding, Utah on US Highway 191 on a parcel of land encompassing all or part of Sections 21, 22, 27, 28, 29, 32, and 33 of T37S, R22E, and Sections 4, 5, 6, 8, 9, and 16 of T38S, R22E, Salt Lake Base and Meridian described as follows (Figure 3.1-1):

> The south half of the south half of Section 21; the southeast quarter of the southeast quarter of Section 22; the northwest quarter of the northwest quarter and lots 1 and 4 of Section 27 all that part of the southwest quarter of the northwest quarter and the northwest quarter southwest quarter of Section 27 lying west of Utah State Highway 163; the northeast quarter of the northwest quarter, the south half of the northwest quarter, the northeast quarter and the south half of Section 28; the southeast quarter of the southeast quarter of Section 29; the east half of Section 32 and all of Section 33, Township 37 South, Range 22 East, Salt Lake Base and Meridian. Lots 1 through 4, inclusive, the south half of the north half, the southwest quarter, the west half of the southeast quarter, the west half of the east half of the southeast quarter and the west half of the east half of the east half of the southeast quarter of Section 4; Lots 1 through 4, inclusive, the south half of the north half and the south half of Section 5 (all); Lots 1 and 2, the south half of

the northeast quarter and the south half of Section 6 (E1/2); the northeast quarter of Section 8; all of Section 9 and all of Section 16, Township 38 South, Range 22 East, Salt Lake Base and Meridian. Additional land is controlled by 46 Mill site claims. Total land holdings are approximately 5,415 acres.

3.2 Facilities to be Reclaimed

See the Drawings for a general layout of the Mill yard and related facilities and the restricted area boundary.

3.2.1 Summary of Facilities to be Reclaimed

The facilities to be reclaimed include the following:

- Cell 1 (evaporation). Cell 1 was previously referred to as Cell 1-I.
- Cells 2, 3, and 4A (tailings).
- Cell 4B (This cell is currently used for evaporation. The reclamation design assumes this cell will be used for tailings in the future).
- Cells 5A/5B. The reclamation design assumes these cells will be used for tailings in the future.
- Mill buildings and equipment.
- On-site contaminated areas.
- Off-site contaminated areas (i.e., potential areas affected by windblown tailings).

The reclamation of the above facilities will include the following:

- Placement of contaminated soils, crystals, and synthetic liner material and any contaminated underlying soils from Cell 1 into the last active tailings cell
- Placement of a liner system on a portion of the Cell 1 impoundment area to be used for disposal of contaminated materials and debris from the Mill site, if needed
- Decommissioning Cell 1
- Placement of materials and debris from Mill decommissioning into the last active tailings cell or Cell 1 Disposal Area
- Placement of an engineered multi-layer cover over the entire area of Cells 2, 3, 4A, 4B, 5A, 5B and the Cell 1 Disposal Area
- Construction of runoff control and diversion channels as necessary
- Reclamation of Mill and ancillary areas
- Reclamation of borrow sources

3.2.2 Tailings and Evaporative Cells

The following subsections describe the cover design and reclamation procedures for Cells 1, 2, 3, 4A, and 4B, 5A and 5B. Complete engineering details and text are presented in the Updated Tailings Cover Design Report included as Appendix A to this Reclamation Plan.

A portion of Cell 1 (i.e., the Cell 1 Disposal Area), adjacent to and running parallel to the downstream cell dike, may be used for permanent disposal of contaminated materials and debris from the Mill site decommissioning and windblown cleanup. The actual area of the Cell 1 Disposal Area needed for storage of additional material will depend on the status of Cells 3, 4A, and 4B at the time of final Mill decommissioning. A portion of the Mill area decommissioning material may be placed in Cells 3, 4A or 4B if space is available, but for purposes of the reclamation design the entire quantity of contaminated materials from the Mill site decommissioning is assumed to be placed in the Cell 1 Disposal Area, which will subsequently be covered with the ET cover. This results in approximately 10 acres of the Cell 1 area constituting the Cell 1 Disposal Area and being utilized for permanent tailings storage. The remaining area of Cell 1 will then be breached and converted to a sedimentation basin. All runoff from the covered Cell 1 Disposal Area, the Mill area and the area immediately north of Cell 1 will be routed into the sedimentation basin and will discharge onto the natural ground via the channel located at the southwest corner of the basin. The channel is designed to accommodate the PMF flood. Hydraulic and erosional analyses are provided in Appendix A. The channel will be a bedrock channel with a 0.1 percent channel slope, 150-foot bottom width, and 3 horizontal: 1 vertical sideslopes.

3.2.2.3 Cell 2

Cell 2 has been filled with tailings and will be covered with the ET cover to a minimum cover thickness of 10.5 feet. The final cover will drain at a slope of 0.5 to 1 percent to the north and south as shown in the Drawings.

The cover will be as described in Section 3.2.2.1 above and will consist of a 2.5 feet of interim fill, followed by 4 feet of compacted cover, overlain by 3.5 feet of growth medium. Half a foot of topsoil or gravel-admixture will be utilized as armor against erosion at the surface of the cover. External side slopes will be graded to a 5:1 slope and will have 6 inches of angular riprap on the cover surface for erosion protection. A rock apron with dimensions as shown in the Drawings will be constructed at the transition areas of the toes of the side slopes of Cell 2.

3.2.2.4 Cell 3

Cell 3 will be filled with tailings, debris and contaminated soils and covered with the same ET cover system and erosion protection as Cell 2, except the total thickness will be 10 feet with a compacted cover layer of 3.5 feet.

3.2.2.5 Cells 4A and 4B

Cells 4A and 4B are designed to be filled with tailings, debris and contaminated soils and will be covered with the same ET cover system as Cell 2 and Cell 3, except the total thickness will be 9.5 feet with a compacted cover layer of 3 feet. The south external side slopes will be graded to 5H:1V and will have 8 inches of angular riprap on the cover surface for erosion protection. A rock apron with dimensions as shown on the drawings will be constructed at the south side slopes of Cells 4A and 4B. The east and west external side slopes will be graded to 5H:1V and have the same erosion protection as the east and west sides slopes of Cells 2 and 3.

3.2.2.6 Cells 5A and 5B

Cells 5A and 5B are designed to be filled with tailings, debris and contaminated soils and will be covered with the same ET cover system as Cell 2 and Cell 3, except the total thickness will be 9.5 feet with a compacted cover layer of 3 feet. The south external side slopes will be graded to 5H:1V and will have 8 inches of angular riprap on the cover surface for erosion protection. A rock apron with dimensions as shown on the drawings will be constructed at the south side slopes of Cells 5A and 5B. The east and west external side slopes will be graded to 5H:1V and have the same erosion protection as the east and west sides slopes of Cells 2 and 3.

3.3 Design Criteria

As required by Part I.H.11 of the GWDP, EFRI has completed an infiltration and contaminant transport model of the final tailings cover system to demonstrate the long-term ability of the ET cover to protect nearby groundwater quality. The ET cover design and basis presented in Appendix A will be used for this version of the Plan.

The design criteria summaries in this section are adapted from the Updated Tailings Cover Design Report. A copy of the Tailings Cover Design Report is included as Appendix A. It contains all of the calculations used in design and summarized in this section.

3.3.1 Regulatory Criteria

Information contained in 10 CFR Part 20, 10 CFR Part 40 and Appendix A to 10 CFR Part 40 (which are incorporated by reference into UAC R313-24-4), and 40 CFR Part 192 were used as criteria in final designs under this Plan. In addition, the following documents also provided guidance:

- Benson, C.H. W.H. Albright, D.O. Fratta, J.M. Tinjum, E. Kucukkirca, S.H. Lee, J. Scalia, P.D. Schlicht, and X. Wang, 2011. Engineered Covers for Waste Containment: Changes in Engineering Properties and Implications for Long-Term Performance Assessment (in four volumes). NUREG/CR-7028, Prepared for the U.S. Nuclear Regulatory Commission, Washington, D.C., December.
- Johnson, T.L., 2002. "Design of Erosion Protection for Long-Term Stabilization." U.S. Nuclear Regulatory Commission (NRC), *NUREG-1623*. September.
- Nelson, J.D. , S.R. Abt, R.L. Volpe, D. Van Zye, N.E. Hinkle, and W.P. Staub, 1986. Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments, NUREG/CR-4620. June.
- U. S. Department of Energy (DOE), 1988. Effect of Freezing and Thawing on UMTRA Covers, Albuquerque, New Mexico, October.
- U.S. Department of Energy (DOE), 1989. UMTRA-DOE Technical Approach Document, Revision II, UMTRA-DOE/AL 050425.0002. December.
- U.S. Nuclear Regulatory Commission (NRC), 1984. Radon Attenuation Handbook for Uranium Mill Tailings Cover Design, NUREG/CR-3533
- U.S. Nuclear Regulatory Commission (NRC), 1989. Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers, Regulatory Guide 3.64.
- U.S. Nuclear Regulatory Commission (NRC), 1990. "Final Staff Technical Position, Design of Erosion Protective Covers for Stabilization of Uranium Mill Tailings Sites," August.
- U.S. Nuclear Regulatory Commission (NRC), 2003. Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites under Title II of the Uranium Mill Tailings Radiation Control Act of 1978. NUREG-1620, Revision 1, June.

computer program SLOPE/W (Geo-Slope, 2007). A complete description of the input parameters and assumptions used in the analyses is provided in Appendix A. Material strength parameters used for the analyses were based on historical laboratory testing on tailings and clay materials (Advanced Terra Testing, 1996; Chen and Associates, 1987; D'Appolonia, 1982; and Western Colorado Testing, 1999), laboratory testing conducted in 2010 and 2012 on potential cover borrow materials (see Attachment B of EFRI, 2012a), laboratory testing conducted in 2013 on tailings (MWH, 2015b) and typical published values.

The mean Peak Ground Acceleration (PGA) for reclaimed conditions is 0.15g based on the site specific PSHA (MWH, 2015a). This PGA represents the seismic loading from the Maximum Credible Earthquake (MCE). The seismic coefficient used for the pseudo static stability analysis was 0.10 g (equal to 2/3 of the PGA).

The calculated factors of safety range from 2.6 to 3.9 and 1.7 to 2.5 for static and pseudo-static loading conditions, respectively. The calculated factors of safety for both the long-term static condition and the pseudo-static condition exceed the required values of 1.5 and 1.1 respectively (NRC, 2003).

3.3.7 Tailings Dewatering

Cells 2, 3, 4A, and 4B are constructed to allow tailings dewatering. Cells 5A and 5B will have the same tailings dewatering system as Cell 4B. Dewatering analyses have been conducted for these tailings management cells assuming the cells receive tailings to the maximum permitted tailings elevation. Dewatering analyses for Cells 2 and 3 were conducted by MWH and are presented in Appendix A. Dewatering analyses for Cells 4A and 4B were conducted by Geosyntec (2007a, 2007b). The pertinent excerpts from MWH (2010), Geosyntec (2007a, 2007b), and DRC (2008) are included in Appendix A.

Water levels in Cells 2 and 3 were measured during the October 2013 tailings investigation (MWH, 2015b). Results of the investigation indicated migration of water towards the sump in Cell 2. This was expected since water has been pumped from the Cell 2 sump since 2008. Dewatering of Cell 3 has not yet started and the October 2013 investigation reflected this, with measured water levels a few feet below the tailings surface.

To monitor changes in water levels due to dewatering prior to and after final cover placement, installation of standpipe piezometers was recommended across the cells prior to the first phase of final cover placement and extension of the piezometers during final cover placement. These piezometers will provide information on the rate and extent of dewatering of the tailings. The piezometers are primarily located adjacent to the settlement monuments to minimize damage to the piezometers during cover construction, while providing sufficient locations to evaluate the water levels. Water levels are recommended to be monitored at the same frequency and duration as the settlement monuments. Piezometer locations for Cell 2 are shown in Appendix L of the Updated Tailings Cover Design Report.

3.3.8 Settlement and Liquefaction Analyses

Settlement analyses and evaluation of liquefaction potential for the tailings were performed for the tailings cells. A discussion of the analyses and results are provided in Appendix A.

One-dimensional settlement analyses were conducted to evaluate settlement due to placement of final cover, dewatering of the tailings cells, long-term static (creep) settlement, and seismically induced (seismic)

5 REVERSION TO EXISTING COVER DESIGN

5.1 Background

On November 11, 2015, the UDEQ Division of Waste Management and Radiation Control (DWMRC) recommended EFRI develop a plan to begin reclamation of the tailings management system cells. This plan would consist of placing the cover system presented in this Plan (the "Proposed Cover System") on Cell 2 and demonstrating acceptable cover performance via a performance monitoring program.

Per the Stipulation and Consent Agreement (SCA) ~~in development~~ between EFRI and DWMRC, Cell 2 reclamation is planned to occur in 2 phases. Phase 1 is comprised of Layers 1 and 2 of the Proposed Cover System, and will be placed on Cell 2 along with a Primary Test Section that contains all of the Proposed Cover System, including the vegetative cover. The Primary Test Section along with a Supplemental Test Section (located off of Cell 2, and relating only to vegetative cover and erosion control) will be tested over a period of approximately 7 years (the "Cell 2 Test Period").

Under the SCA, the Cell 2 Primary Test Section and Supplemental Test Section will have to meet required performance criteria to verify the effectiveness of the Proposed Cover System and initiate Phase 2 cover placement.

5.2 Proposed Cover Design Meets all Applicable Regulatory Criteria

If the Primary Test Section and Supplemental Test Section demonstrate that the Proposed Cover System meets all applicable regulatory criteria, then:

a) Cell 2

Phase 2, comprised of Layer 3, Layer 4 and the vegetative cover of the Proposed Cover System, will be placed on Cell 2, in accordance with the SCA and Section 6.0 below;

b) Other Tailings Management System Cells being Reclaimed during Cell 2 Test Period

In the event that any other tailings management system cells are to be reclaimed during the Cell 2 Test Period, such tailings impoundments will be reclaimed by placing Phase 1 of the Proposed Cover System on the cell, and then waiting until the Cell 2 test is completed. Thereafter, reclamation of the cells will be completed in the same manner as Cell 2, in accordance with the SCA and Section 6.0 below; and

c) Other Tailings Management System Cells Being Reclaimed after Cell 2 Test Period

Upon final reclamation in accordance with Section 6.0 below, the other tailings management system cells, which had not commenced reclamation during the Cell 2 test period, would be reclaimed with the Proposed Cover System.

(b) When Final Closure of an Impoundment Begins

Final closure of an impoundment begins when the owner or operator provides written notice to the EPA and to the Director that:

i) In the case of a conventional impoundment (i.e., a tailings impoundment), the impoundment is no longer receiving uranium byproduct material or tailings, is no longer on standby status for such receipt and is being managed under an approved reclamation plan for that impoundment or facility closure plan; and

ii) In the case of a non-conventional impoundment (e.g., an evaporation pond), the impoundment is no longer required for evaporation or holding purposes, is no longer on standby for such purposes and is being managed under an approved reclamation plan for that impoundment or facility closure plan.

An approved reclamation plan prepared and approved in accordance with 10 CFR part 40, Appendix A is considered a reclamation plan for purposes of this paragraph 6.2.1(b).

(c) The Existing Tailings Management System at the Mill

The tailings management system at the Mill currently consists of three tailings impoundments: Cell 2, which is not in operation and is in final closure, and Cells 3 and 4A, which are in operation. Cell 1 is an evaporation pond. Cell 4B is currently being used as an evaporation pond and will continue to be used as an evaporation pond until it first starts to receive tailings sands or other byproduct material (other than solutions) for disposal. Future cells, including Cell 5A and Cell 5B, may commence as evaporation ponds, and will continue as evaporation ponds until they first receive tailings sands or other byproduct material (other than solutions) for disposal, at which time they will become tailings impoundments.

(d) The Proposed Cover Design and Existing Cover Design

This Plan presents a proposed evapotranspiration (ET) cover (the "**Proposed Cover Design**") as a component of the reclamation plan for the tailings impoundments, to replace the rock armor cover design (the "**Existing Cover Design**") set out in Appendix D to the Reclamation Plan Version 3.2b (Denison, 2011b).

The Stipulation and Consent Agreement described in Section 6.2.1(e) below and Section 5.0 above describe a set of circumstances under which the Final Cover Design could be the Existing Cover Design rather than the Proposed Cover Design. Section 5.0 of this Plan describes the manner in which EFRI would revert from the Proposed Cover Design to the Existing Cover Design if so required by the Stipulation and Consent Agreement.

Stantec

Stantec Consulting Services Inc.
3325 South Timberline Road Suite 150, Fort Collins CO 80525-2903

June 15, 2018
File: 233001001

Attention: Ms. Kathy Weinel
Energy Fuels Resources (USA) Inc.
225 Union Blvd., Suite 600
Lakewood Colorado 80228

Reference: Conceptual Cover Design for White Mesa Uranium Mill Proposed Cells 5A and 5B

Dear Kathy,

This letter provides a summary of the conceptual cover design for the Energy Fuels Resources (USA) Inc. (EFRI) White Mesa Uranium Mill proposed Cells 5A and 5B (cells designed by others). The conceptual cover design is based on the Appendix A (Updated Tailings Cover Design Report) to the EFRI Reclamation Plan, Revision 5.1B dated February 2018.

The plan view for the reclamation of Cells 5A and 5B is shown on Figure 1. The cover slope for Cells 5A and 5B is designed at a 0.8 percent slope, which is consistent with the Cells 4A and 4B cover slopes and aligns with the proposed cell design for Cells 5A and 5B. The external side slopes of the Cells 5A and 5B embankments will be graded to 5:1 (horizontal:vertical) as required for reclamation.

The cover system for Cells 5A and 5B is designed as a monolithic evapotranspiration cover. This is consistent with the current cover design for the other tailings management cells. The proposed cover design is designed with sufficient thickness to protect against frost penetration, attenuate radon flux, minimize both plant root and burrowing animal intrusion, and provide adequate water storage capacity to minimize the rate of infiltration into the underlying tailings. The radium-226 activity concentration for the materials to be placed in Cells 5A and 5B are expected to be similar to the materials that have been and may be placed in Cells 4A and 4B. Therefore, the cover thickness is proposed to be the same for Cells 5A and 5B as Cells 4A and 4B.

The ET cover system is designed to have a minimum thickness of 9.5 feet, and consist of the following materials listed below from top to bottom (see Figure 2):

- Layer 4 - 0.5 ft (15 cm) thick Erosion Protection Layer (gravel-admixture)
- Layer 3 - 3.5 ft (107 cm) thick Growth Medium Layer acting as a Water Storage/Biointrusion/Frost Protection/Secondary Radon Attenuation Layer (loam to sandy clay)
- Layer 2 – 3.0 ft (91 cm) thick Compacted Cover Layer acting as the Primary Radon Attenuation Layer (highly compacted loam to sandy clay)
- Layer 1 - 2.5 ft (76 cm) thick (minimum) Interim Fill Layer actin as a Secondary Radon Attenuation and Grading Layer (loam to sandy clay)

Reference: Conceptual Cover Design for White Mesa Uranium Mill Proposed Cells 5A and 5B

Preliminary erosional stability calculations indicate that the top cover surface of Cells 5A and 5B will require 25 percent (by weight) 1-inch minus gravel mixed in with the topsoil. This is consistent with the cover design for Cells 4A and 4B.

Please contact me if you have questions on this letter or need additional information.

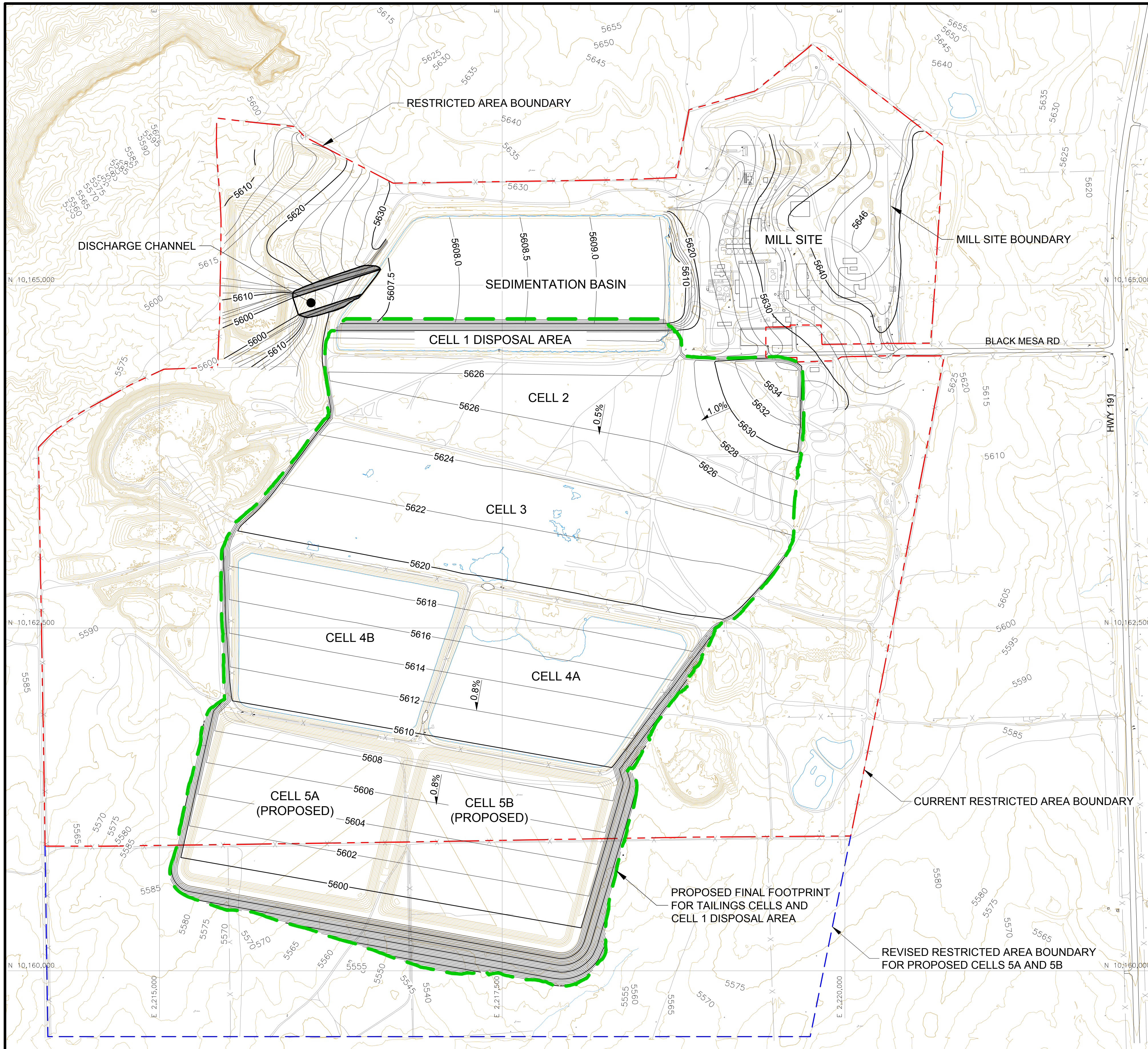
Regards,

Stantec Consulting Services Inc.

Melanie M. Davis

Melanie Davis P.E.
Senior Associate Geotechnical Engineer
Office: 970-212-2749
Mobile: 970-214-6403
melanie.davis@stantec.com

Attachments: Figures



LEGEND:

5605	EXISTING GROUND SURFACE CONTOUR AND ELEVATION, FEET (SEE REFERENCE)
5605	FINAL GRADING SURFACE CONTOUR AND ELEVATION, FEET
	EXISTING ROAD
	EXISTING WATER
	EXISTING TRAIL
X	EXISTING FENCE
□	EXISTING STRUCTURE

0 400' 800'

ISSUE	DESCRIPTION	TECH	ENG	DATE
A	CELL 5A/5B CONCEPTUAL RECLAMATION DESIGN	KR	MD	06–18

DISCLAIMER:
THIS DRAWING WAS DEVELOPED THROUGH THE APPLICATION OF PROFESSIONAL ENGINEERING SKILL AND PROPRIETARY METHODOLOGIES, PROCESSES AND KNOW HOW OF MWH AS AUTHOR ALL PURSUANT TO THE TERMS OF A CONTRACTUAL SCOPE OF WORK GOVERNING ITS PREPARATION. THIS DRAWING MAY NOT BE USED OR MODIFIED OTHER THAN IN STRICT ACCORDANCE WITH THE TERMS OF THE GOVERNING CONTRACT AND SCOPE OF WORK OR OTHERWISE ABSENT THE INVOLVEMENT AND CONSENT OF THE AUTHOR. ANY ALTERATION OR ADAPTATION OF THIS DRAWING SHALL BE CONSISTENT WITH THE AUTHOR'S CONTRACTUAL AND PROPRIETARY RIGHTS AND BE AT USER'S SOLE RISK AND WITHOUT ANY LIABILITY OR LEGAL RESPONSIBILITY OF MWH.

DRAWING REFERENCE(S):
- EXISTING TOPOGRAPHY BASED UPON FILE PROVIDED FROM ENERGY FUELS ON JULY 20, 2015. PER ENERGY FUELS, GROUND SURFACE CONTOURS ARE FROM 2012 AERIAL SURVEY CONDUCTED BY JONES & DeMILLE ENGINEERING INC., EXCEPT FOR CELLS 2 AND 3. CELL 2 TOPOGRAPHY FROM ENERGY FUELS SURVEY CONDUCTED OCTOBER 2013. CELL 3 TOPOGRAPHY FROM ENERGY FUELS SURVEY CONDUCTED ON JULY 8, 2014.

DESIGNED BY	M DAVIS	06–18
DRAWN BY	K REED	06–18
CHECKED BY	C STRACHAN	06–18
APPROVED BY	M DAVIS	06–18
PROJECT MANAGER	M DAVIS	06–18
CLIENT APPROVAL		
CLIENT REFERENCE NO.		

ENERGY FUELS

PROJECT LOCATION: BLANDING, UTAH

PROJECT: WHITE MESA MILL SITE RECLAMATION

TITLE: PLAN VIEW OF RECLAMATION FEATURES

Stantec

SHEET: 1
REVISION: A
FILE NAME: WMM CELL 5 COVER
DATE: JUNE 2018

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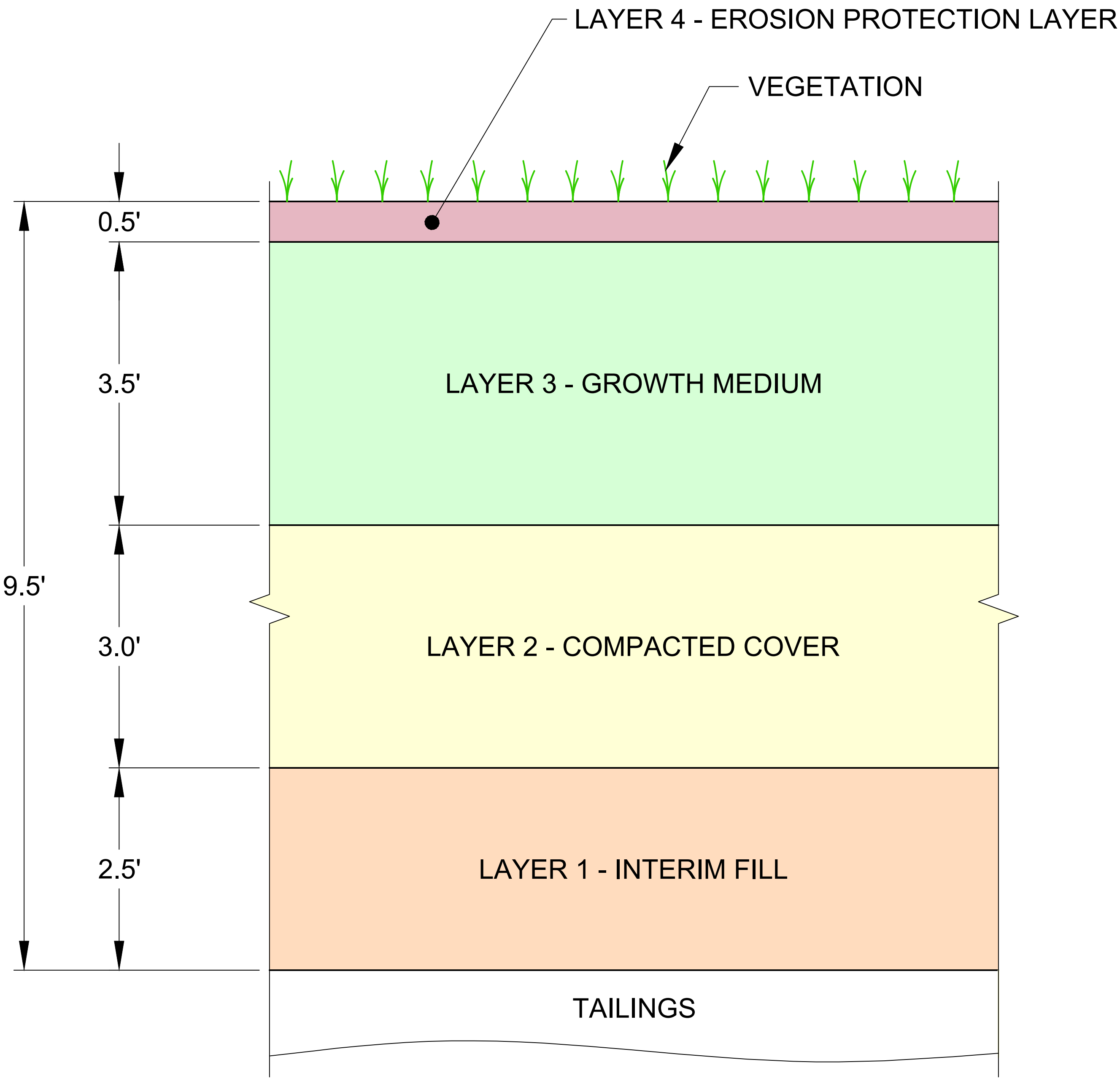

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ENERGY FUELS

PROJECT
WHITE MESA MILL TAILINGS RECLAMATION

TITLE
COVER PROFILE WITHIN LYSIMETER

Stantec

DATE
JUNE 2018

FIGURE 2

FILE NAME
1009740 WM ET COVR

Prepared for

Energy Fuels Resources (USA), Inc.
6425 S. Highway 191
P.O. Box 809
Blanding, UT 84511

CELLS 5A & 5B DESIGN REPORT

WHITE MESA MILL
BLANDING, UTAH

Prepared by

Geosyntec consultants

engineers | scientists | innovators

16644 West Bernardo Drive, Suite 301
San Diego, CA 92127

Project Number SC0634A

July 2018

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1. INTRODUCTION

This report presents the results of design analyses performed in support of the Cells 5A and 5B construction at the White Mesa Mill Facility in Blanding, Utah (site). The San Diego office of Geosyntec Consultants, Inc. (Geosyntec) prepared this report for Energy Fuels Resources (USA), Inc. (EF). This report was prepared by Mr. Jay Griffin and reviewed by Ms. Rebecca Oliver, both of Geosyntec. Mr. Gregory Corcoran, P.E. of Geosyntec was in responsible charge and provided senior peer review of the work presented herein in accordance with the internal peer review policy of the firm.

1.1 Objective

The objective of this report is to present the components of Cells 5A and 5B, including two alternative liner systems: Option A – Triple Liner and Option B- Double Liner with Geosynthetic Clay Liner (GCL). EF will decide which Option to construct and notify Utah Division of Waste Management and Radiation Control (UDWMRC) at least 30 days prior to starting construction of the selected Option liner system. This report demonstrates that the proposed Cell 5A and 5B designs and both liner system options comply with the applicable regulatory standards for the State of Utah, the United States Nuclear Regulatory Commission, and the Federal Environmental Protection Agency (USEPA). In particular, the designs are in accordance with the Utah Administrative Code (UAC) R317-6, and the Best Available Technology requirements mandated by Part I.D. of existing site Ground Water Discharge Permit No. UGW370004.

This report contains the design and permitting information for both Options including Construction Drawings (Appendix A-1 and A-2 for Options A and B, respectively), Construction Quality Assurance (CQA) Plan (Appendix B), Technical Specifications (Appendix C), Design Calculations (Appendix D), and supporting boring logs and geotechnical laboratory results (Appendix E).

1.2 Background

Current site operations utilize Cells 1, and 4B for process liquids evaporation and Cells 3 and 4A for disposal of tailings and by-products from the processing operations at the site. Cells 4A and 4B are adjacent to the proposed 5A and 5B cells. Cells 5A and 5B will initially be used for evaporation of process liquids and as needed thereafter for final storage of solids contained in the tailings and by-products from processing operations at the site. Cell 5A will be constructed first and Cell 5B will be constructed in the future.

1.3 Report Organization

The remainder of this design report is organized into the following sections:

- Section 2, *Background and Site Conditions*, presents general information on the site and background information on the existing conditions at Cells 5A and 5B.
- Section 3, *Design*, presents the design for Cells 5A and 5B.
- Section 4, *Summary and Conclusions*, presents the summary, conclusions, and limitations of this technical design report.

As described previously, the Cell 5A and 5B permit documents include Construction Drawings (Appendix A), a Construction Quality Assurance (CQA) Plan (Appendix B), Technical Specifications (Appendix C), engineering design calculations (Appendix D), and seismic refraction data, trench logs, and geotechnical laboratory data (Appendix E).

2. BACKGROUND AND SITE CONDITIONS

2.1 Site Location

The location of the site is shown on Sheet 1 of the Construction Drawings (Appendix A-1 and A-2). The site is located approximately 6 miles south of Blanding, Utah on Highway 191. Per the Universal Transverse Mercator (UTM) Coordinate System, the site is located at 4,159,100 meters Northing and 634,400 meters Easting.

The Mill is located on a parcel of fee land, State of Utah lease property and associated mill site claims, covering approximately 5,415 acres. The site mill operations are limited to approximately 50 acres located directly east of Cell 1. The existing tailings disposal Cells (Cells 1 through 4B) are approximately 454 acres. Cells 5A and 5B are located south of existing cells 4A and 4B. The site plan is shown on Sheet 2 of the Construction Drawings (Appendix A-1 and A-2).

2.2 Climatology

The climate of southeastern Utah is classified as dry to arid. Although varying somewhat with elevation and terrain, the climate in the vicinity of the site can be considered as semi-arid with normal precipitation of about 13.4 in (WRCC, 2005). Most precipitation is in the form of rain, with snowfall accounting for about 30 percent of the annual precipitation total. There are two separate rainfall seasons in the region, the first in late summer and early autumn (August to October) and the second during the winter months (December to March).

The average temperature in Blanding ranges from approximately 30 degrees Fahrenheit (ºF) in January to approximately 76ºF in July. Average minimum temperatures are approximately 18ºF in January and average maximum temperatures are approximately 91ºF in July (City-Data.com, 2007).

The mean annual relative humidity is about 44 percent and is normally highest in January and lowest in July. The average annual Class I pan evaporation rate is 86 inches (WRCC, 2007), with the largest evaporation occurring in July. Values of pan coefficients range from 60 percent to 81 percent. The annual lake evaporation rate for the site is 47.6 inches and the net evaporation rate is 34.2 inches per year.

2.3 Topography

The existing topography within the Cells 5A and 5B area consists of a gently sloping grade (approximately 2 percent) from the northwestern portion of Cell 5A to the southwestern portion of Cell 5B and from the northeastern portion of Cell 5B to the southwestern portion of Cell 5B. Existing Cell 4A and 4B slopes within the proposed Cell 5A and 5B area are inclined at a slope of approximately 3 horizontal : 1 vertical (3H:1V).

2.4 Existing Soil Conditions

2.4.1 Surface Conditions

Currently, the proposed 5A and 5B Cells are undeveloped and covered by native low grass and shrub vegetation. The site is bordered to the north by the existing Cells 4A and 4B and to the south, east, and west by undeveloped lands.

The existing ground surface within the area of the proposed Cell 5A slopes gently from northwest to south-southeast from respective elevations of approximately 5600 feet to 5554 feet, above Mean Sea Level (MSL). The existing ground surface within the proposed Cell 5B area gently slopes from northeast to southwest from respective elevation of approximately 5590 feet to 5550 feet above MSL.

2.4.2 Soil Berms

Soil berms exist on the northern perimeters of the proposed Cells 5A and 5B. These berms were constructed previously of engineered fill with approximately 3H:1V side slopes.

2.4.3 Subsurface Conditions

Geosyntec performed a geotechnical investigation within the proposed limits of Cells 5A and 5B (Figure 1). The geotechnical investigation consisted of a site reconnaissance, seismic refraction surveys lines, test pit excavation and observation, soil sampling, and geotechnical laboratory analysis of soil samples collected.

Soils encountered during soil sampling and test pit excavation and observation were consistent with formations in Southern Utah. Within the limits of the explorations, the site is underlain by surficial windblown loess and eolian deposits and variably weathered deposits of the Dakota Sandstone.

Loess and eolian deposits were encountered at the ground surface across the site extending to approximate depths of 1 to 7 feet. The deposit is generally thickest along the western portion of the site and thins to the east and southeast, with locally thicker deposits in between. The loess and eolian deposits are generally homogeneous across the site consisting of firm to stiff, yellowish red sandy clay (Unified Soil Classification System Classification CL). Test pit logs and geotechnical laboratory results are presented in Appendix E.

The Dakota Sandstone underlies the surficial deposits at depth across the entire site area. The deposit generally exhibits a weathering rind approximately 0 to 7.5 feet thick consisting of dense to very dense, pale yellow to pink, silty fine sandstone with irregular zones of caliche accumulation. The unweathered Dakota Sandstone is encountered at approximately 1 to 11 feet below the ground surface. The deposit generally consists of very dense, very pale brown to white, fine grained sandstone with little silt.

2.5 Surface Water

Surface water at the facility is diverted around the Cells, including the proposed Cells 5A and 5B. Surface water run-on into Cells 5A and 5B is primarily limited to direct precipitation.

The site has implemented a Storm Water Best Management Practices Plan in accordance with the facility permit. Site construction activities will be performed in accordance with the site Storm Water Best Management Practices Plan.

2.6 Groundwater

Groundwater is located at a depth of approximately 50 to 80 feet at the site. Groundwater monitoring wells DR-12 and DR-13 will be abandoned during construction of this project. Groundwater monitoring wells MW-14, MW-15, MW-17, MW-33, MW-34, MW-37, and DR-11 will be protected in place and raised as necessary.

2.7 Tailings

Cells 5A and 5B will accept process liquids, tailings, and by-products associated with onsite processing operations for both conventional ores and alternate feed materials. The liquids are typically highly acidic with a pH generally between 1 and 2. Tailings are generally comprised of ore that is ground to a maximum grain size of approximately 28 Mesh (US #30 Sieve) (0.023 inches (0.6 millimeters)), resulting in a fine sand and silt material.

3. DESIGN

The liner system is designed to provide a Cell for disposal of by-products from the onsite processing operations while protecting the groundwater beneath the site. The liner system is designed to meet the Best Available Technology requirements of the UAC R317-6, which require that the facility be designed to achieve the maximum reduction of a pollutant achievable by available processes and methods taking into account energy, public health, environmental and economic impacts, and other costs. Two liner systems have been proposed for the cells, from top to bottom:

Option A – Triple Liner

- Slimes drain system;
- Primary geomembrane liner;
- Leak detection system;
- Secondary geomembrane liner;
- Leak detection system; and
- Tertiary geomembrane liner.

Option B – Double Liner with Geosynthetic Clay Liner

- Slimes drain system;
- Primary geomembrane liner;
- Leak detection system;
- Secondary geomembrane liner; and
- Geosynthetic Clay Liner (GCL).

These components and related design considerations are discussed below.

3.1 Cell Capacity and Geometry

Cell 5A has been designed to accommodate storage of up to 1,330 acre-feet (2.15 million cubic yards) of tailings with solids storage to within 1.5-feet of the top of the geomembrane liner, and Cell 5B has been designed to accommodate storage of up to 1,360 acre-feet (2.20 million cubic yards) of tailings with solids storage to within 1.5-feet of the top of the geomembrane liner. The lowest elevation in Cell 5A is the sump located in the southeast corner at an elevation of approximately 5,541 feet above MSL, and the lowest elevation in Cell 5B is the sump located in the southwest corner at an elevation of approximately 5,539 feet above MSL.

Interior side slopes of Cell 5A and 5B will be constructed with 2H:1V inclinations with the exception of the northwest and southeast corners of Cell 5A and the northeast and southwest corners of Cell 5B, which will be constructed with 3H:1V slope inclinations. This will require re-grading of the southern berms of Cells 4A and 4B, which currently have exterior side slopes of 3H:1V. The eastern berm of Cell 5A will be constructed with a 2H:1V interior slope and 3H:1V exterior slope. During construction of Cell 5B, the slope will be reduced to 2H:1V. The proposed southern berms of Cell 5A and 5B will have 2H:1V interior slopes and 3H:1V exterior slopes. The eastern berm of Cell 5B will be constructed with 2H:1V interior slopes and 5H:1V exterior slopes. An approximately 25-foot wide berm, containing an unpaved access road, is proposed to surround Cells 5A and 5B. Cell layout is shown on Construction Drawing (Appendix A).

3.2 Slope Stability

Static and pseudostatic slope stability analysis was conducted for the final earthen berms and interim waste/tailings slopes associated with the operation of Cells 5A and 5B. Final slope stability and operational conditions are required to maintain a minimum factor of safety of approximately 1.5 for final berm slope conditions and 1.3 for interim slope conditions based on the proposed design of the cell and its liner system.

Three cross-sections from Cells 5A and 5B were analyzed which represent worst-case conditions in the cells. Each cross-section was modeled for four different loading conditions. These four conditions were static analysis, pseudo-static analysis for seismic loading conditions, interim construction loading, and evaluation of the yield acceleration. Numerous potential failure surfaces were analyzed for each model to evaluate various slip surface geometries and to identify the critical slip surface for each cross-section and condition.

Slope stability analysis of all three cross-sections for the four different loading conditions resulted in factors of safety above 1.5 for final conditions and above 1.3 for interim conditions. A detailed description of the slope stability calculations is presented in Appendix D.

3.3 Earthwork

Earthwork will consist of excavation, blasting, ripping, trenching, hauling, placing, moisture conditioning, backfilling, compacting, and grading. The requirements for earthwork for Cells 5A and 5B construction is provided in Appendix C, Section 02200 of the Technical Specifications.

3.3.1 Excavation

Prior to excavating soils and rock for Cells 5A and 5B, vegetation will be cleared and grubbed and surficial unsuitable materials will be removed. Excavation will proceed with the removal of topsoil and then in-situ soils for placement as fill for the construction of Cells 5A and 5B south berms. Excess soils will be stockpiled to the west of Cell 5A or to the east of Cell 5B in designated stockpile areas (Appendix A).

Rock will be ripped, blasted, or mechanically removed and stockpiled west of Cell 5A or east of Cell 5B, in a separate stockpile from the excess soil stockpile. Rock will be excavated a minimum of 6-inches below final grade and fill will be placed, moisture conditioned, compacted, and graded to provide a surface on which the geosynthetic liner system components will be installed.

Leak detection system and anchor trenches will be excavated as shown on the Construction Drawings (Appendix A).

3.3.2 Fill Placement

Along the southern perimeter of the proposed Cells 5A and 5B, berms will be constructed of fill with 2H:1V inside slopes and 3H:1V outer slopes. During construction of Cell 5A, a berm with 2H:1V inside slopes and interim, 3H:1V outer slopes will be constructed between Cell 5A and future Cell 5B. During construction of Cell 5B, the interior slope of the berm between Cell 5A and Cell 5B will be reduced from 3H:1V to 2H:1V. Along the eastern perimeter of Cell 5A, a berm with 2H:1V inside slopes and 5H:1V outside slopes will be constructed. Berms will be constructed with a top width of 25-feet.

Settlement analyses have been performed to evaluate the potential settlement of the berm and potential associated strain that could develop in the liner system components (Appendix D). The results of the conservative analyses indicate a maximum strain in the liner due to potential differential settlement of 0.002 percent, which is much less than the liner components can tolerate and is therefore acceptable.

Construction materials used for fill will consist of onsite soils placed in lifts resulting in a compacted thickness no greater than 8-inches and compacted to 90 percent of maximum dry density per American Society for Testing and Materials (ASTM) standard D1557 (Modified Proctor) at a moisture content of ±3 percent of optimum. Fill soil used in construction of the berm will consist of onsite soils with maximum particle size of 6-inches.

3.3.3 Subgrade Preparation

Subgrade preparation includes placement, moisture conditioning, compaction, and grading of subgrade soil. The subgrade will consist of a minimum of 6-inches of soil material with a maximum particle size of 3-inches compacted above the rock. Subgrade fill will be placed in loose lifts of no more than 8-inches and compacted to 90 percent of the maximum density at a moisture content of ±3 percent of optimum moisture content, as determined by ASTM D1557. The surface of the subgrade will have protrusions no greater than 0.7-inches. Section 02220 of the Technical Specifications, in Appendix C, provides the requirements for subgrade for Cells 5A and 5B construction.

3.3.4 Anchor Trench

The liner system will be anchored at the top of the slope with an anchor trench. The anchor trench was sized to resist anticipated maximum wind uplift forces, see Anchor Trench Capacity Calculations provided in Appendix D. The anchor trench will be a minimum of 1.5 feet deep and 2 feet wide and filled with compacted soil, as shown on the Construction Drawings (Appendix A). During construction, the contractor will be allowed to construct deeper anchor trenches to allow partial backfilling between subsequent liner component installation to facilitate temporary anchoring of each geosynthetic layer as it is installed. Anchor trench backfill will be placed in lifts of no more than 12-inches and compacted to 90 percent of the maximum density at a moisture content of ±3 percent of optimum moisture content, as determined by ASTM D1557.

3.4 Liner System

Two liner systems are proposed for Cells 5A and 5B: Option A – Triple Liner and Option B – Double Liner with GCL. Option A includes both a primary and secondary leak detection system while Option B includes a primary leak detection system. The liner system for the base of the cells will consist of (from top to bottom):

Option A – Triple Liner

- Slimes Drain System;
- 60-mil smooth high density polyethylene (HDPE) geomembrane (Primary Liner);
- 300-mil geonet;
- 60-mil smooth HDPE geomembrane (Secondary Liner);
- 60-mil HDPE Drain Liner™ geomembrane (Tertiary Liner)[1]; and
- Prepared Subgrade.

Option B – Double Liner with GCL

- Slimes Drain System;
- 60-mil smooth high density polyethylene (HDPE) geomembrane (Primary Liner);
- 300-mil geonet;
- 60-mil smooth HDPE geomembrane (Secondary Liner);
- GCL; and
- Prepared Subgrade.

(Composite Secondary Liner)

[1] The 60-mil HDPE Drain Liner™ geomembrane consists of a geomembrane with continuously molded 130-mil HDPE studs (in addition to the 60-mil geomembrane thickness) on one side to create an integrated transmissive layer between the Drain Liner™ and overlying geomembrane.

The liner system for the side slopes of the cells will consist of (from top to bottom):

Option A – Triple Liner	**Option B – Double Liner with GCL**
• 60-mil smooth HDPE geomembrane (Primary Liner);	• 60-mil smooth HDPE geomembrane (Primary Liner);
• 60-mil HDPE Drain Liner™ geomembrane (Secondary Liner);	• 60-mil HDPE Drain Liner™ geomembrane (Secondary Liner); (Composite Secondary Liner)
• 60-mil HDPE Drain Liner™ geomembrane (Tertiary Liner); and	• GCL; and (Composite Secondary Liner)
• Prepared Subgrade	• Prepared Subgrade

Construction materials were selected for chemical resistance, including resistance to acidic and chemical processing solids and liquids from both conventional ores and alternate feed materials, as well as resistance to ultraviolet (UV) degradation. HDPE geomembrane and geonet was selected due to its high resistance to chemical and UV degradation and ability to retain durability in an acidic environment. The chemical resistance lists for the most common HDPE geomembrane manufacturers, AGRU and GSE (now SolmaxGSE) are included in Appendix F (electronic only).

Stability analyses were conducted to evaluate the various slip surface geometries and to identify the critical slip surfaces for three cross-sections with various conditions. The analysis determined the minimum factor of safety of 1.3 for interim conditions and 1.5 for final conditions will be met during and after filling operations. The complete calculation is located in Appendix D.

3.4.1 Slimes Drain System

A slimes drain system will be placed on top of the primary geomembrane liner in the bottom of the cell to facilitate dewatering of the tailings prior to final reclamation of the cell. The slimes drain system will consist of perforated 4-inch diameter schedule 40 polyvinyl chloride (PVC) pipe, concrete sand filled sand bags, drainage aggregate, cushion geotextile, filter geotextile, and strip composite that will provide a means to drain the tailings disposed within Cells 5A and 5B. The slimes drain system is shown on the Construction Drawings (Appendix A).

The slimes drain system is designed to remove the liquids within Cells 5A and 5B in a reasonable time. Based on the calculations presented in Appendix D, the slimes drain is expected to drain the tailings in approximately 5.6 years. A sump pump capable of pumping 147 gallons per minute (gpm) will be required upon start-up of the slimes drain system. The pumping rate is anticipated to decrease with time as the head within Cells 5A and 5B decreases.

The perforated PVC pipe is designed to resist crushing and wall buckling due to the anticipated loading associated with the maximum height of overlying tailings. The design analyses for the pipe are presented in Appendix D, while Appendix C, Section 02616 provides material specifications for the pipe and strip composite and Section 02225 provides material specifications for the drainage aggregate. The strip composite will be comprised of a 1-inch thick by 12-inch wide high density polyethylene, or equivalent acid resistant material, wrapped in a nonwoven polypropylene geotextile. The drainage aggregate will consist of a crushed rock that has a carbonate content loss of no more than 10 percent by weight.

A continuous row of sand bags filled with a concrete sand meeting Utah Department of Transportation (UDOT) standard specifications for Portland Cement Concrete will overlie the strip composite laterals to act as an additional filter layer above the geotextile component of the strip composite. The proposed UDOT concrete sand will be placed in sand bags consisting of woven geotextile capable of allowing liquids to pass. When placed overlying the strip composite, the sand bags will have an approximate length of 18 inches, width of 12 inches, and a height of 3 inches. This results in a sand bag that is approximately 30 to 35 pounds and will provide sufficient coverage over the width and ends of the strip composite to act as an additional filter layer. The UDOT concrete sand will consist of sand that has a carbonate content loss of no more than 10 percent by weight. Alternatively, a woven geotextile may be placed above the strip composite with concrete sand installed above. Following placement of a minimum of 3 inches of sand above the strip composite, the geotextile will be folded over and seamed creating a continuous sand layer above the strip composites.

The cushion geotextile that is to be installed beneath the drainage aggregate surrounding the PVC pipe is designed to protect the underlying primary high density polyethylene (HDPE) geomembrane from puncture due to the drainage aggregate and the anticipated loading associated with the maximum height of overlying tailings and final cover (9-feet of soil). The design analyses for the cushion geotextile are presented in Appendix D, while Appendix C, Section 02771 provides material specifications. Overlying the drainage aggregate and cushion geotextile will be a woven geotextile, as shown on the Construction Drawings (Appendix A), that will serve to separate the tailings and the drainage aggregate.

The Slimes Drain sump will include a side slope riser pipe to allow installation of a submersible pump for manual collection of liquids in the sump. The sump and riser pipes are shown on the Construction Drawings (Appendix A).

3.4.2 Primary Liner Systems

The primary liner will consist of smooth 60-mil HDPE geomembrane. The geomembrane will have a white surface that will limit geomembrane movement and the creation of wrinkles due to temperature variations. The limit of the liner systems (both primary and secondary) and details are shown on the Construction Drawings (Appendix A).

Tension due to wind up lift was analyzed for the 60-mil HDPE geomembrane. Based on the analysis, the geomembrane anchor trench has been sized to accommodate the loading associated with a wind speed of 25 miles per hour and a slope length of approximately 103 feet. The design analyses for the HDPE liner uplift are presented in Appendix D.

The HDPE geomembrane will be constructed in accordance with the current standard of practice for geomembrane liner installation, as outlined in the site Technical Specifications (Appendix C, Section 02770) and the site CQA Plan (Appendix B). Seams will be welded to provide a continuous geomembrane liner. Testing during construction will include both non-destructive and destructive testing, as outlined in the Technical Specifications and CQA Plan. Upon completion of construction, the geomembrane manufacturer will provide a 20-year warranty for the geomembrane.

3.4.3 Primary Leak Detection System (Option A and Option B)

The primary leak detection system (LDS) will underlie the primary liner and is designed to collect potential leakage through the liner and convey the liquid to the sump for manual detection through monitoring of sump levels. The bottom LDS consists of a 300-mil thick geonet above a 60-mil HDPE geomembrane and a network of gravel trenches throughout the bottom of Cells 5A and 5B. The trenches will contain a 4-inch diameter perforated schedule 40 PVC pipe, drainage aggregate, and a cushion geotextile, which will drain to sumps located in the southeast corner of Cell 5A and the southwest corner of Cell 5B. The trenches will aid in rapidly conveying leakage to the LDS sump. On the side slopes, the primary leak detection system consists of a 130-mil Drain Liner™ geomembrane. The LDS is shown on the Construction Drawings (Appendix A).

3.4.3.1 Action Leakage Rate

The Action Leakage Rate (ALR) was calculated for the LDS in accordance with Part 254.302 of the USEPA Code of Federal Regulations. The ALR was evaluated for various scenarios within Cells 5A and 5B. The most conservative approaches were selected and evaluated in the calculation packages included in Appendix D. The ALR was calculated to be 526 gallons per day per acre in the primary LDS. The flow in the primary LDS side slope Drain Liner™ was evaluated against the flow through a defect in the primary geomembrane. The flow in the Drain Liner™ was found to be 4.08×10^{-6} m^3/sec, or 1.6 times greater than the flow through a defect; therefore, the Drain Liner™ will be adequate for leak detection on the side slopes.

The total travel time for liquids entering the geonet LDS layer to travel from the leak to the LDS piping system was estimated to be approximately one day for the primary LDS. Assuming a worst case scenario under which all the primary geomembrane defects are located at the high end of the leakage collection layer slope, the liquid head on the secondary liner does not exceed 13.4 mils (0.0134 in). This value is well below the required maximum limit of 12 inches and the collection layer thickness of 300 mils. The geonet and Drain Liner™ provide sufficient flow rates to accommodate the ALR on the cell bottoms and side slopes, respectively. The complete ALR calculation is located in Appendix D and Sections 02770 and 02773 of Appendix C provides material specifications for the geonet.

3.4.3.2 Perforated Pipe

The perforated PVC pipe is designed to resist crushing and wall buckling due to the anticipated loading associated with the maximum height of overlying tailings. Pipe strength analysis indicated the 4-inch PVC pipe with a maximum allowable deflection of 7.5 percent will have the ability to resist the anticipated maximum load associated with a tailing deposit height of 43 feet and additional cover soil height of 9 feet. The design analysis for the pipe is presented in Appendix D, while Appendix C, Section 02616 provides material specifications for the pipe and Section 02225 provides material specifications for the drainage aggregate.

3.4.3.3 Puncture Protection

The cushion geotextile is designed to protect the underlying secondary HDPE and overlying primary HDPE geomembrane from puncture due to the drainage aggregate and the anticipated loading associated with the maximum height of overlying tailings. Puncture analysis indicated a 16 ounce per square yard (oz./yd^2) cushion geotextile and 1-inch maximum particle size would provide puncture protection for the 60-mil HDPE smooth geomembrane. The design analyses for the cushion geotextile are presented in Appendix D, while Appendix C, Section 02771 provides material specifications.

3.4.3.4 Sump

The LDS sump will include a side slope riser pipe and submersible pump to allow for manual collection of liquids in the LDS sump. The LDS sump and riser pipes are shown on the Construction Drawings (Appendix A).

3.4.4 Secondary Leak Detection System (Option A Only)

The primary purpose of the secondary liner is to provide a flow barrier so that potential leakage through the primary liner will collect on top of the secondary liner then flow through the LDS to the LDS sump for manual collection. The secondary liner also provides an added hydraulic barrier against leakage to the subsurface soils and groundwater. The secondary liner consists of a 60-mil HDPE Drain Liner™ for both the base liner the side slopes.

The secondary LDS will underlie the secondary geomembrane and primary LDS and is designed to collect potential leakage through the secondary liner and convey the liquid to the sump for manual detection through monitoring of sump levels. On the side slopes and bottom of the cells the secondary LDS consists of a 130-mil Drain Liner™ geomembrane. On the bottom of the cells, a network of gravel trenches. Similar to the primary LDS, the trenches will contain a 4-inch diameter perforated schedule 40 PVC pipe, drainage aggregate, and a cushion geotextile, which will drain to sumps located in the southeast corner of Cell 5A and the southwest corner of Cell 5B. The trenches will aid in rapidly conveying leakage to the LDS sump. The LDS is shown on the Construction Drawings (Appendix A-1).

3.4.4.1 Action Leakage Rate

The Action Leakage Rate (ALR) was calculated for the LDS in accordance with Part 254.302 of the USEPA Code of Federal Regulations. The ALR was evaluated for various scenarios within Cells 5A and 5B. The most conservative approaches were selected and evaluated in the calculation packages included in Appendix D. The ALR was calculated to be 15 gallons per day per acre and the total travel time for liquids entering the Drain Liner™ LDS layer to travel from the leak to the LDS piping system was estimated to be approximately 5.1 hours. Assuming a worst case scenario under which all the primary geomembrane defects are located at the high end of the leakage collection layer slope, the liquid head on the secondary liner does not exceed 0.1 mils (0.0001-inches), well below the required maximum limit of 12 inches (1-foot) and the collection layer thickness of 130-mil. The Drain Liner™ provides sufficient flow rate to accommodate the ALR. The complete ALR calculation is located in Appendix D and Section 02770 of Appendix C provides material specifications for the Drain Liner™.

3.4.4.2 Puncture Protection

The tertiary geomembrane resistance to puncture was evaluated for direct contact between the subgrade and tertiary geomembrane. Puncture analysis indicated a maximum subgrade protrusion height of 0.7 inch would not puncture the Drain Liner™ geomembrane. The design analysis is presented in Appendix D.

3.4.4.3 Sump

The secondary LDS sump will include a side slope riser pipe and submersible pump to allow for manual collection of liquids in the secondary LDS sump. The secondary LDS sump and riser pipes are shown on the Construction Drawings (Appendix A-1).

3.4.5 Secondary Composite Liner System (Option B Only)

The primary purpose of the secondary liner is to provide a flow barrier so that potential leakage through the primary liner will collect on top of the secondary liner then flow through the LDS to the LDS sump for manual collection. The secondary liner also provides an added hydraulic barrier against leakage to the subsurface soils and groundwater. The secondary liner consists of a composite liner that includes a 60-mil HDPE geomembrane overlying a GCL.

3.4.5.1 Secondary Geomembrane Liner

The geomembrane component of the secondary liner system will consist of a smooth 60-mil HDPE geomembrane for the base liner and 60-mil HDPE Drain Liner™ for the side slope liner and will meet the same criteria as the primary liner geomembrane (Section 3.4.2). The limit of the liner system (both primary and secondary) and details are shown on the Construction Drawings (Appendix A-2).

3.4.5.2 Secondary GCL Liner

The GCL component of the secondary liner system consists of bentonite sandwiched between two geotextile layers that are subsequently needle-punched together to form a single composite hydraulic barrier material. The GCL is approximately 0.2-inches thick with a hydraulic conductivity on the order of 1×10^{-9} cm per second (cm/s) (Daniel and Scranton, 1996). The GCL will be hydrated to account for the high acidity of the tailings.

Since 1986, GCLs have been increasingly used as an alternative to compacted clay liners (CCLs) on containment projects due to their low cost, ease of construction/placement, and resistance to freeze-thaw and wet-dry cycles. In general, the USEPA and the containment industry accept that GCLs are hydraulically equivalent to a minimum of 2 feet of compacted clay liner consisting of 1×10^{-7} cm/s soil materials.

For the Cell 4A design, and in accordance with Permit no. UGW370004, Geosyntec demonstrated that a secondary composite liner system consisting of a 60-mil HDPE geomembrane overlying a GCL has equivalent or better fluid migration characteristics when compared with a secondary composite liner system consisting of a 60-mil HDPE geomembrane overlying a CCL having a saturated hydraulic conductivity less than 1×10^{-7} cm/s (Geosyntec, 2006). This analysis accounted for the loading conditions and anticipated liquid head on the secondary liner system, the amount of flow through the secondary liner system with CCL was evaluated to be 8.51 times greater than flow through the secondary liner system with GCL for a liquid head of 0.16 inches, which is more than the calculated Cell 5A and 5B liquid head (0.0134 inches). Therefore, in terms of limiting fluid flow through the composite secondary liner system, the secondary liner system containing a GCL performs better than the secondary liner system containing a CCL.

The following site specific conditions must be considered prior to use of a GCL in place of CCL (Koerner and Daniel, 1993):

- Puncture Resistance: While CCLs naturally provide greater puncture resistance than GCLs due to their inherent thickness, proper subgrade preparation and design of the geotextile components of the GCL can result in protection from puncture. The geotextile components of the GCL for Cell 4B are designed to protect the overlying secondary HDPE geomembrane from puncture due to protrusions from the subgrade and the anticipated loading associated with the maximum height of overlying tailings. The puncture protection analysis of the GCL indicated that a 3 oz/yd^2 geotextile and 6 oz/yd^2 geotextile above and below (respectively) the GCL and a maximum subgrade protrusion height of ½-inch will provide puncture protection for the secondary HDPE geomembrane. The design analyses considers a 60-mil geomembrane placed directly on the subgrade which is more conservative than the GCL placed directly on the subgrade and beneath the 60-mil geomembrane. The puncture calculations for the geomembrane on subgrade are presented in Appendix D, while Appendix C, Section 02772 provides material specifications.
- Hydraulic Conductivity: Due to the acidic nature of the fluid to be stored in the cell, Geosyntec conducted hydraulic conductivity testing on hydrated specimens of GCL for the Cell 4A project (Geosyntec 2007). Based on the results, the GCL will be hydrated to a moisture content of 50% during construction.
- Chemical Adsorption Capacity: Due to the thickness of a CCL, the chemical adsorption capacity of a CCL is greater than that of a GCL. However,

adsorption capacity is only relevant in the short term and not considered a parameter for steady-state analyses.

- Stability: The internal strength of a GCL can be significantly lower than that of a CCL, especially at high confinement stresses. This reduced strength can have significant effects on stability, especially at disposal facilities with high waste slopes and the potential for seismic activity. Strength of the GCL and its effects on stability are not a concern at Cells 5A and 5B due to the low confining stresses expected and geometry of the cell. Waste deposits will not be placed above the elevation of the perimeter road. Since no above grade slopes will be present, there are no long term destabilizing forces on the liner system.
- Construction Issues: For the Cells 5A and 5B liner system, GCLs may be considered superior to the CCLs with respect to construction issues. Construction of GCLs is typically much quicker and is more easily placed than a CCL, which requires moisture conditioning and compaction for placement. Further, CQA testing for a GCL is much simpler and less affected by interpretation of field staff than that for a CCL, which requires careful control of material type, moisture conditions, clod size, maximum particle size, lift thickness, etc.
- Physical/Mechanical Issues: Physical and mechanical issues include items such as the effect of freeze/thaw and wetting/drying cycles. CCLs may undergo significant increases in hydraulic conductivity as a result of freeze/thaw. Existing laboratory data suggests that GCLs do not undergo increases in hydraulic conductivity as a result of freeze/thaw. CCLs are also known to form desiccation cracks upon drying which can result in significant increases in hydraulic conductivity. This increase drastically jeopardizes the effectiveness of the CCL as a barrier layer. Available laboratory data on GCLs indicates that upon re-hydration after desiccation, GCLs swell and the cracks developed during drying cycles are 'self-healed'. Due to the arid environment at the site, GCL performance in the Cells 5A and 5B liner system with respect to physical and mechanical issues is expected to be superior to that of a CCL.

Based on review of the above site-specific considerations, a GCL is considered superior to a CCL for use in the secondary composite liner system.

3.5 Splash Pad

Approximately eighteen splash pads will be constructed in Cells 5A and 5B, nine splash pads in each, to allow filling of the cells without damaging the liner system. The splash pads consist of an additional textured geomembrane placed along the side slope of the Cell extending a minimum of 5 feet from the toe of the slope. The geomembrane will protect the underlying liner system from contact with the inlet pipes. A cross section of a typical splash pad is shown on the Construction Drawings (Appendix A). The locations of the splash pads will be finalized in the field during construction, based on site operational needs.

3.6 Emergency Spillway

Emergency spillways will be constructed between Cells 4B and 5A and Cells 5A and 5B. The spillway locations and details are shown on the Construction Drawings (Appendix A).

The spillway between Cells 4B and 5A will be located on the berm separating the two cells in the southeastern portion of Cell 4B and the northeastern portion of Cell 5A and will be constructed during the Cell 5A construction. The spillway will be approximately 5.5 feet deep, sloped at 2% toward Cell 5A, and include 10H:1V approach pads that will allow traffic moving along the top of the berm to pass through the spillway (when dry). The spillway will consist of a 6-inch thick reinforced concrete pad, designed to withstand loadings from truck traffic, see Concrete Calculations provided in Appendix D. The spillway is designed to handle the Probable Maximum Precipitation (PMP) for a 6 hour storm event for the site, see Spillway Calculations provided in Appendix D.

The spillway between Cells 5A and 5B will be located on the berm separating the two cells in the southeastern portion of Cell 5A and the southwestern portion of Cell 5B and will be constructed during the Cell 5B construction. The spillway will be approximately 5.8 feet deep, sloped at 2% toward Cell 5B, and include 10H:1V approach pads that will allow traffic moving along the top of the berm to pass through the spillway (when dry). The spillway will consist of a 6-inch thick reinforced concrete pad, designed to withstand loadings from truck traffic, see Concrete Calculations provided in Appendix D. The spillway is designed to handle the Probable Maximum Precipitation (PMP) for a 6 hour storm event for the site, see Spillway Calculations provided in Appendix D.

4. SUMMARY AND CONCLUSIONS

This report presents the engineering design evaluations for Cells 5A and 5B at the White Mesa Mill Facility. The calculations presented in this Design Report establish the dimensions and properties of the liner system components (Appendix D). The design plans and details are presented in the Construction Drawings (Appendix A), recommended construction quality testing and observation requirements are provided in the CQA Plan (Appendix B), and material requirements are provided in the project Technical Specifications (Appendix C).

4.1 Limitations

The professional opinions and recommendations expressed in this report are made in accordance with generally accepted standards of geotechnical engineering practice. This warranty is in lieu of any other warranty either express or implied. We are responsible for the conclusions and recommendations contained in this report based on the data relating only to the specific project and location discussed herein. We are not responsible for use of the information contained in this report for purposes other than those expressly stated in this report. In the event that there are changes in the design or location of this project that do not conform to the project as described herein, we will not be responsible for these changes unless given the opportunity to review them and concur with them in writing. We are not responsible for any conclusions or recommendations made by others based upon the data or conclusions contained herein unless given the opportunity to review them and concur with them in writing.

Gregory T. Corcoran, P.E.
Utah Registration No. 6020077-2202

REGISTERED PROFESSIONAL ENGINEER
No. 6020077-2202
GREGORY T. CORCORAN
STATE OF UTAH

5. REFERENCES

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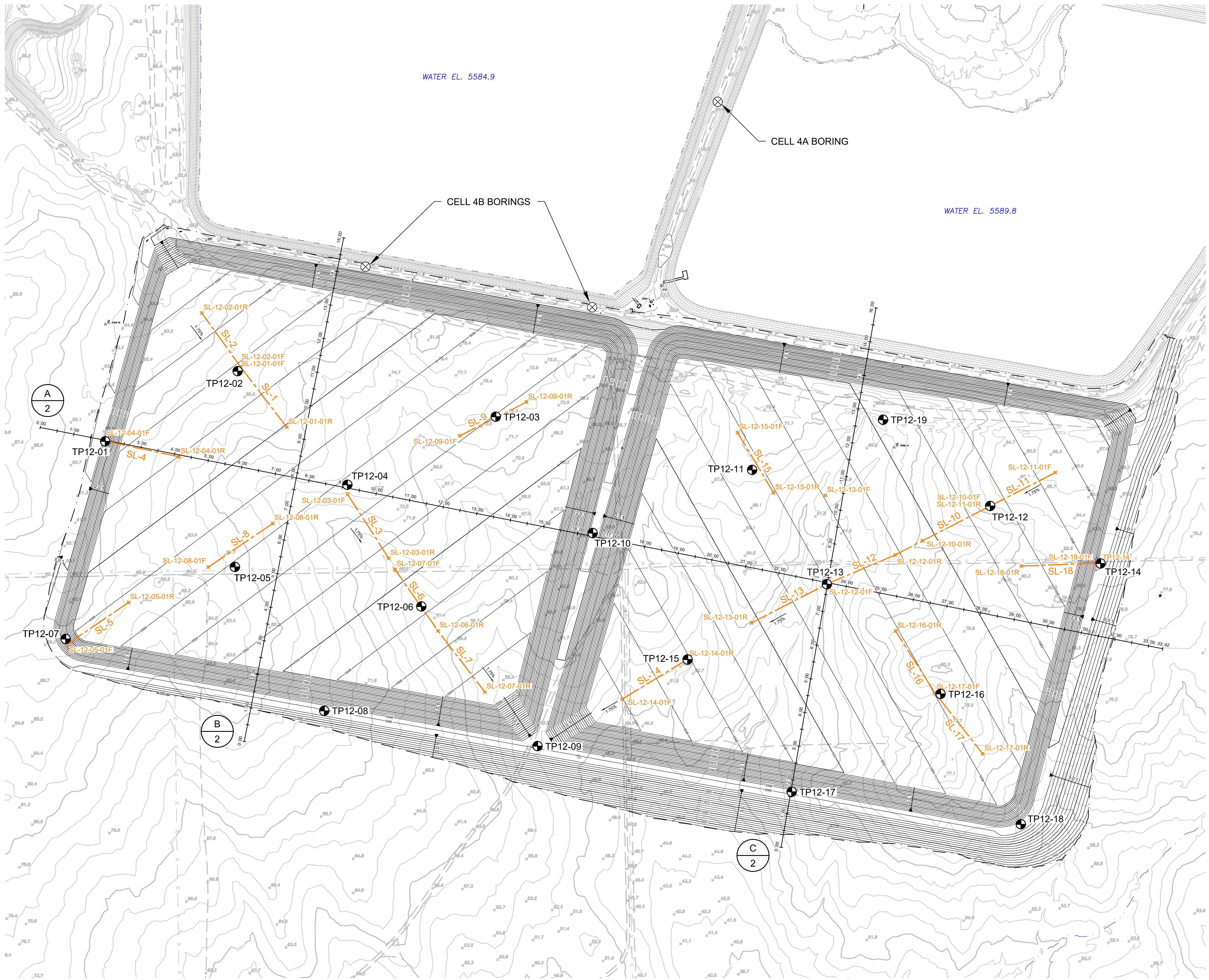
FIGURES



LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- PROPOSED GRADING MAJOR CONTOUR (10')
- PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- TP12-01 AS-BUILT TRENCH LOCATION
- AS-BUILT SEISMIC LINES

0 150' 300'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: CELL 5A AND 5B PROPOSED GRADING

PROJECT: CELL 5A AND 5B PRELIMINARY CELL DESIGN

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0349
CHECKED BY:	GTC	FILE:	
REVIEWED BY:	GTC	FIGURE NO.:	
APPROVED BY:	GTC	1 OF 2	

PRELIMINARY DESIGN DRAWINGS
NOT FOR CONSTRUCTION

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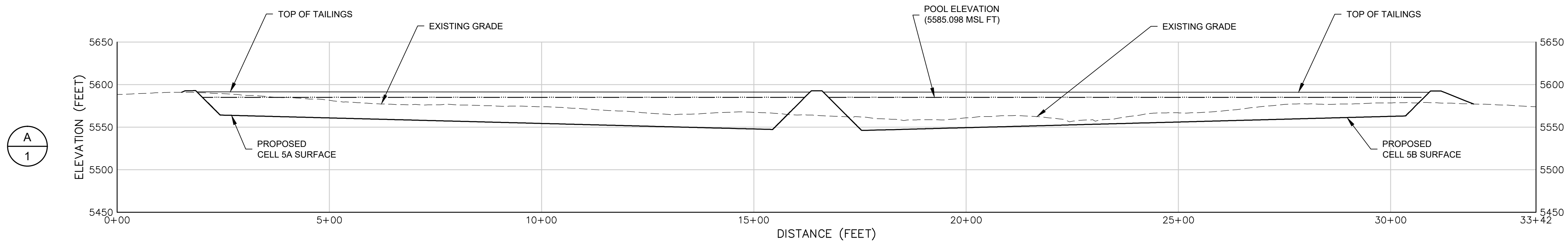

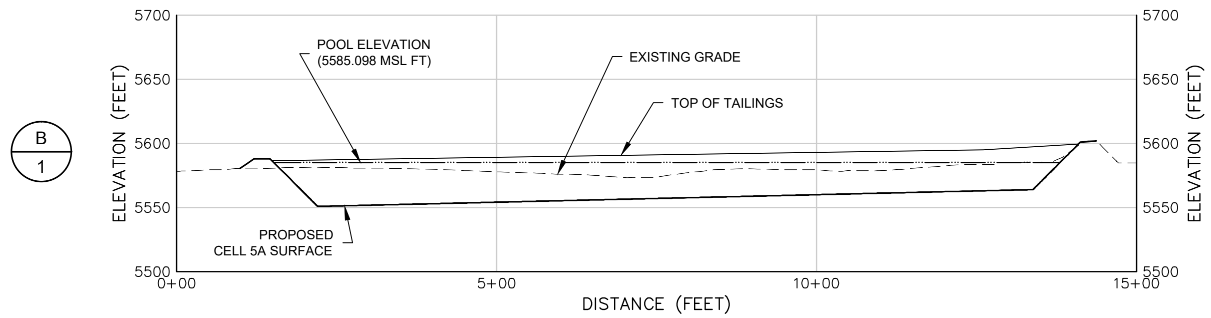

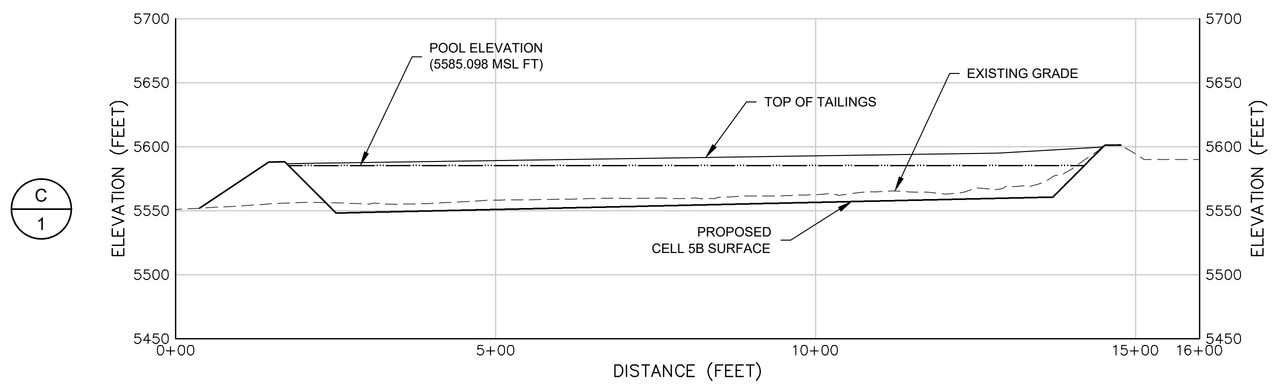

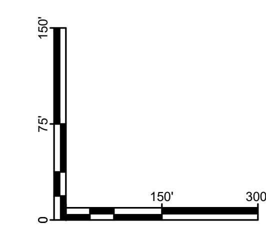

LEGEND

- JUNE 2011 EXISTING GROUND SURFACE
- PROPOSED GRADING SURFACE
- POOL SURFACE
- TOP OF TAILINGS SURFACE

REV	DATE	DESCRIPTION	DRN	APP

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Energy Fuels Resources (USA) Inc.

TITLE: CELL 5A AND 5B PROPOSED GRADING - PROFILES

PROJECT: CELL 5A AND 5B PRELIMINARY CELL DESIGN

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0349
CHECKED BY:	GTC	FILE:	
REVIEWED BY:	GTC	FIGURE NO.:	
APPROVED BY:	GTC	2 OF 2	

PRELIMINARY DESIGN DRAWINGS
NOT FOR CONSTRUCTION

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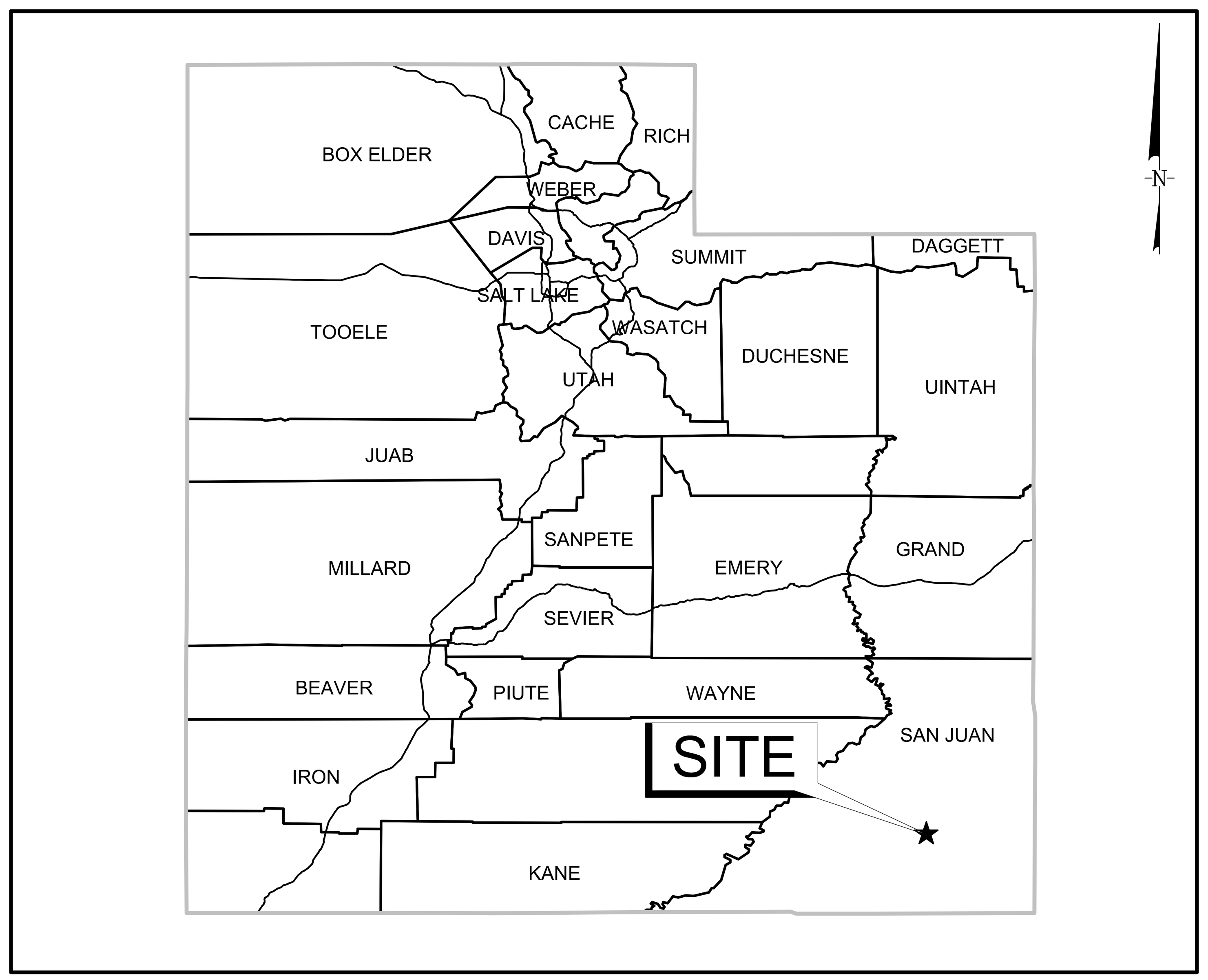
APPENDIX A-1

Construction Drawings

Option A – Triple Liner

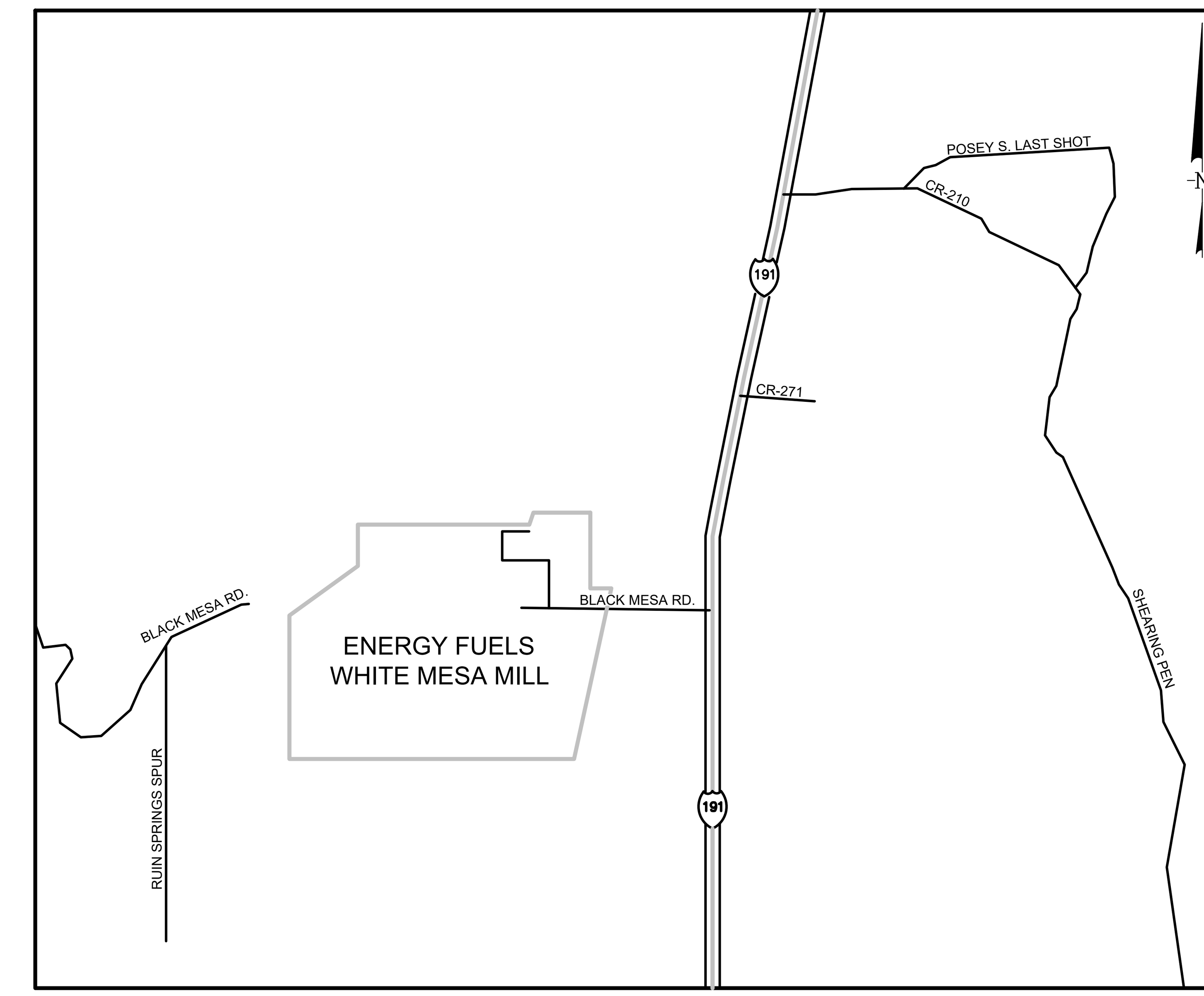
PERMIT LEVEL DESIGN DRAWINGS
CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER
ENERGY FUELS WHITE MESA MILL
BLANDING, UTAH
JUNE 2018



VICINITY MAP
NOT TO SCALE

LIST OF DRAWINGS

DRAWING	DESCRIPTION
01	TITLE SHEET
02	SITE PLAN
03A	CELL 5A PROPOSED GRADING
03B	CELL 5B PROPOSED GRADING
04A	PIPE LAYOUT PLAN AND DETAILS - CELL 5A
04B	PIPE LAYOUT PLAN AND DETAILS - CELL 5B
05	LINER SYSTEM DETAILS I
06	LINER SYSTEM DETAILS II
07	DETAILS & SECTIONS III
08	DETAILS & SECTIONS IV
09	DETAILS & SECTIONS V
10	DETAILS & SECTIONS VI



LOCATION MAP
NOT TO SCALE

4 / 6 — DETAIL NUMBER; SHEET ON WHICH ABOVE DETAIL IS PRESENTED

DETAIL NUMBER — 4 — DETAIL
SHEET ON WHICH ABOVE DETAIL WAS FIRST REFERENCED — 3 — TITLE OF DETAIL
SCALE: 1"=2'

EXAMPLE: DETAIL NUMBER 4 PRESENTED ON SHEET NO. 6 WAS REFERENCED FOR THE FIRST TIME ON SHEET NO. 3.

DETAIL IDENTIFICATION LEGEND

(ABOVE SYSTEM ALSO APPLIES TO SECTION IDENTIFICATIONS, HOWEVER, LETTERS ARE USED INSTEAD OF NUMBERS.)

PREPARED FOR:

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PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

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Energy Fuels Resources (USA) Inc.

TITLE: TITLE SHEET

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

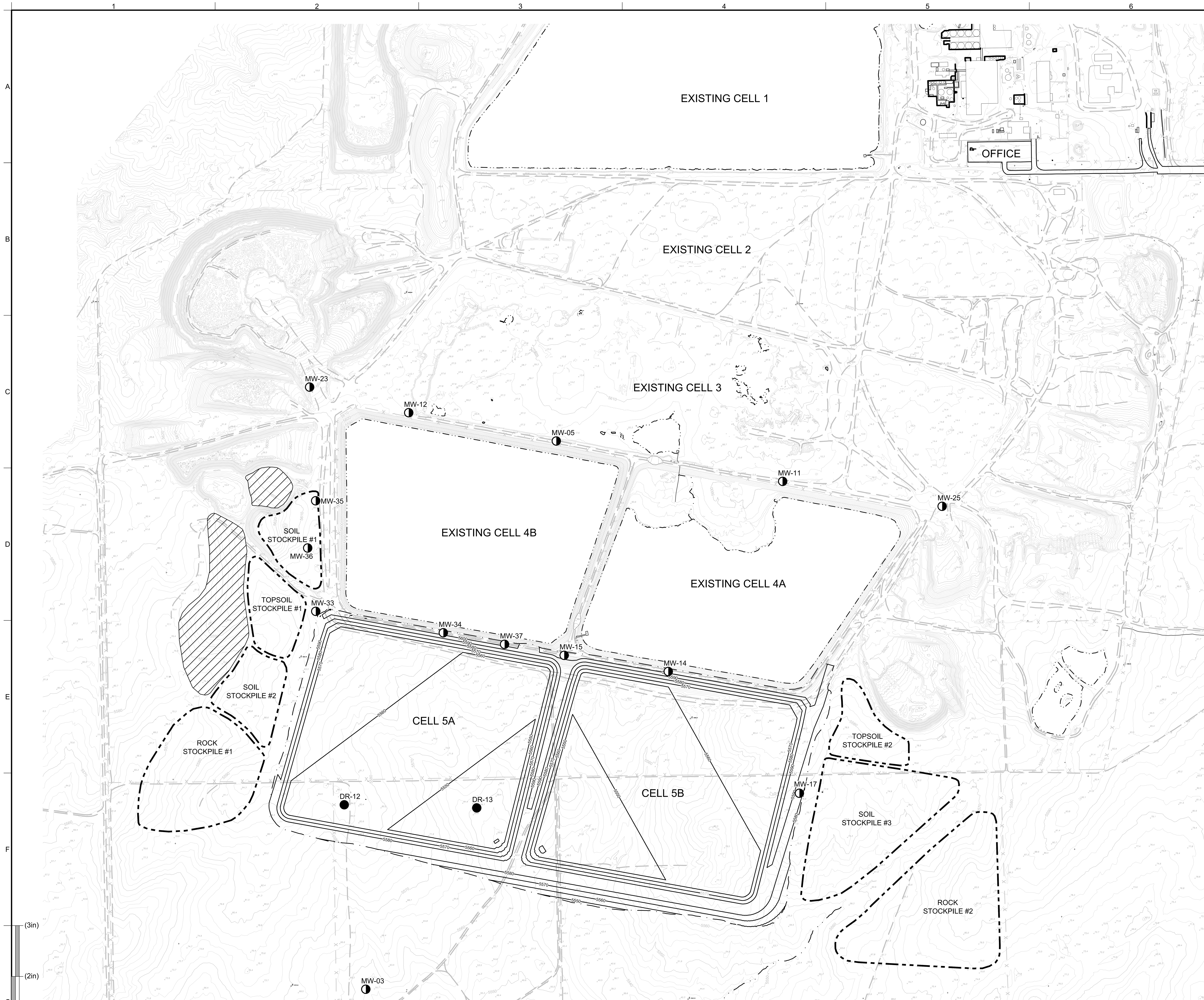
THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-01
REVIEWED BY:	GTC	DRAWING NO.:	01 OF 10
APPROVED BY:	GTC		

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634-01.dwg Last Edited by: SBerdy on 6/25/2018 3:03 PM



LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- SURFACE WATER BOUNDARY
- SURFACE WATER DRAINAGE
- 5600 PROPOSED GRADING MAJOR CONTOUR (10')
- PROPOSED GRADING LIMIT
- PROPOSED STOCKPILE BOUNDARIES
- KNOWN ARCHEOLOGICAL AREAS (SEE NOTE 6)
- DR-13 MW-12 EXISTING GROUNDWATER MONITORING WELLS

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. EXISTING WELLS, PIPING, AND OTHER SITE FEATURES SHALL BE PROTECTED IN PLACE, EXCEPT AS NOTED OTHERWISE.
3. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL, AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
4. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
5. CONSTRUCTION WATER TO BE PROVIDED BY OWNER AT NORTHEAST CORNER OF CELL 4A.
6. CONTRACTOR TO AVOID KNOWN ARCHEOLOGICAL AREAS. OWNER TO CLEAR ARCHEOLOGICAL AREAS WITHIN LIMITS OF WORK PRIOR TO BEGINNING EXCAVATION.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: SITE PLAN

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

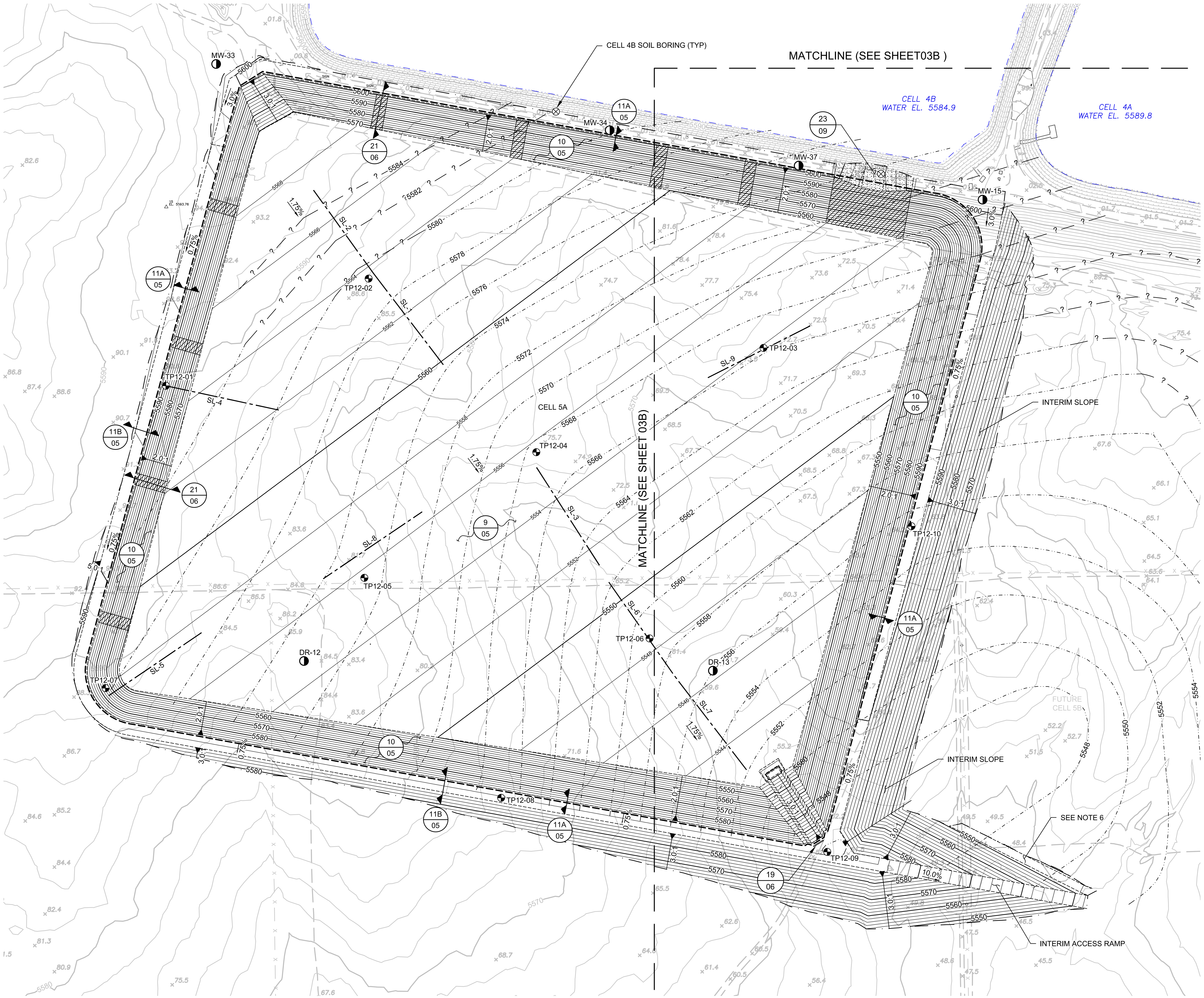
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-02
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	02 OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



LEGEND

5570	JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
	EXISTING DIRT ROAD
x x	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	PROPOSED GRADE BREAK
	LIMIT OF LINER SYSTEM
5570	APPROXIMATE TOP OF ROCK CONTOUR (1') (SEE NOTES 4 AND 5)
	SPLASH PAD 21/06
TP12-03	EXPLORATORY TRENCH LOCATION
	SEISMIC LINE LOCATIONS (SEE NOTE 4)
⊗	CELL 4B SOIL BORINGS (SEE NOTE 4)
MW-33	EXISTING GROUNDWATER MONITOR WELL

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
4. SEISMIC LINE DATA AND CELL 4B BORINGS ARE PROVIDED IN SECTION 02200 OF THE TECHNICAL SPECIFICATIONS.
5. ROCK SURFACE IS APPROXIMATE AND BASED ON TRENCHES PERFORMED AT THE SITE. WHERE QUESTION MARKS ARE SHOWN, SURFACE IS ESTIMATED AND NOT BASED ON TRENCHES.
6. LOCALLY GRADE AREA NORTH OF BERM TO DRAIN AROUND BERM.

0 100' 200'
SCALE IN FEET

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: CELL 5A PROPOSED GRADING

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

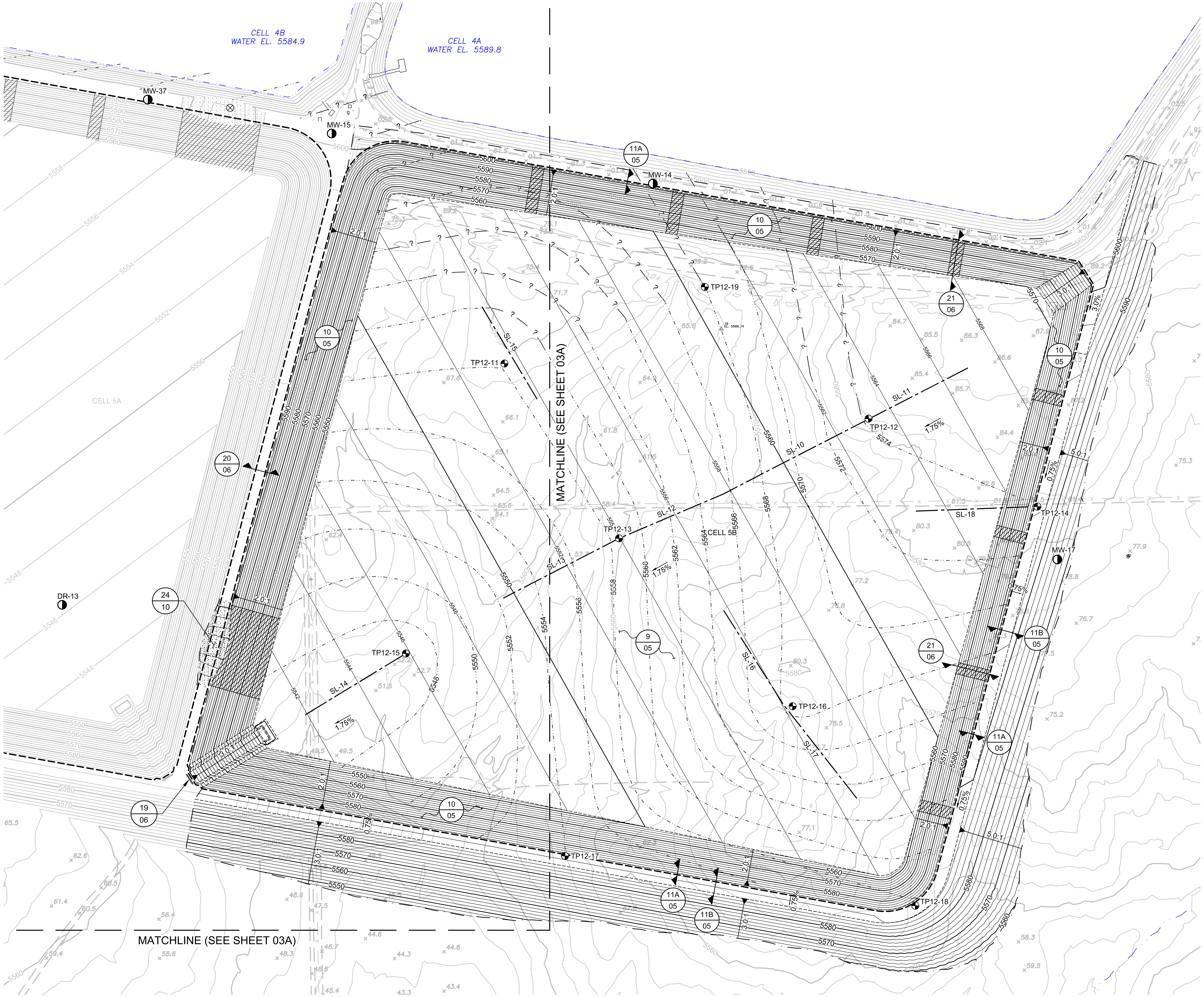
SIGNATURE

06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER
No. 6020077-2202
GREGORY T. CORCORAN
STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	03A OF 10	

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



LEGEND

5570	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
	EXISTING DIRT ROAD
x x	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	PROPOSED GRADE BREAK
	LIMIT OF LINER
5570	APPROXIMATE TOP OF ROCK CONTOUR (1') (SEE NOTES 4 AND 5)
	SPLASH PAD 21/06
TP12-03	EXPLORATORY TRENCH LOCATION
	SEISMIC LINE LOCATIONS (SEE NOTE 4)
⊗	CELL 4B SOIL BORINGS (SEE NOTE 4)
MW-33	EXISTING GROUNDWATER MONITORING WELL

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
4. SEISMIC LINE DATA AND CELL 4B BORINGS ARE PROVIDED IN SECTION 02200 OF THE TECHNICAL SPECIFICATIONS.
5. ROCK SURFACE IS APPROXIMATE AND BASED ON TRENCHES PERFORMED AT THE SITE. WHERE QUESTION MARKS ARE SHOWN, SURFACE IS ESTIMATED AND NOT BASED ON TRENCHES.

N

0 100' 200'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUITE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: CELL 5B PROPOSED GRADING

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

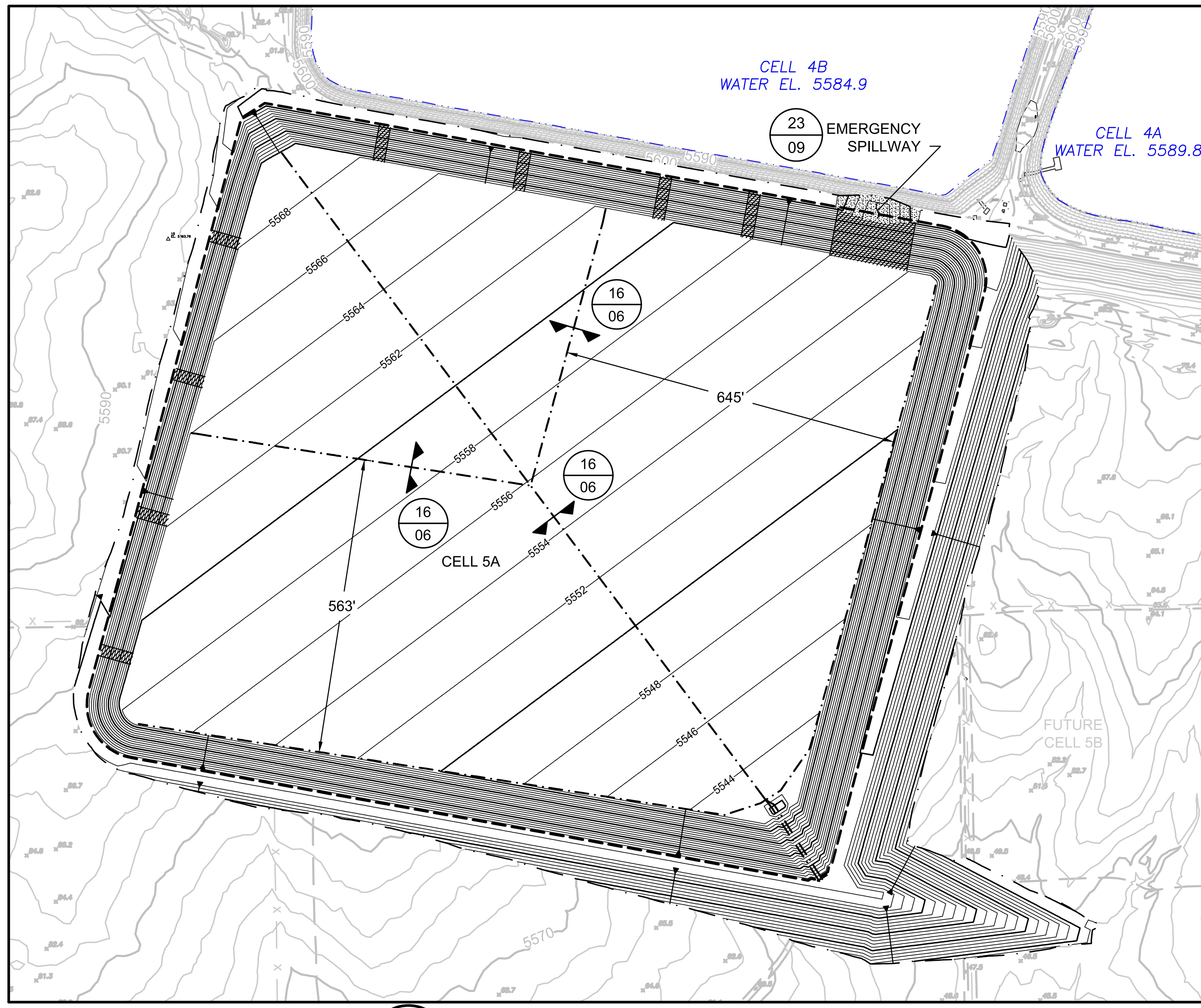
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

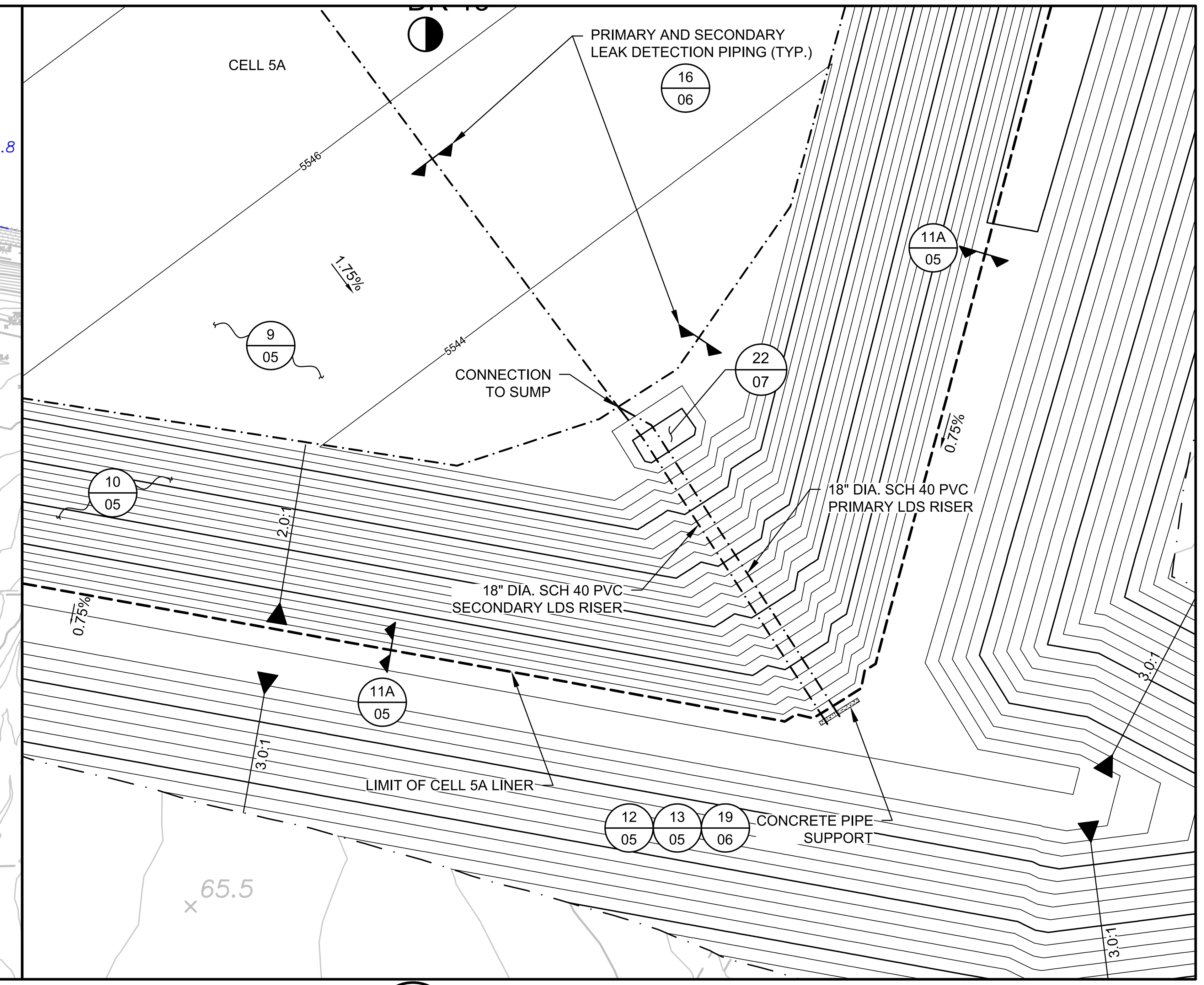
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	03B OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

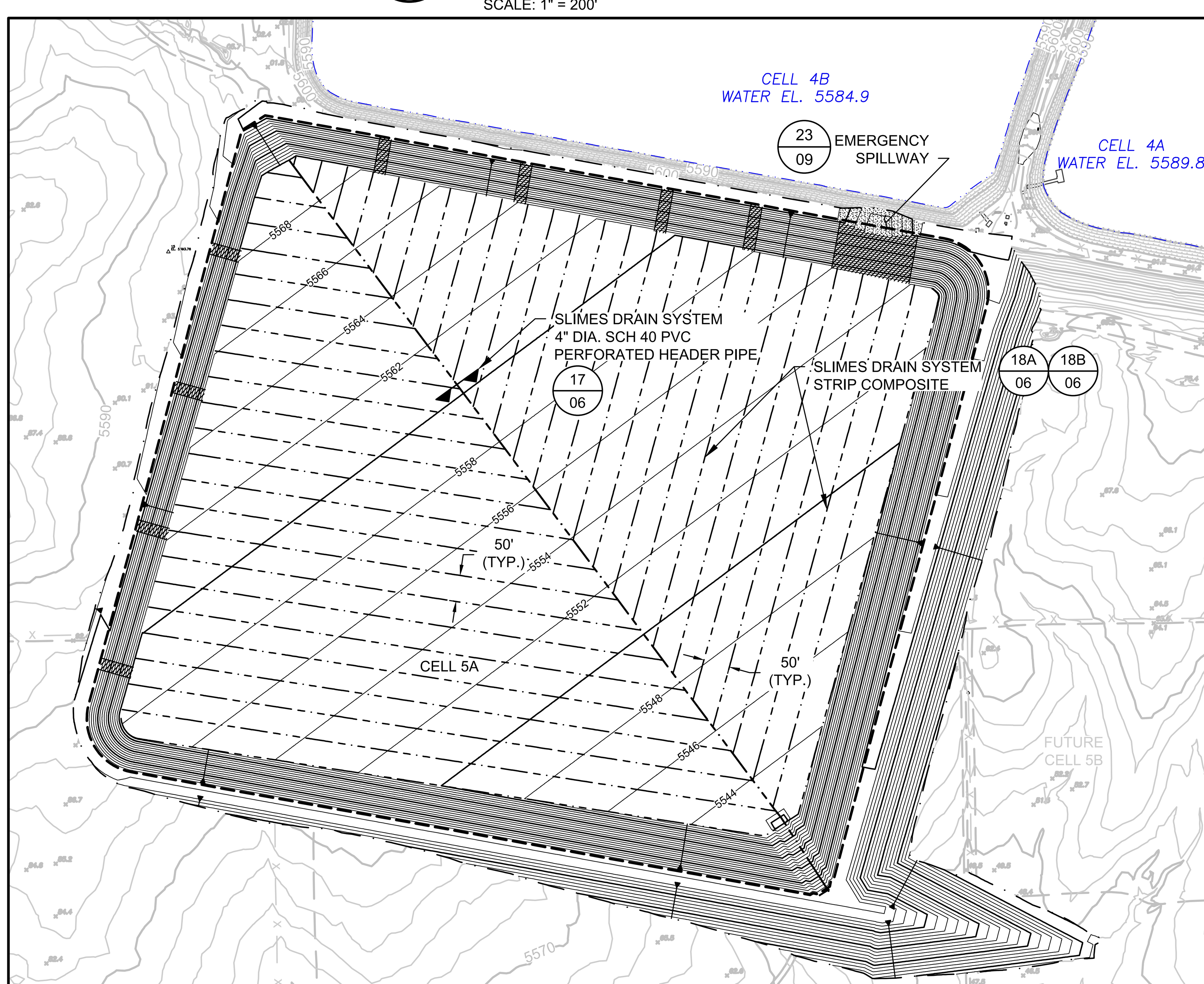
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



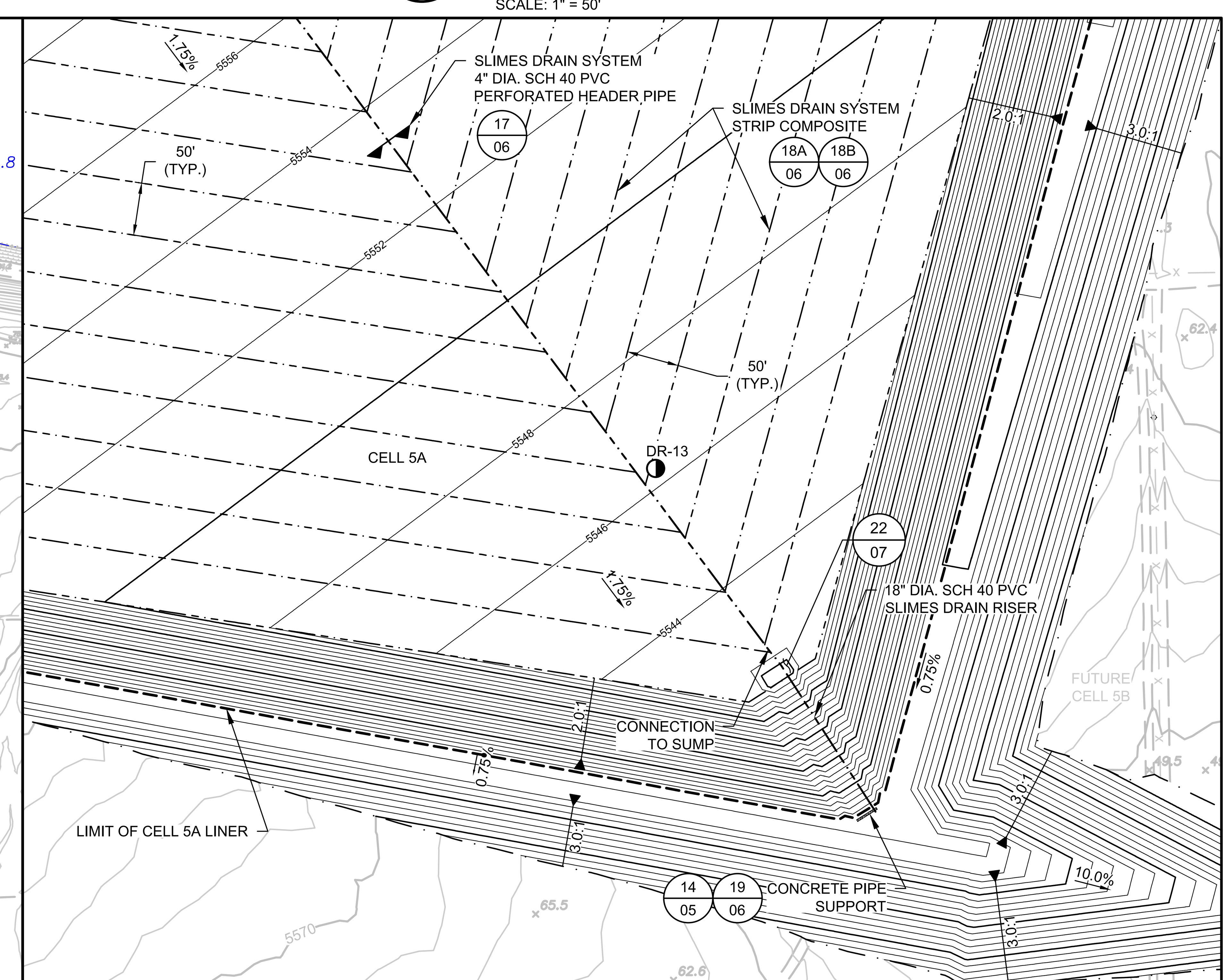
1 - PLAN
CELL 5A LEAK DETECTION SYSTEM
SCALE: 1" = 200'



2 - DETAIL
CELL 5A LEAK DETECTION SYSTEM
SCALE: 1" = 50'



3 - PLAN
CELL 5A SLIMES DRAIN SYSTEM
SCALE: 1" = 200'



4 - DETAIL
CELL 5A SLIMES DRAIN SYSTEM
SCALE: 1" = 100'

LEGEND

- 5570 — JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- x — x EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- 5602 — PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- LIMIT OF LINER SYSTEM
- PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- SPLASH PAD (21/06)

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL, AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.

N

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5A

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	04A OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

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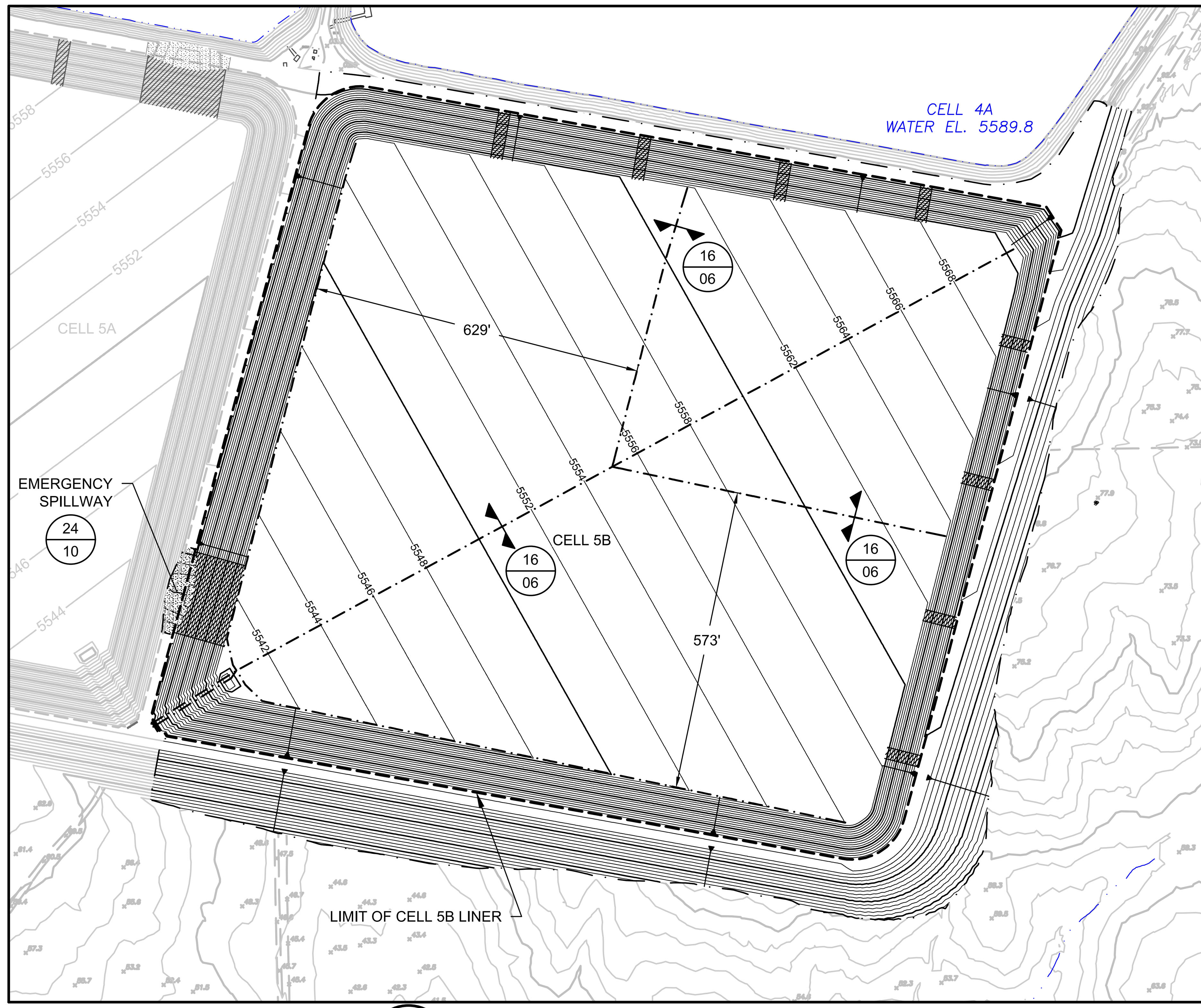
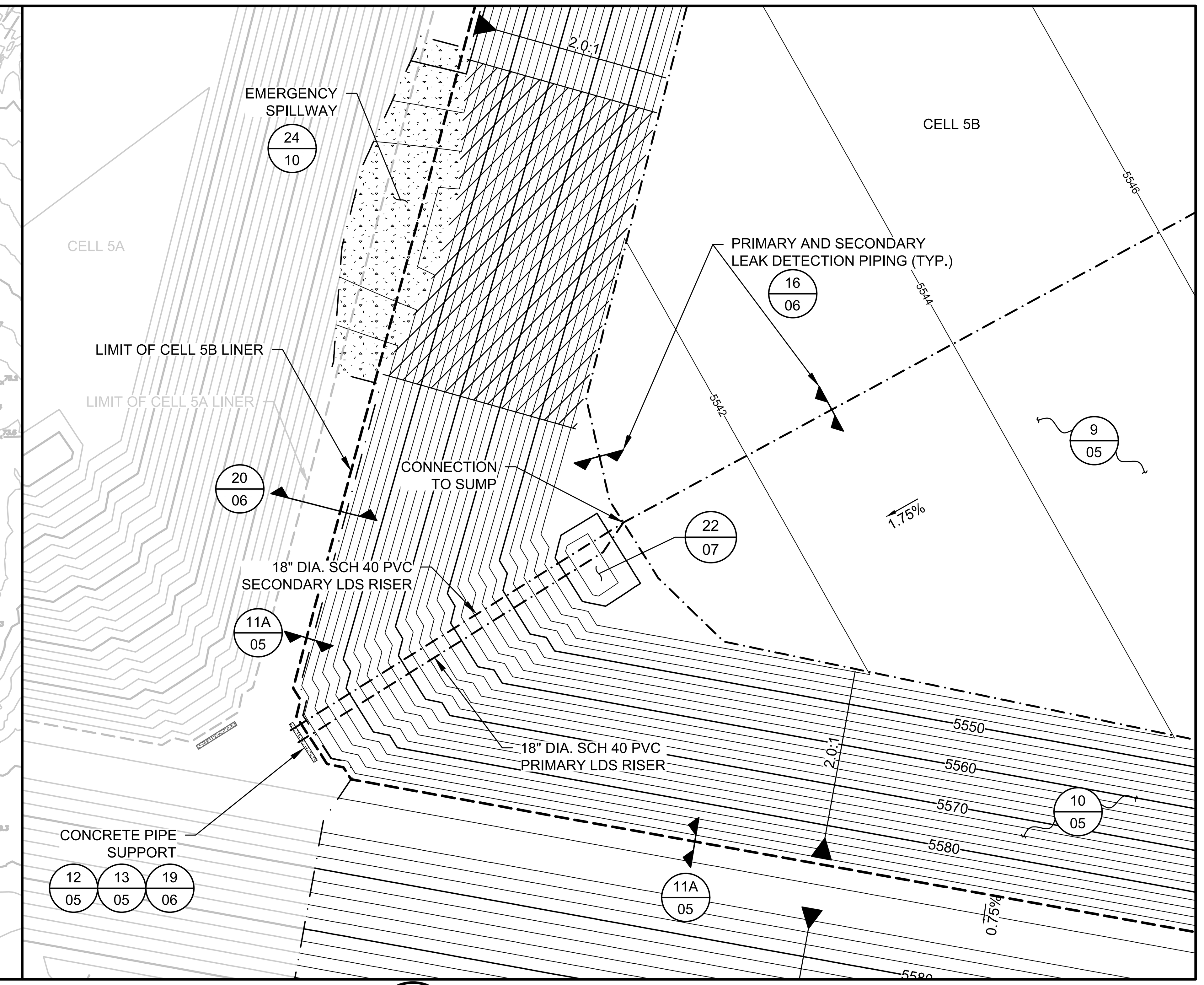
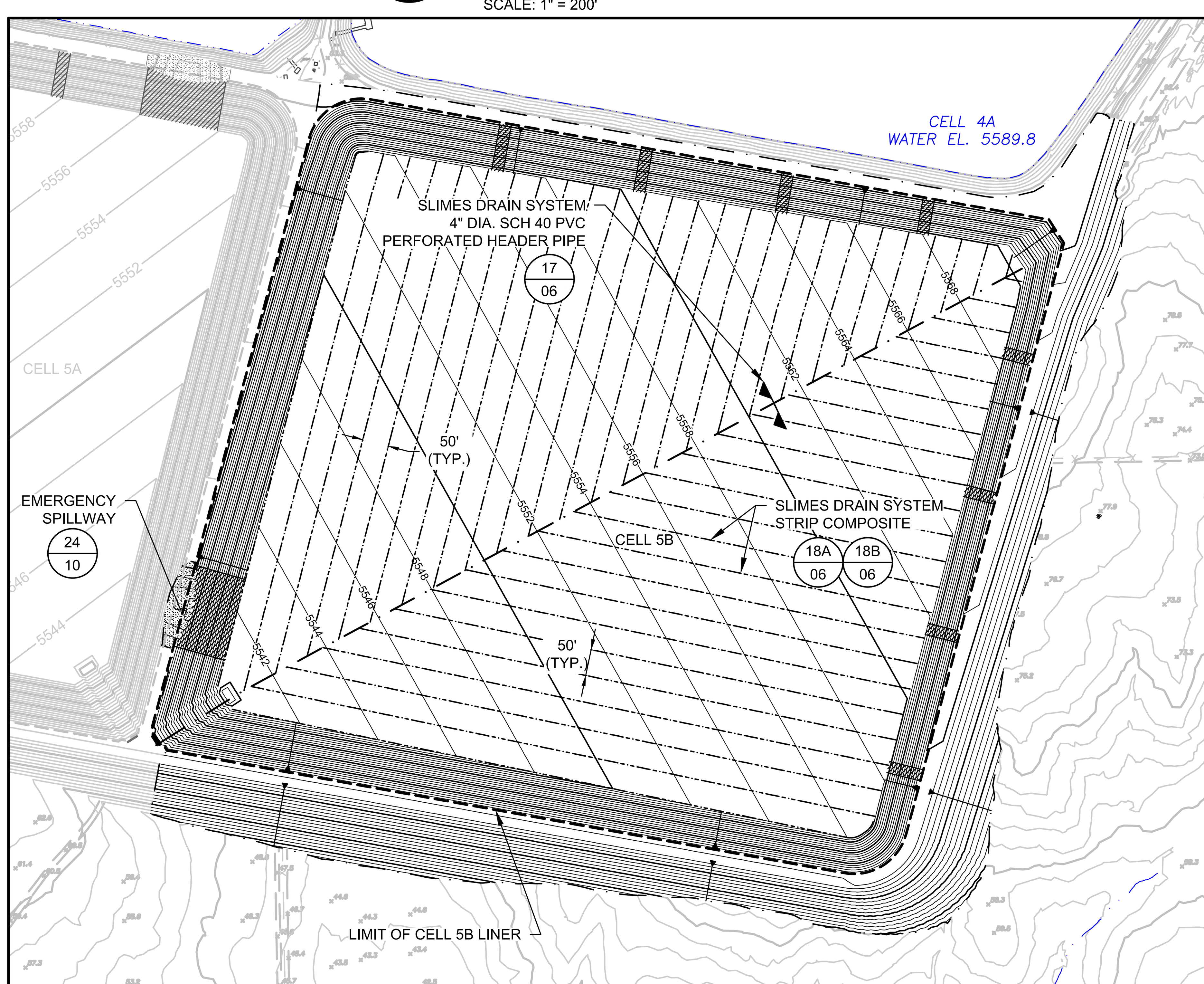


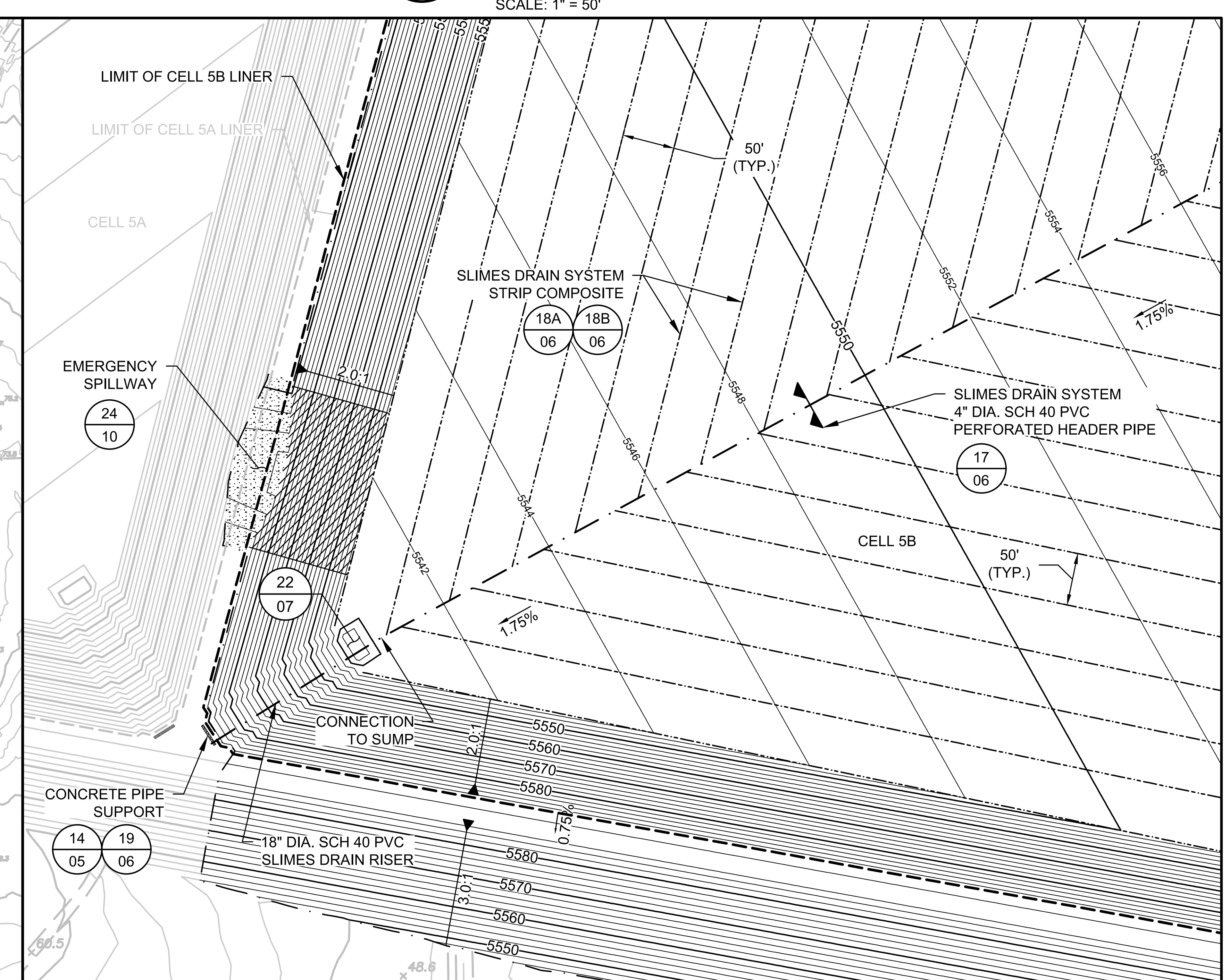
5 PLAN
CELL 5B LEAK DETECTION SYSTEM
SCALE: 1" = 200'



6 DETAIL
CELL 5B LEAK DETECTION SYSTEM
SCALE: 1" = 50'



7 PLAN
CELL 5B SLIMES DRAIN SYSTEM
SCALE: 1" = 200'



8 DETAIL
CELL 5B SLIMES DRAIN SYSTEM
SCALE: 1" = 100'

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

LEGEND

5570	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
	EXISTING DIRT ROAD
x x	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	LIMIT OF LINER SYSTEM
	PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
	SLIMES DRAIN SYSTEM PIPING
	SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
	SPLASH PAD 21 / 06

NOTES

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3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5B

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	04B OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

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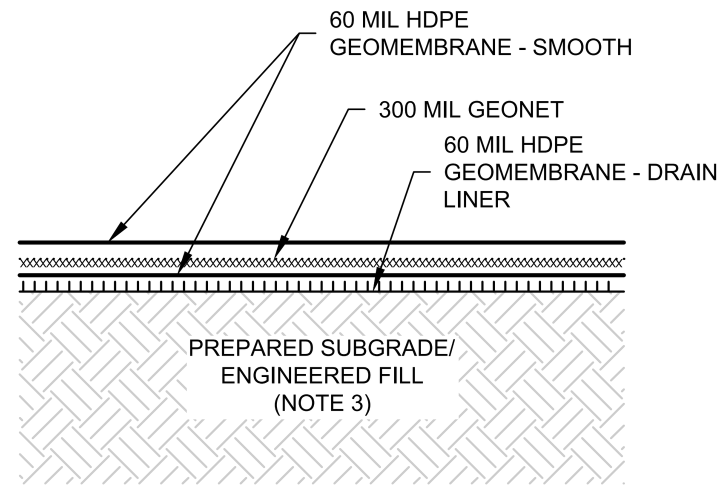
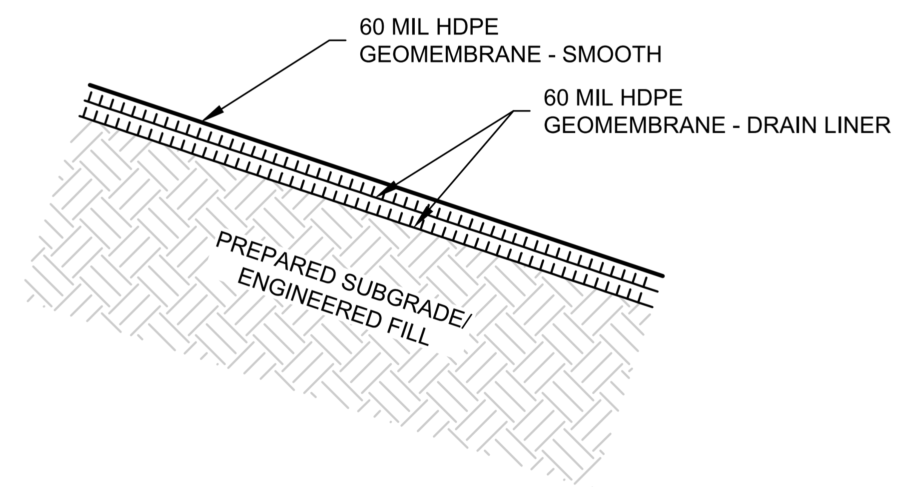
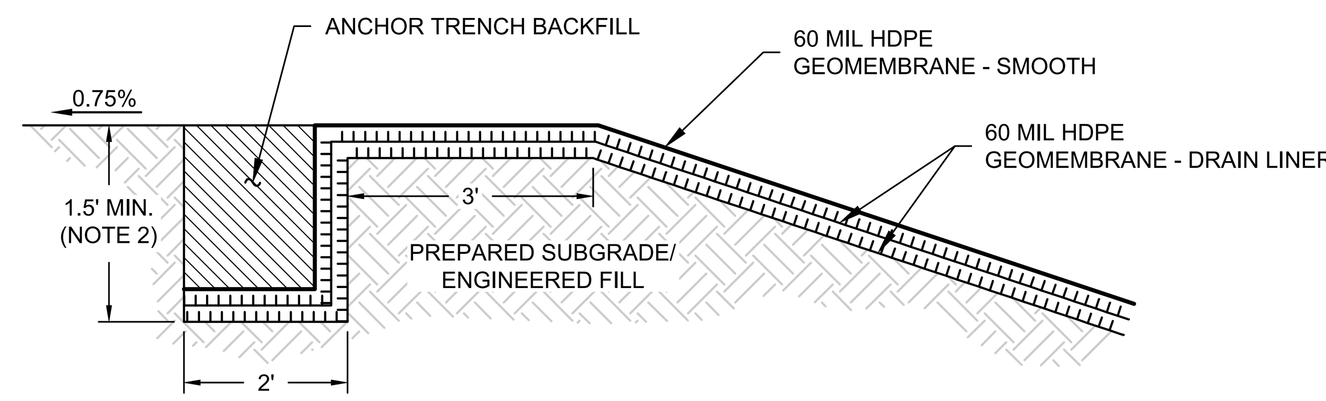


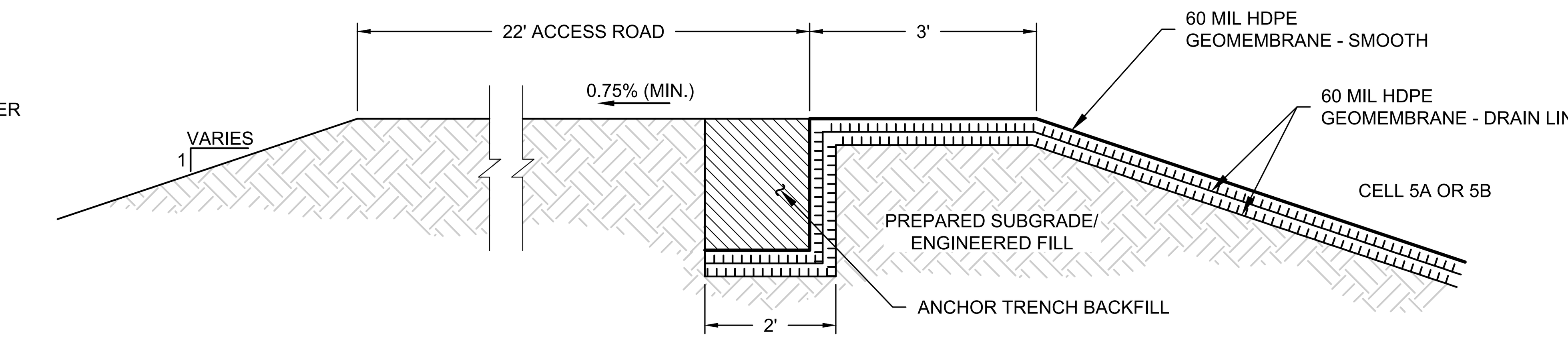
9 DETAIL
03A,03B,04A,04B BASE LINER SYSTEM
SCALE: 1" = 2'



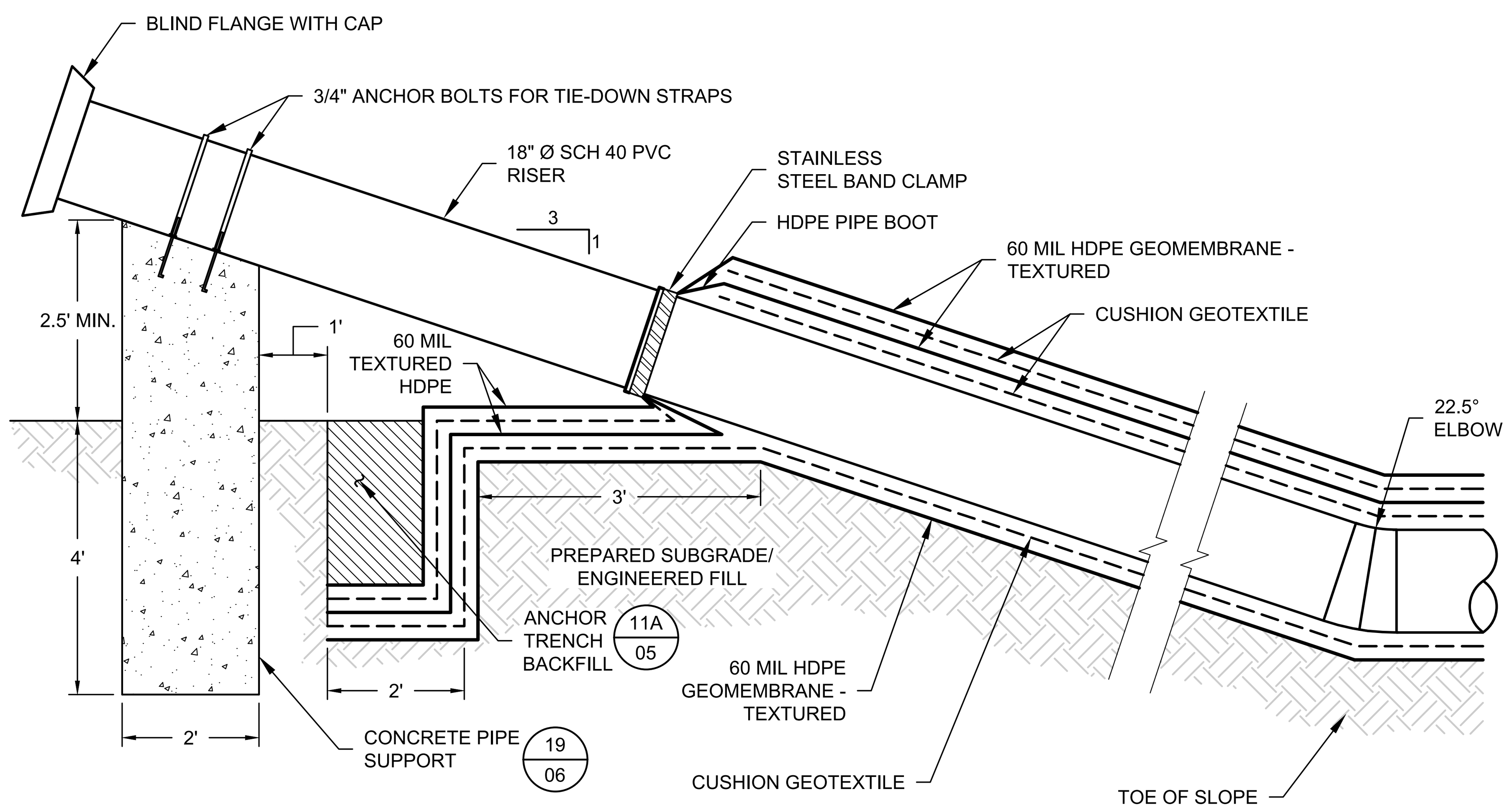
10 DETAIL
03A,03B,04A,04B SIDE SLOPE LINER SYSTEM
SCALE: 1" = 2'



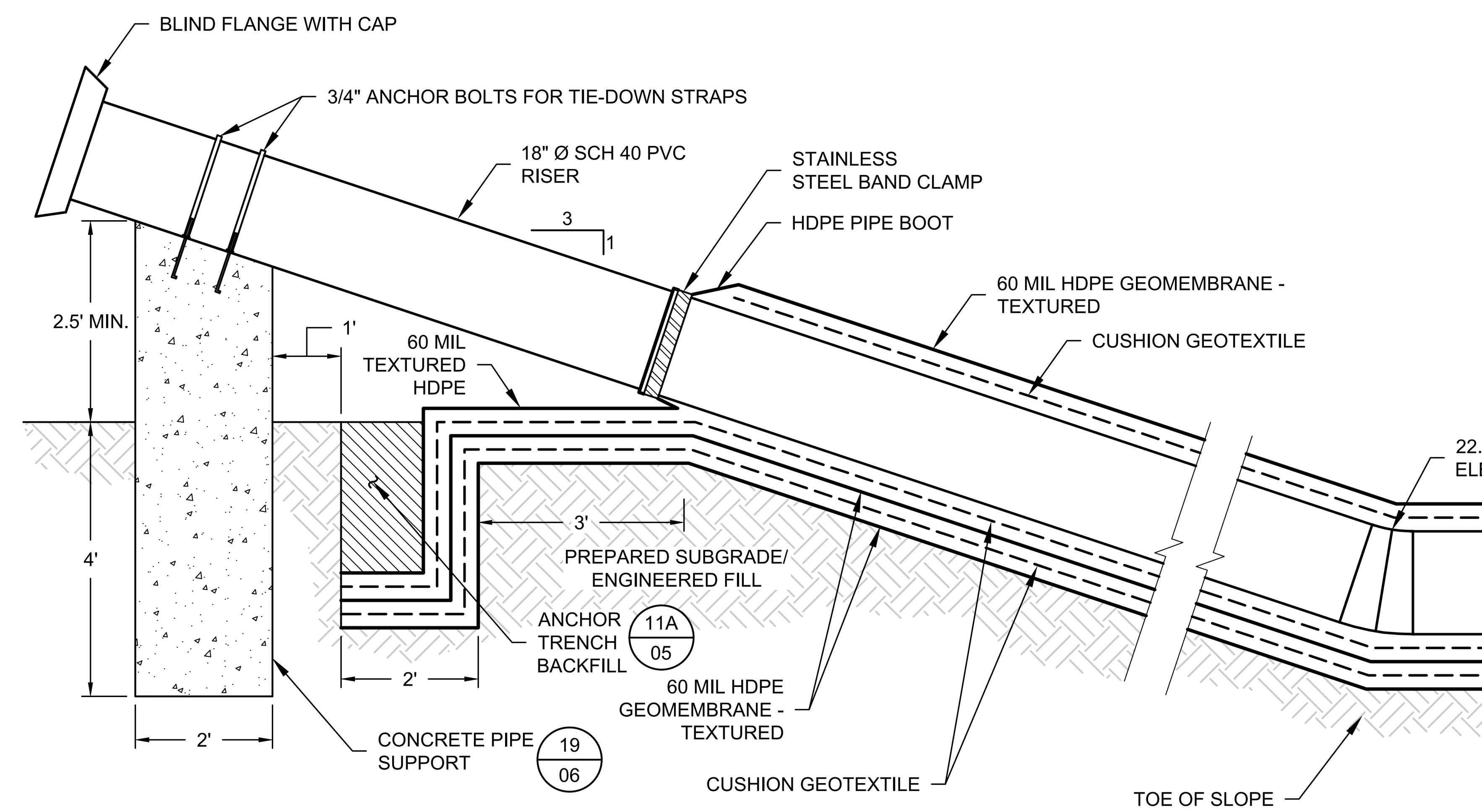
11A DETAIL
03A,03B,04A,04B,05,06,09 ANCHOR TRENCH
SCALE: 1" = 2'



11B DETAIL
03A,03B ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



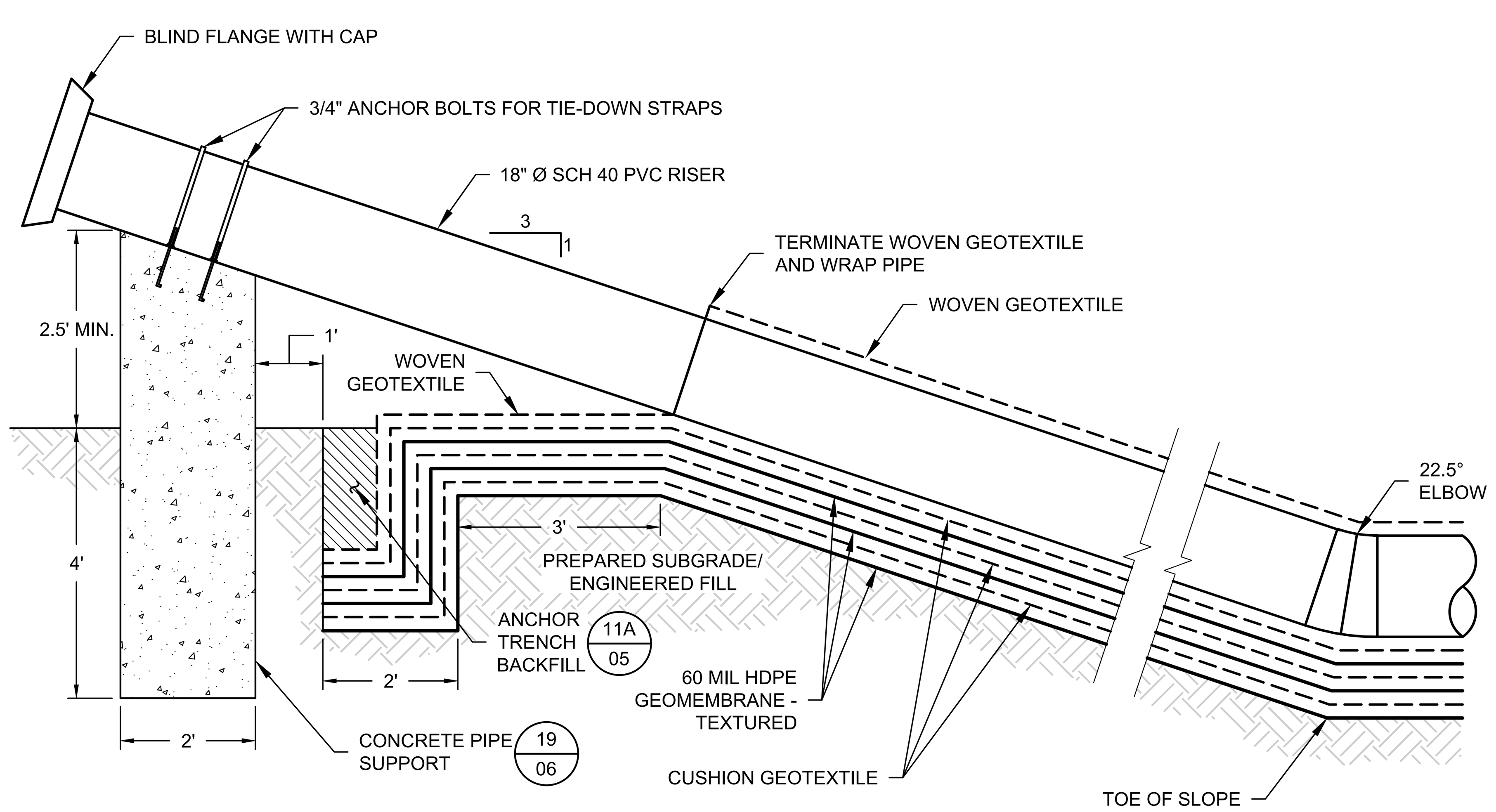
12 DETAIL
04A,04B SECONDARY LEAK DETECTION
RISER PENETRATION
SCALE: 1" = 2'



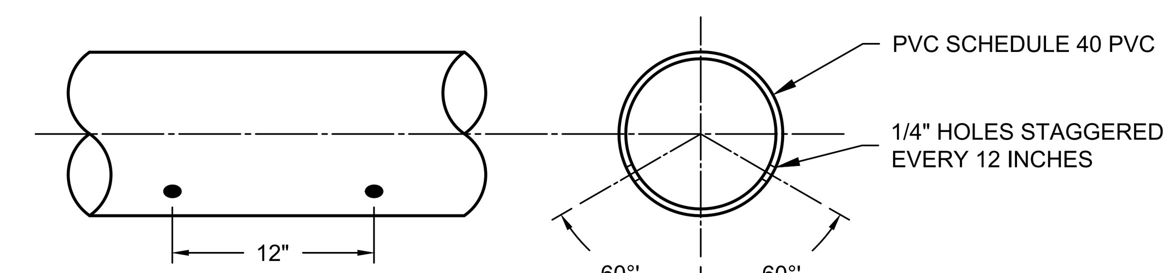
13 DETAIL
04A,04B PRIMARY LEAK DETECTION
SYSTEM RISER PENETRATION
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. ANCHOR TRENCHES MAY BE CONSTRUCTED WITH A MAXIMUM DEPTH OF 3.5 FEET WITH UP TO 1 FOOT OF BACKFILL BETWEEN EACH GEOMEMBRANE IN BOTTOM OF ANCHOR TRENCH.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.



14 DETAIL
04A,04B SLIMES DRAIN RISER
PENETRATION
SCALE: 1" = 2'



15 DETAIL
07,08 PERFORATED PIPE
SCALE: 1" = 1'

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS I

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	05 OF 10	

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

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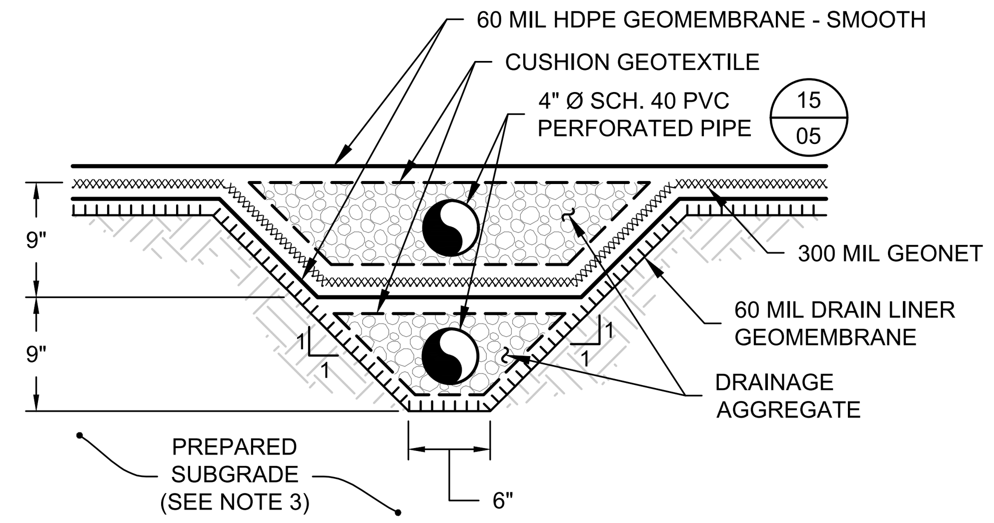
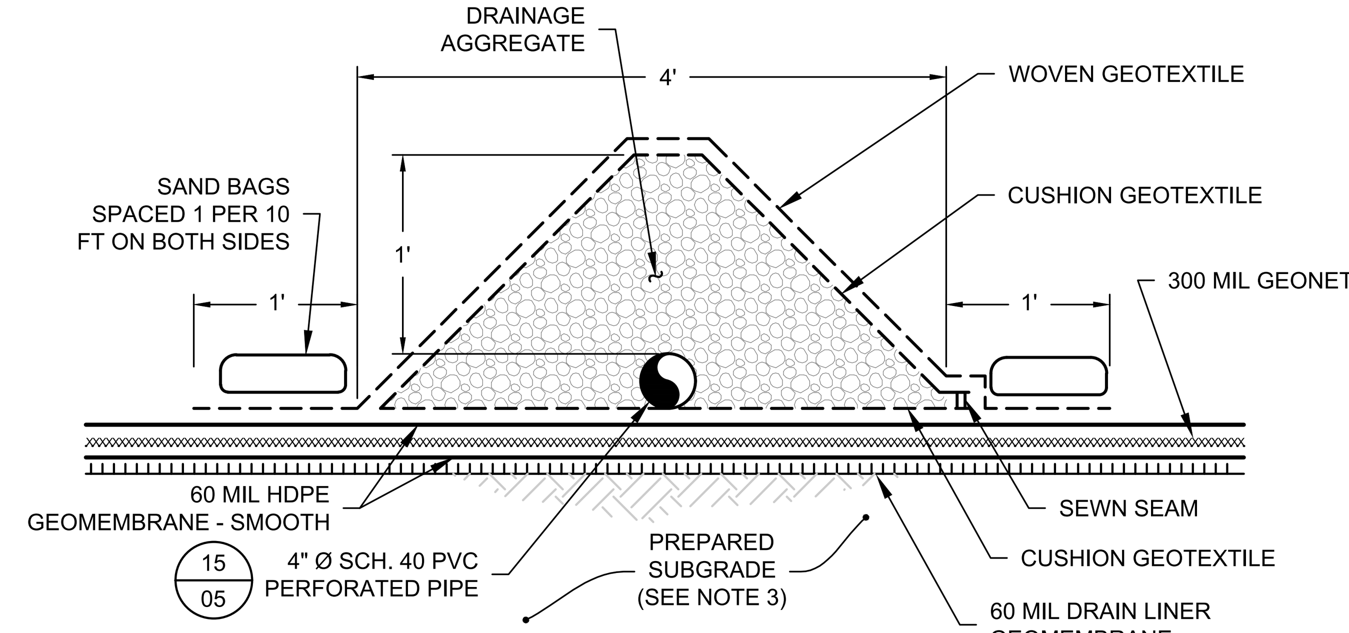
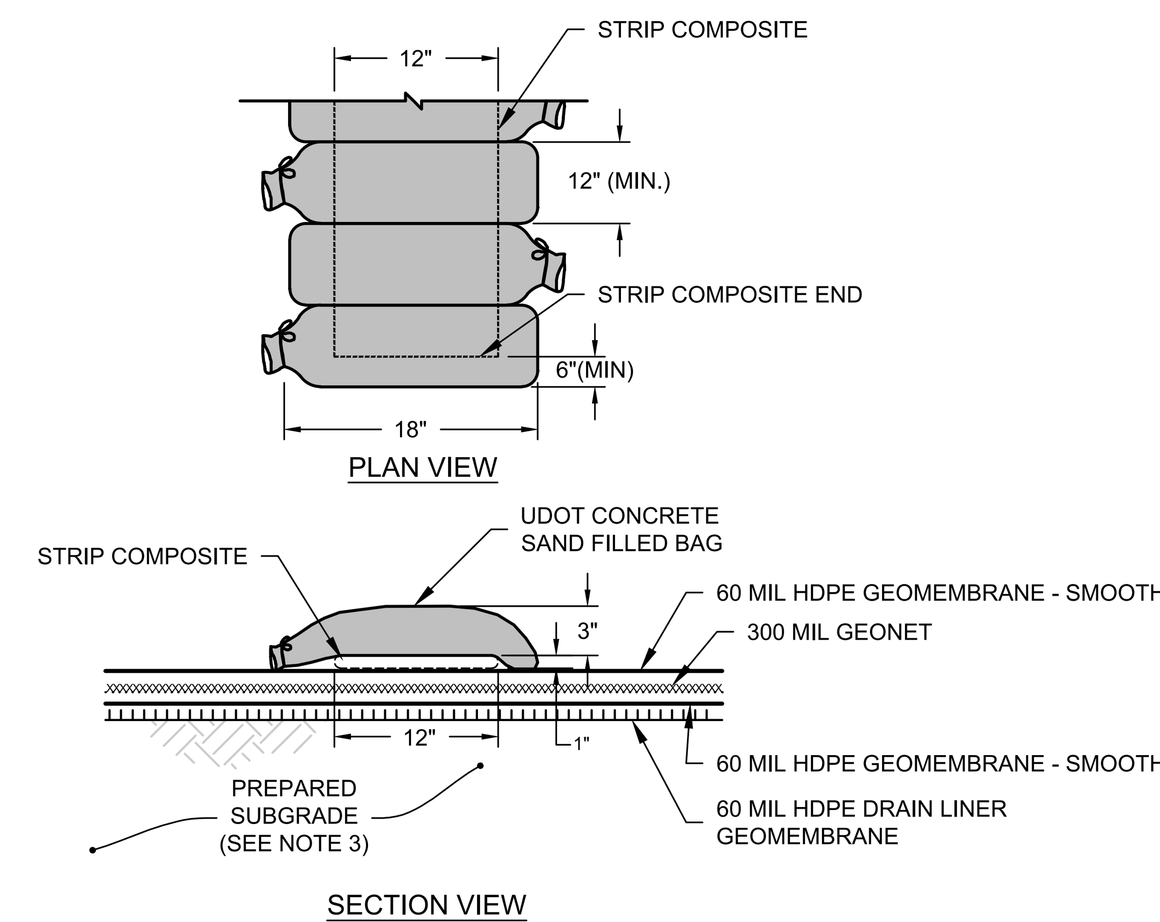


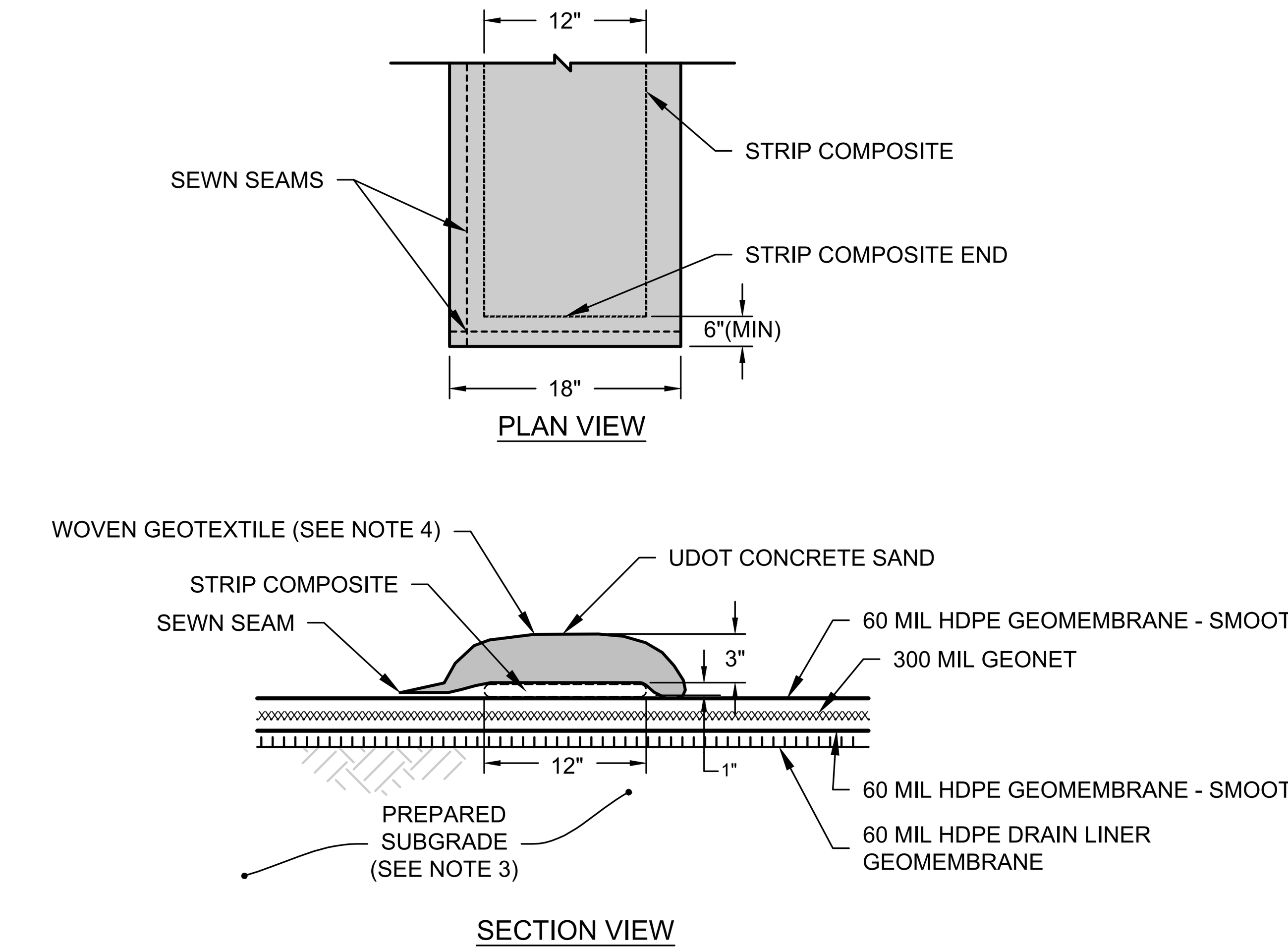
16 DETAIL
04A,04B
LEAK DETECTION SYSTEM TRENCHES
SCALE: 1" = 1'



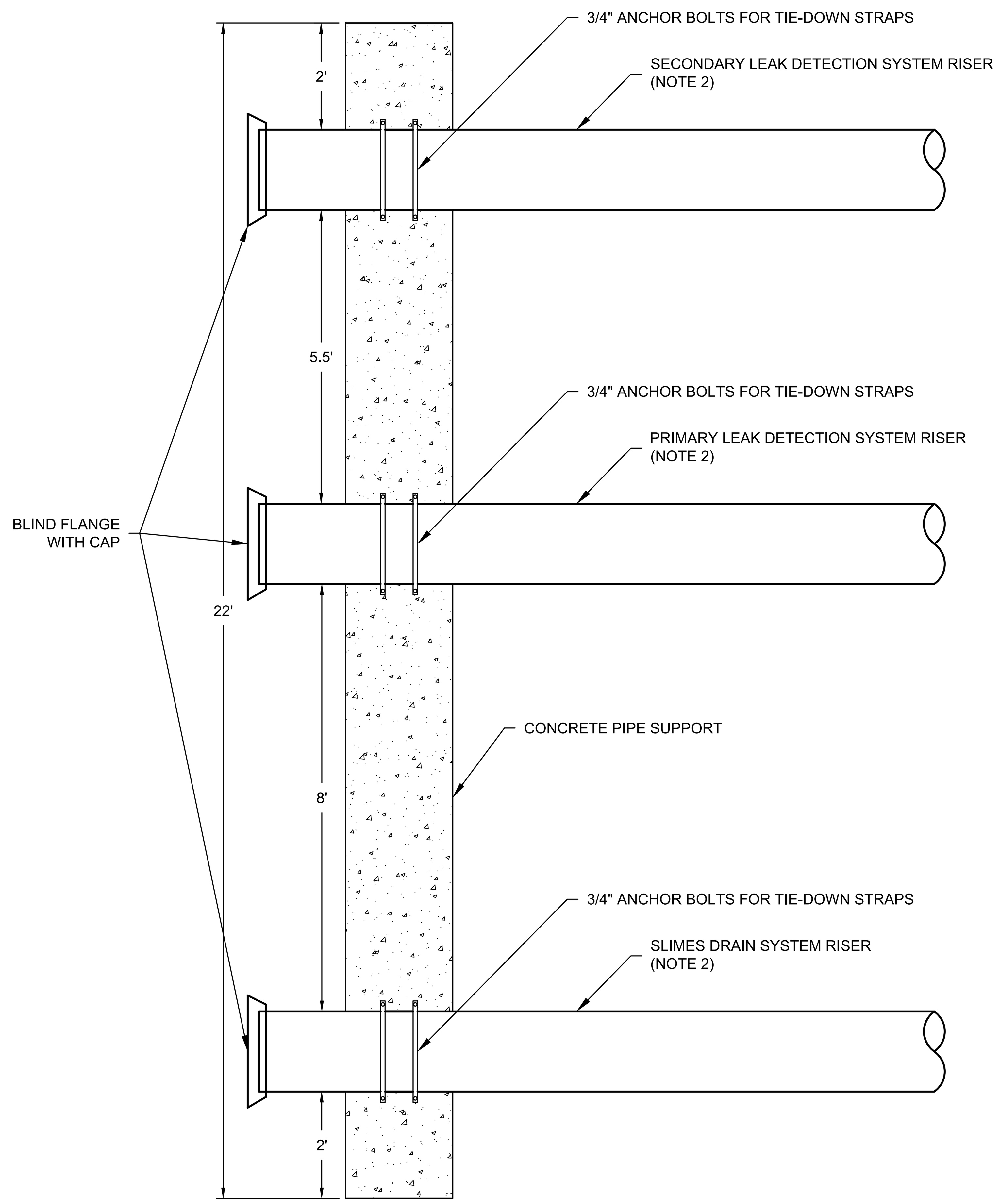
17 DETAIL
04A,04B
SLIMES DRAIN HEADER
SCALE: 1" = 1'



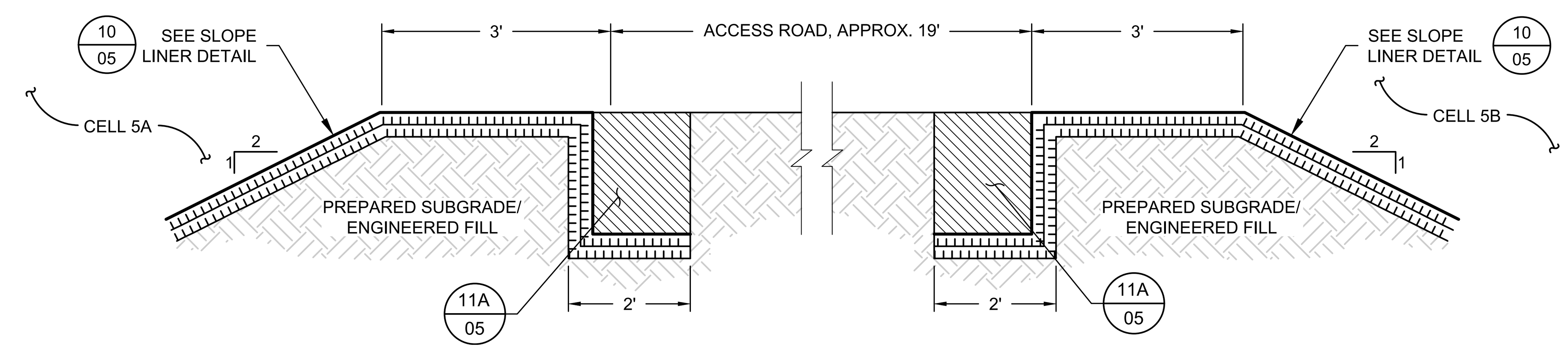
18A DETAIL
04A,04B
SLIMES DRAIN LATERAL - OPTION 1
SCALE: NTS



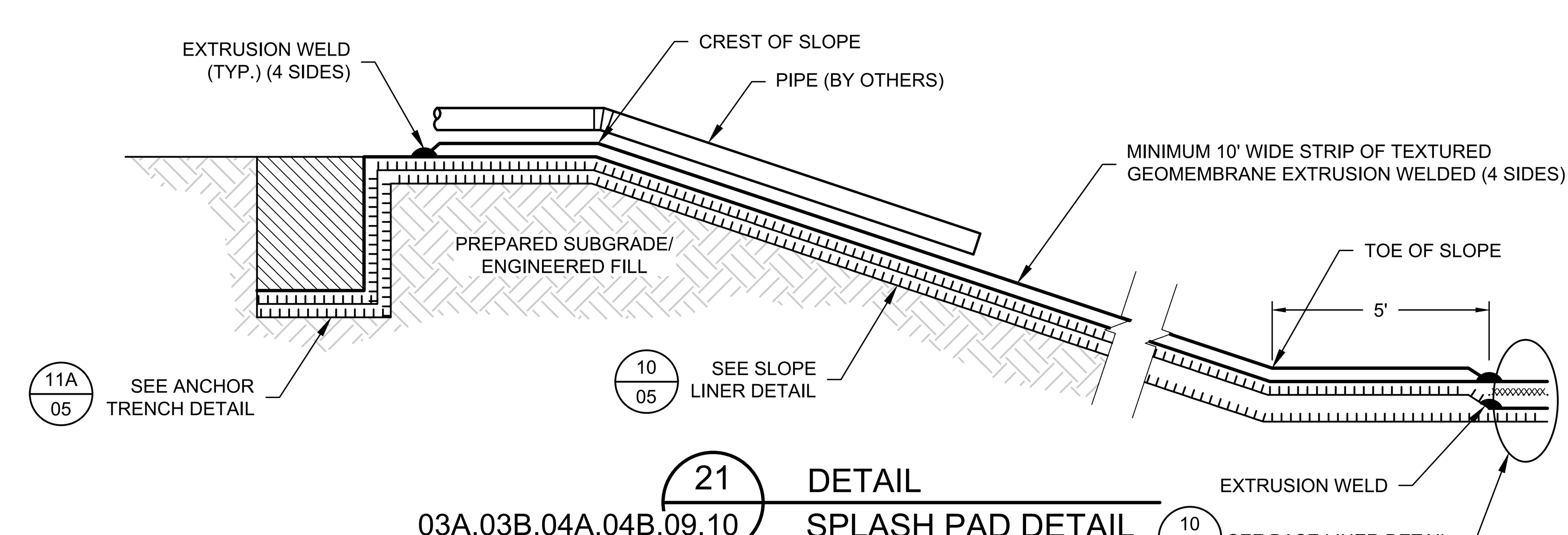
18B DETAIL
04A,04B
SLIMES DRAIN LATERAL - OPTION 2
SCALE: NTS



19 DETAIL
03A,03B,04A,04B
CONCRETE PIPE SUPPORT
SCALE: 1" = 2'



20 DETAIL
03B,04B
CELL 5A - CELL 5B ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



21 DETAIL
03A,03B,04A,04B,09,10
SPLASH PAD DETAIL
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. EXPOSED PVC PIPE SHALL BE PAINTED TO MINIMIZE DAMAGE DUE TO UV.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.
4. WOVEN GEOTEXTILE SHALL BE FOLDED OVER AND SEAMED. GEOTEXTILE SHALL BE FILLED WITH UDOT CONCRETE SAND TO CREATE A CONTINUOUS SANDBAG-LIKE STRUCTURE WITH A MINIMUM OF 3" OF SAND ABOVE STRIP COMPOSITE. ENDS SHALL BE SEAMED FOLLOWING SAND FILLING.

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS II

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

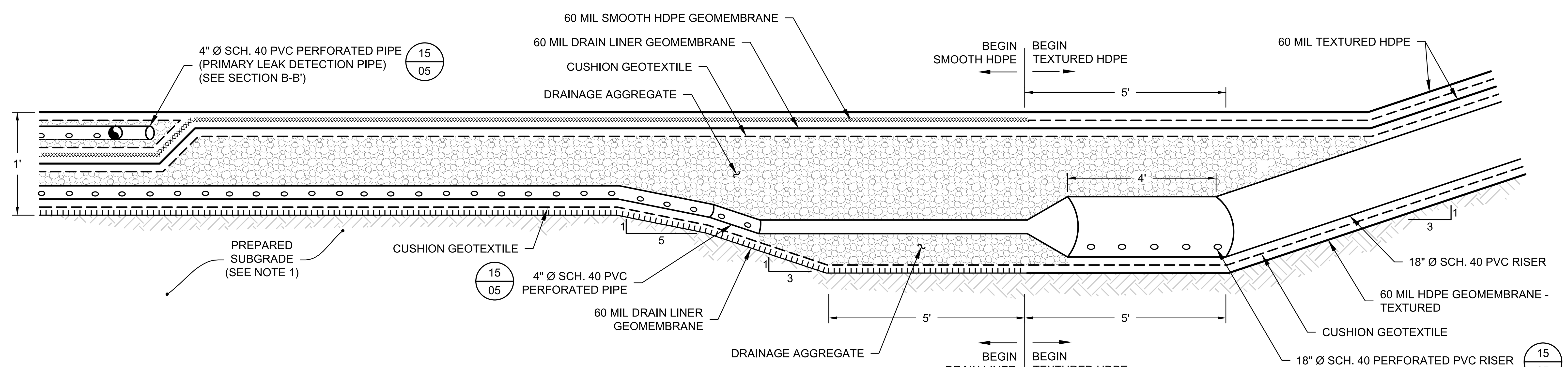
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

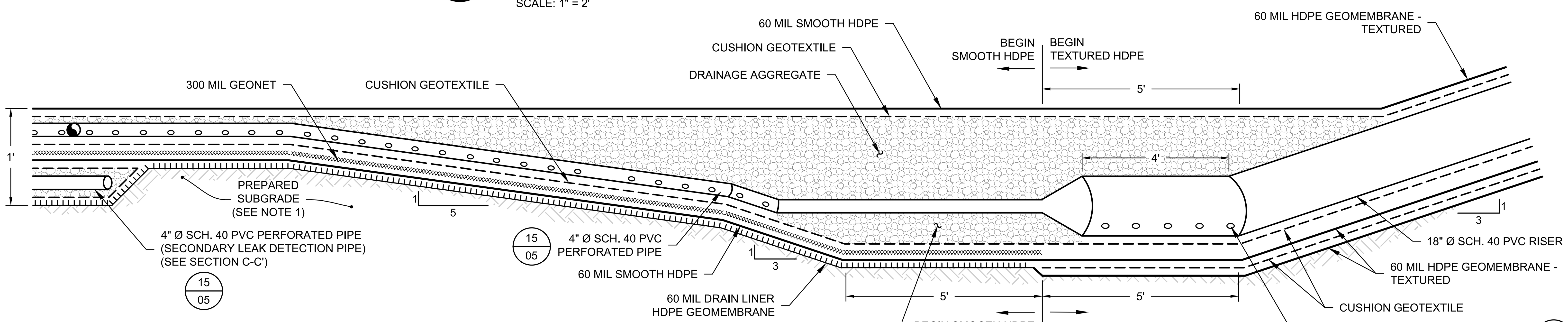
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	06 OF 10	

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

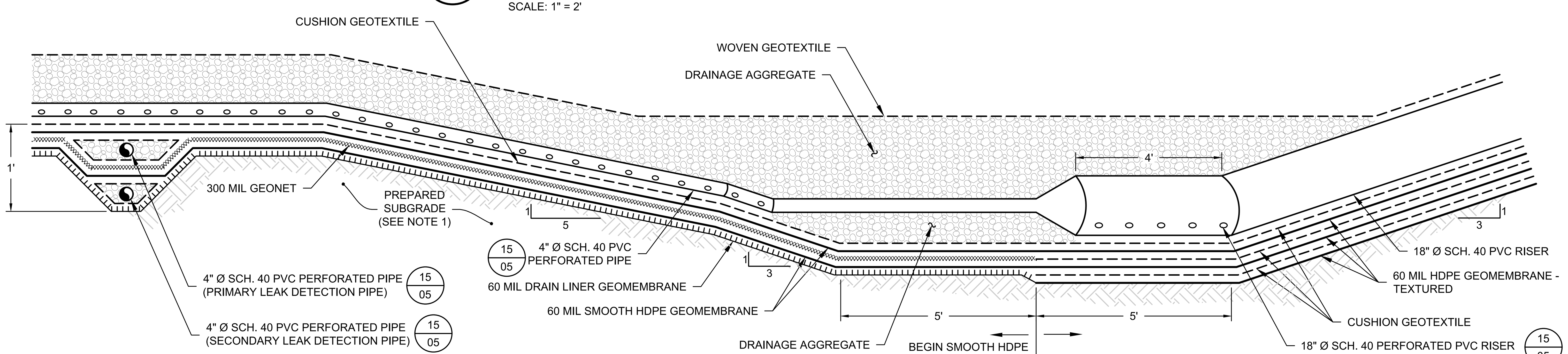
P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634-05-07.dwg Last Edited by: SBerdy on 6/25/2018 3:42 PM



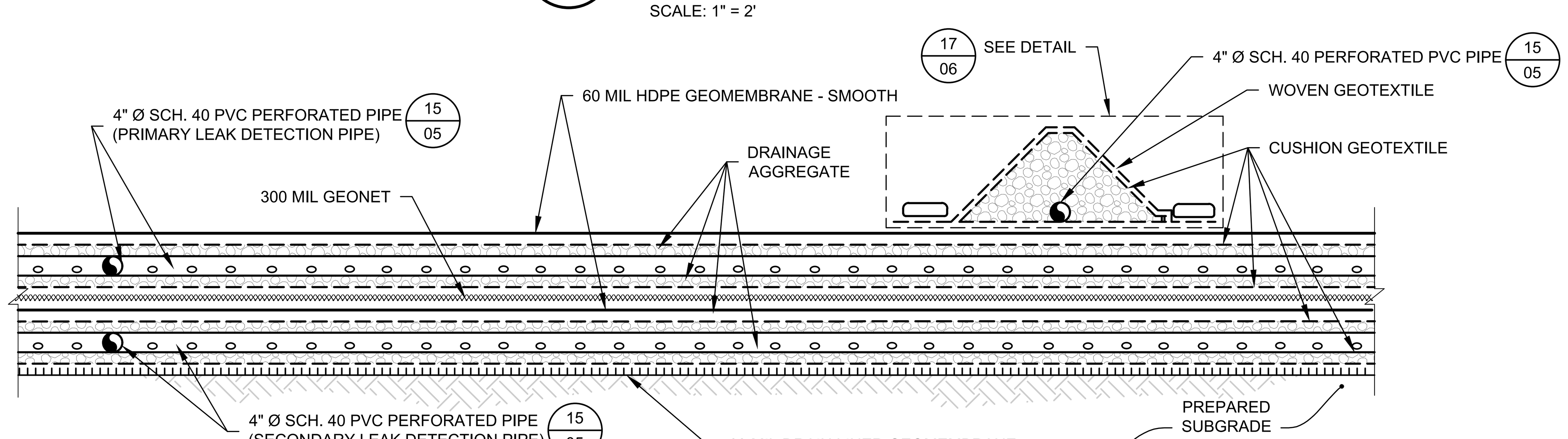
A - SECTION
SECONDARY LEAK DETECTION SUMP
SCALE: 1" = 2'



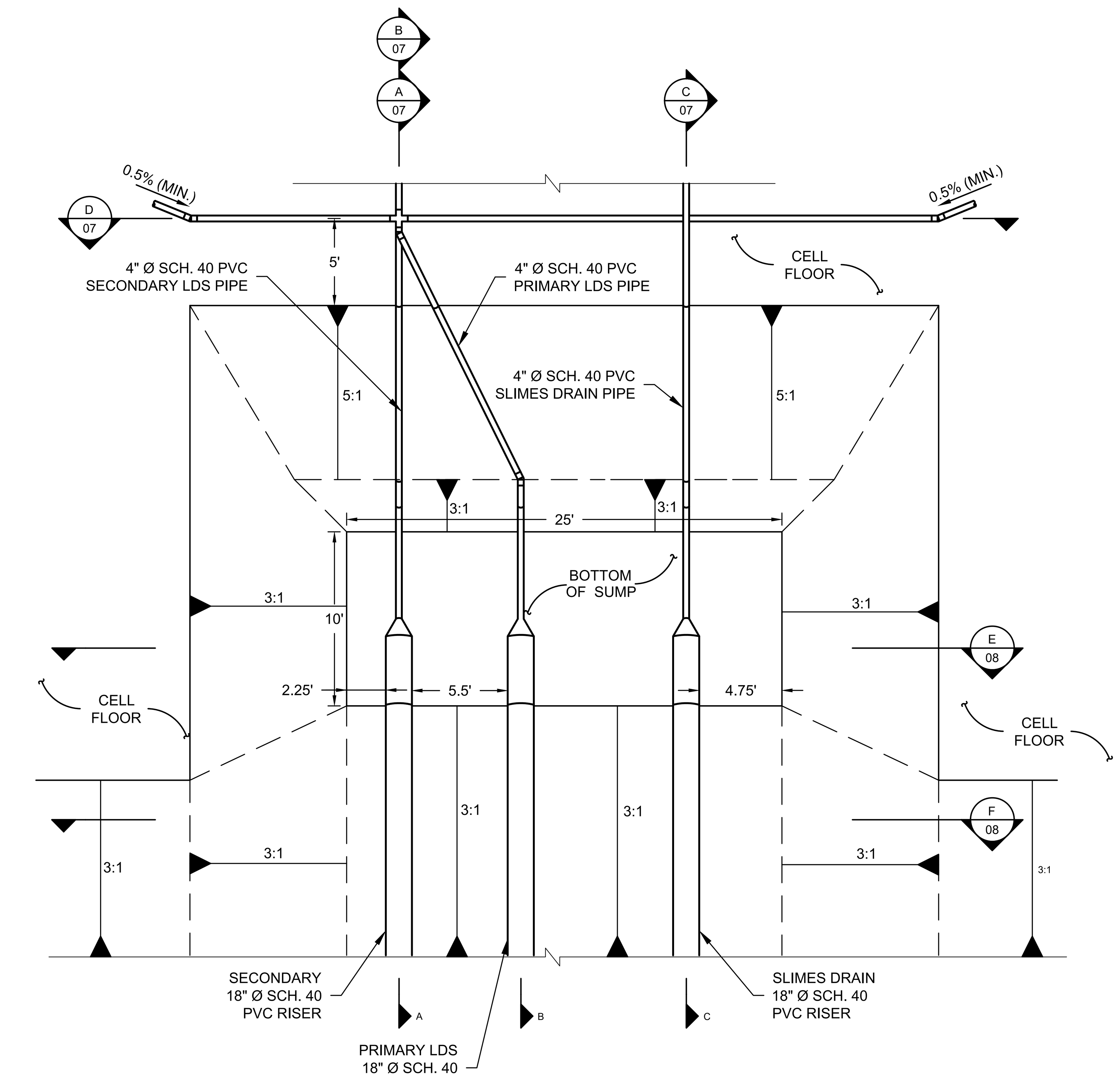
B - SECTION
PRIMARY LEAK DETECTION SUMP
SCALE: 1" = 2'



C - SECTION
SLIMES DRAIN SUMP
SCALE: 1" = 2'



D - SECTION
SLIMES DRAIN AND LDS PIPING SECTION
SCALE: 1" = 2'



22 PLAN
04A,04B SUMP PLAN VIEW
SCALE: 1" = 6'

NOTES:

1. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.

2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. SOIL THICKNESSES ARE MINIMUMS.

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS III

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

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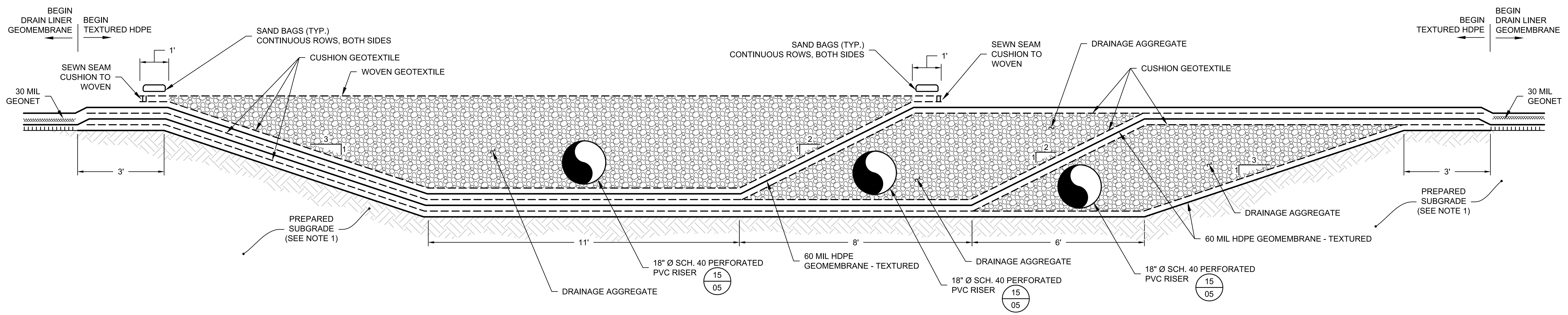
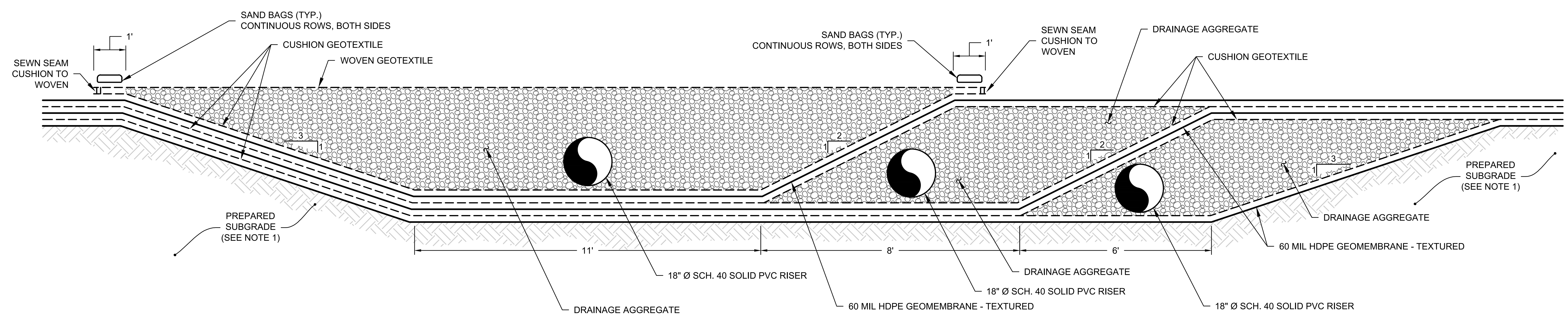
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	07 OF 10	



E / 07 SECTION
SUMP SECTION (FLOOR)
SCALE: 1" = 2'



F / 07 SECTION
SUMP SECTION (SLOPE)
SCALE: 1" = 2'

NOTES:

1. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. SOIL THICKNESSES ARE MINIMUMS.

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS IV

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

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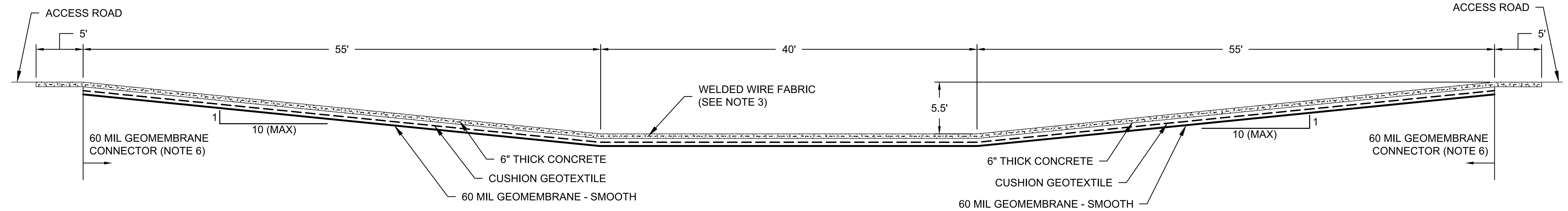
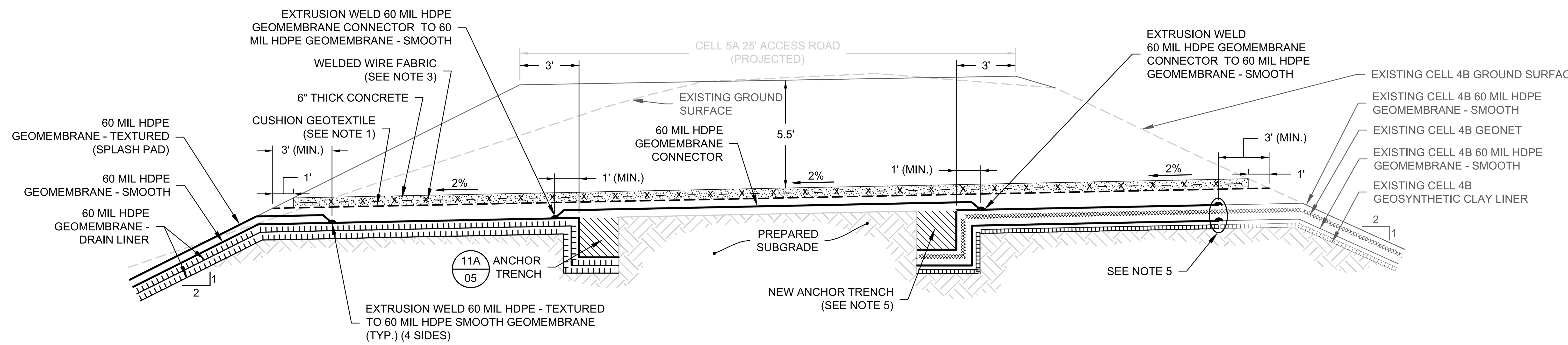
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

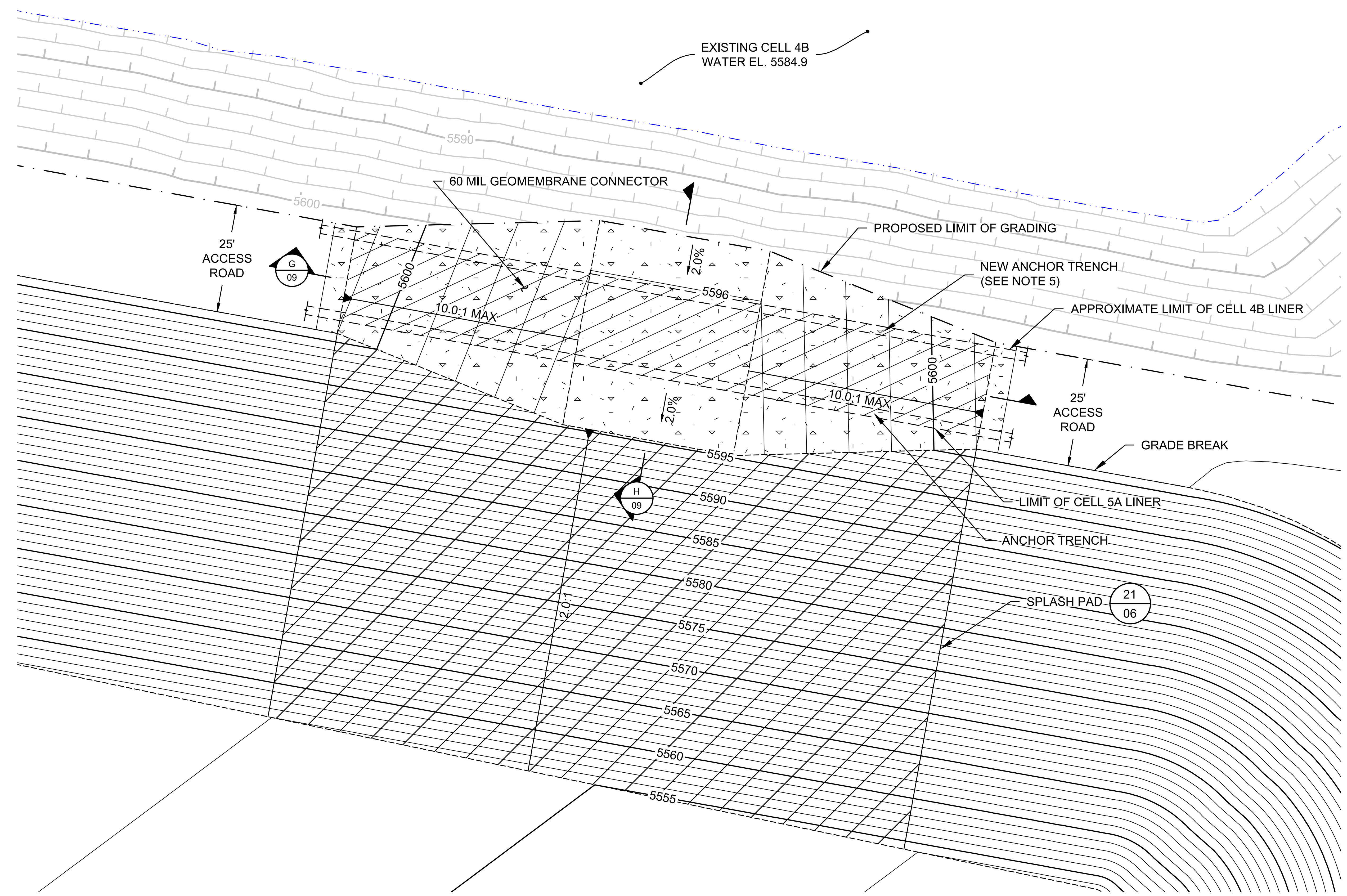
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	08 OF 10	



G / -
SECTION
SPILLWAY - SECTION-5A
SCALE: 1" = 8'



H / -
SECTION
SPILLWAY - SECTION 2-5A
SCALE: 1" = 4'



23 / 03A,04A
PLAN
SPILLWAY PLAN - 5A
SCALE: 1" = 20'

NOTES:

1. CUSHION GEOTEXTILE SHALL BE PLACED OVERLYING PRIMARY GEOMEMBRANE WHERE CONCRETE IS INSTALLED.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
3. WELDED WIRE FABRIC SHALL BE INSTALLED AT CENTER OF CONCRETE SLAB SECTION.
4. SPLASH PAD AT SPILLWAY SHALL BE 150' WIDE, SHALL EXTEND 5' ONTO THE FLOOR AND BE EXTRUSION WELDED ON ALL FOUR (4) SIDES TO PRIMARY GEOMEMBRANE.
5. CUT AND FOLD BACK EXISTING LINER SYSTEM GEOSYNTHETIC LAYERS (60 mil HDPE MEMBRANE, 300 mil GEONET, 60 mil HDPE GEOMEMBRANE, GCL) TO ALLOW EXCAVATION OF SPILLWAY. REPLACE LINER SYSTEM GEOSYNTHETICS LAYERS ONTO NEW SPILLWAY GRADES AND NEW ANCHOR TRENCH. NEW ANCHOR TRENCH SHALL BE TIED INTO EXISTING ANCHOR TRENCH.
6. ANCHOR 60 MIL GEOMEMBRANE CONNECTOR AT TOP OF 10H:1V SLOPE IN 12" DEEP ANCHOR TRENCH.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS V

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	09 OF 10	

PERMIT LEVEL DESIGN
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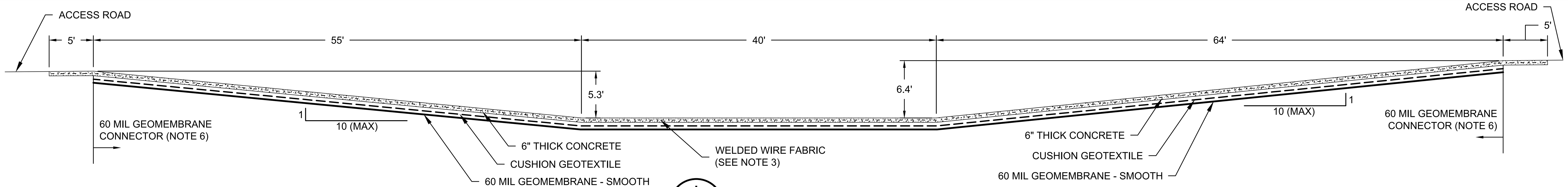
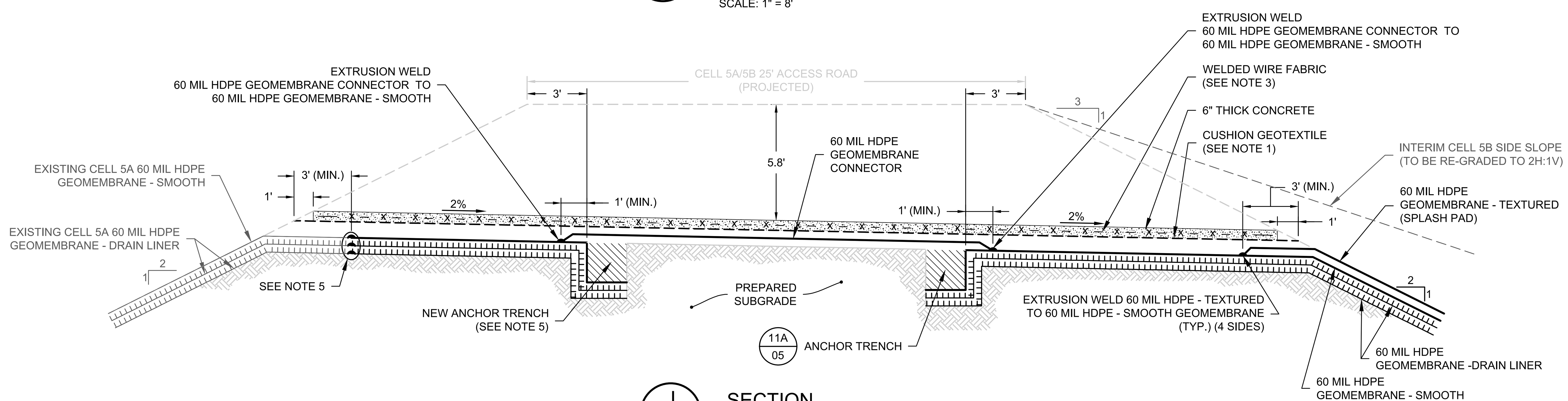
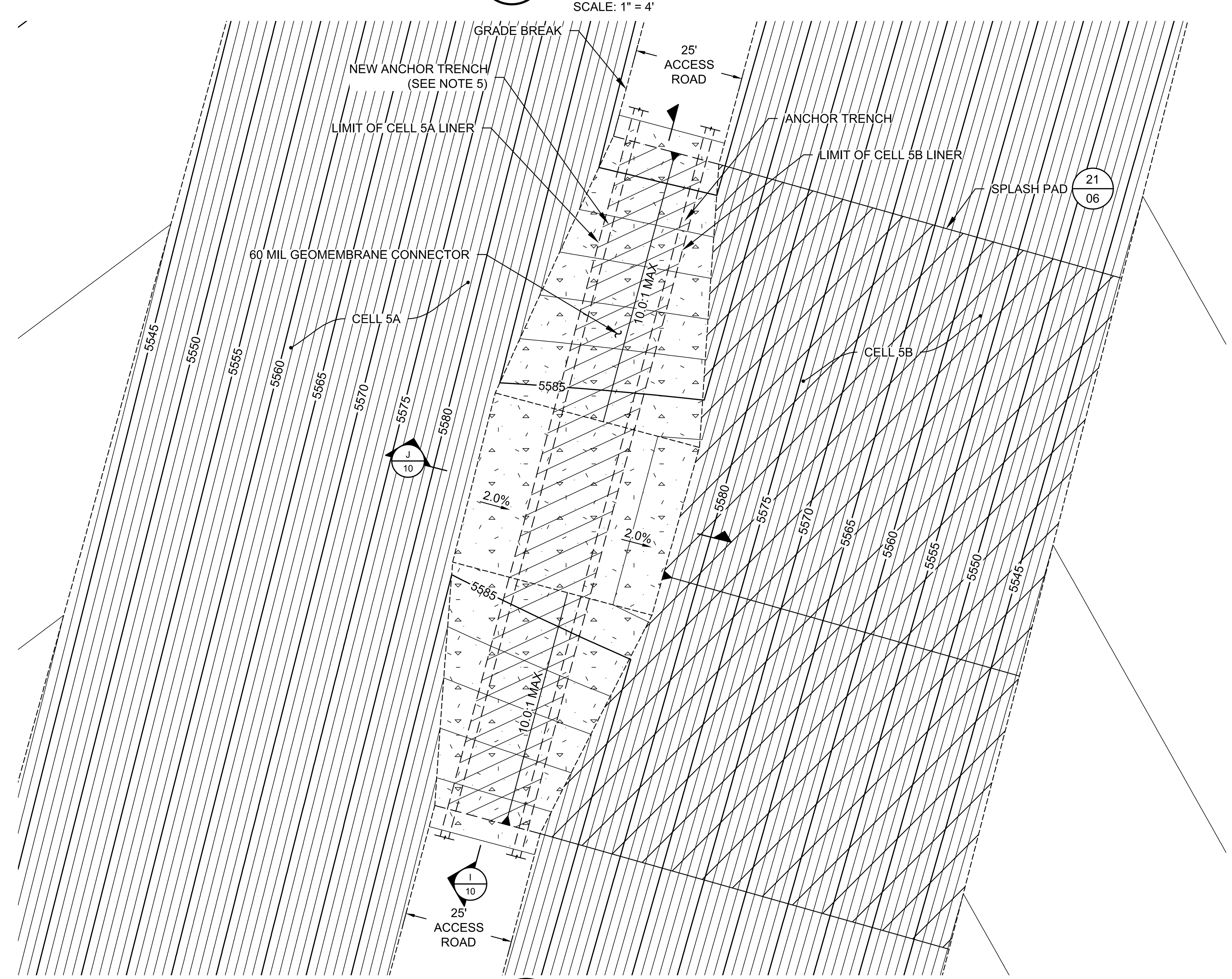
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



SECTION I
SPILLWAY - SECTION-5B
SCALE: 1" = 8'



SECTION J
SPILLWAY - SECTION 2 - 5B
SCALE: 1" = 4'



PLAN 24
SPILLWAY PLAN - 5B
SCALE: 1" = 20'

NOTES:

1. CUSHION GEOTEXTILE SHALL BE PLACED OVERLYING PRIMARY GEOMEMBRANE WHERE CONCRETE IS INSTALLED.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
3. WELDED WIRE FABRIC SHALL BE INSTALLED AT CENTER OF CONCRETE SLAB SECTION.
4. SPLASH PAD AT SPILLWAY SHALL BE 159' WIDE, SHALL EXTEND 5' ONTO THE FLOOR AND BE EXTRUSION WELDED ON ALL FOUR (4) SIDES TO PRIMARY GEOMEMBRANE.
5. CUT AND FOLD BACK EXISTING LINER SYSTEM GEOSYNTHETIC LAYERS (60 mil HDPE MEMBRANE, 300 mil GEONET, 60 mil HDPE GEOMEMBRANE, GCL) TO ALLOW EXCAVATION OF SPILLWAY. REPLACE LINER SYSTEM GEOSYNTHETICS LAYERS ONTO NEW SPILLWAY GRADES AND NEW ANCHOR TRENCH. NEW ANCHOR TRENCH SHALL BE TIED INTO EXISTING ANCHOR TRENCH.
6. ANCHOR 60 MIL GEOMEMBRANE CONNECTOR AT TOP OF 10H:1V SLOPE IN 12" DEEP ANCHOR TRENCH.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS VI

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B OPTION A - TRIPLE LINER

SITE: WHITE MESA MILL BLANDING, UTAH

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SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	10 OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

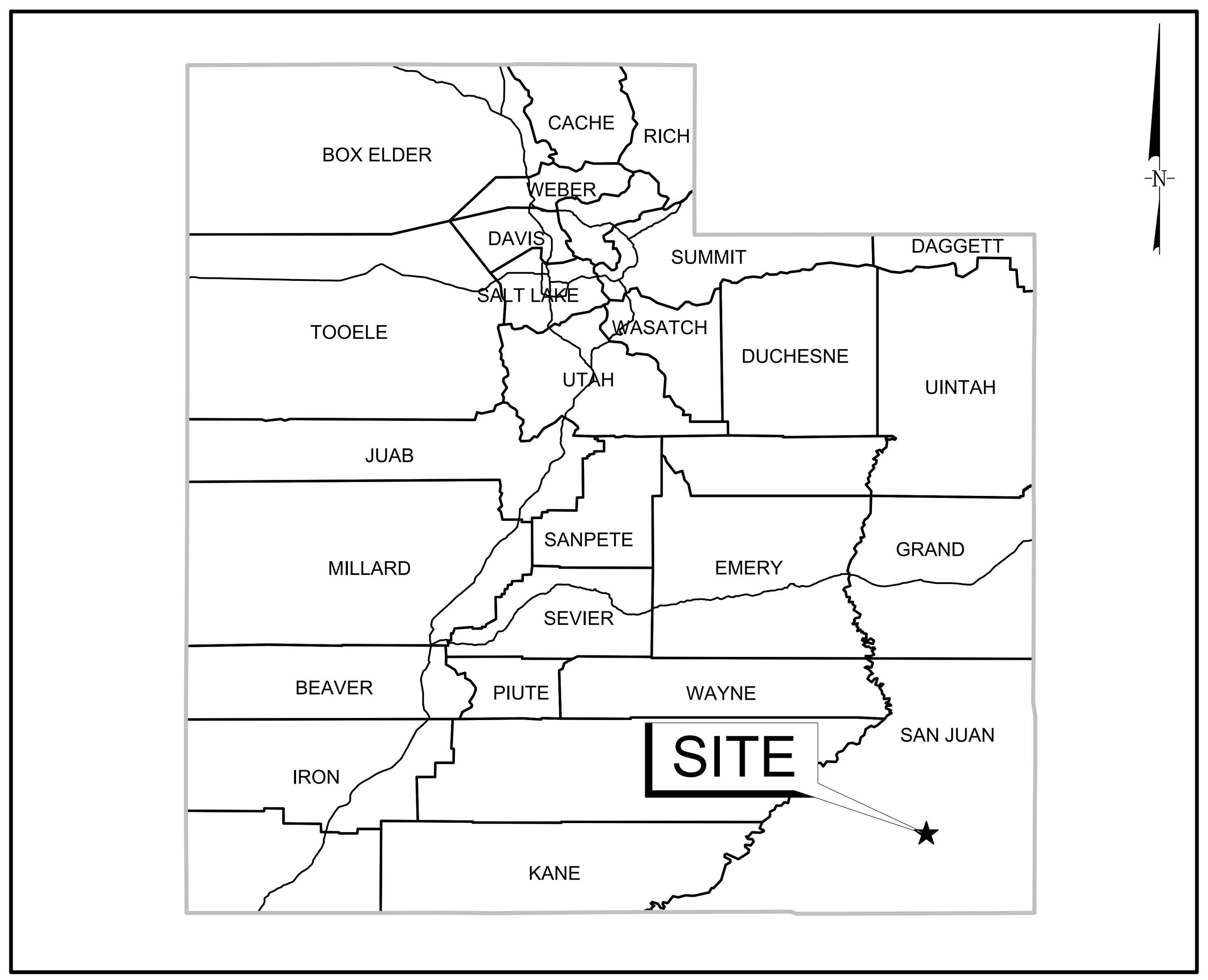
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

APPENDIX A-2

Construction Drawings

Option B – Double Liner with Geosynthetic Clay Liner

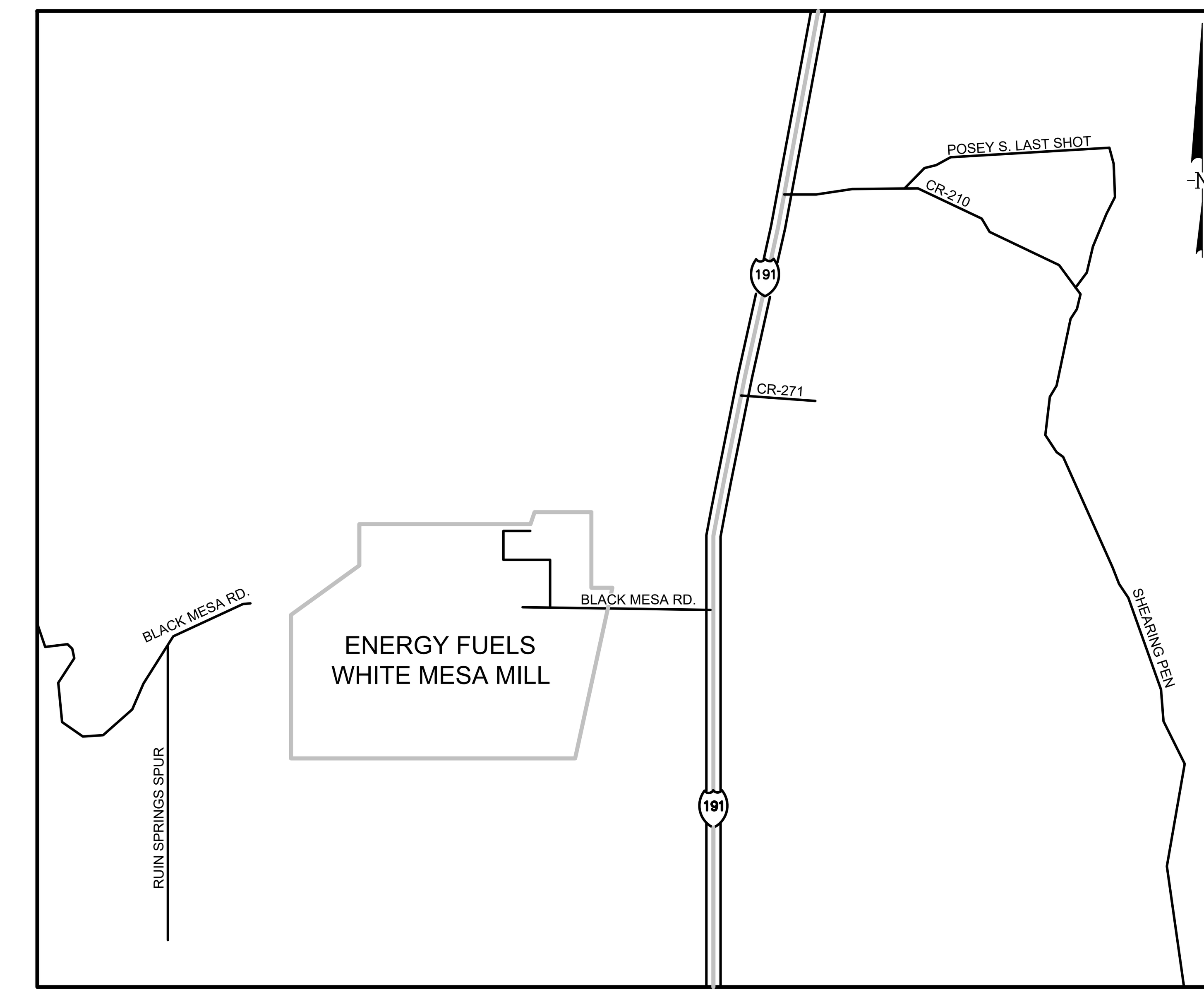
PERMIT LEVEL DESIGN DRAWINGS
CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL
ENERGY FUELS WHITE MESA MILL
BLANDING, UTAH
JUNE 2018



VICINITY MAP
NOT TO SCALE

LIST OF DRAWINGS

DRAWING	DESCRIPTION
01	TITLE SHEET
02	SITE PLAN
03A	CELL 5A PROPOSED GRADING
03B	CELL 5B PROPOSED GRADING
04A	PIPE LAYOUT PLAN AND DETAILS - CELL 5A
04B	PIPE LAYOUT PLAN AND DETAILS - CELL 5B
05	LINER SYSTEM DETAILS I
06	LINER SYSTEM DETAILS II
07	DETAILS & SECTIONS III
08	DETAILS & SECTIONS IV
09	DETAILS & SECTIONS V
10	DETAILS & SECTIONS VI



LOCATION MAP
NOT TO SCALE

4 — DETAIL NUMBER
6 — SHEET ON WHICH ABOVE DETAIL IS PRESENTED

DETAIL NUMBER — 4 — DETAIL
SHEET ON WHICH ABOVE DETAIL WAS FIRST REFERENCED — 3 — TITLE OF DETAIL
SCALE: 1"=2'

EXAMPLE: DETAIL NUMBER 4 PRESENTED ON SHEET NO. 6 WAS REFERENCED FOR THE FIRST TIME ON SHEET NO. 3.

DETAIL IDENTIFICATION LEGEND

(ABOVE SYSTEM ALSO APPLIES TO SECTION IDENTIFICATIONS, HOWEVER, LETTERS ARE USED INSTEAD OF NUMBERS.)

PREPARED FOR:

Energy Fuels Resources (USA) Inc.

ENERGY FUELS RESOURCES (USA) INC.
6425 S. HIGHWAY 191
P.O. BOX 809
BLANDING, UTAH 84511
(306) 628-7798

PREPARED BY:

Geosyntec consultants

GEOSYNTEC CONSULTANTS
16644 WEST BERNARDO DRIVE, SUITE 301
SAN DIEGO, CALIFORNIA 92127
(858) 674-6559

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUITE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: TITLE SHEET

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

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DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-01
REVIEWED BY:	GTC	DRAWING NO.:	01 OF 10
APPROVED BY:	GTC		

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

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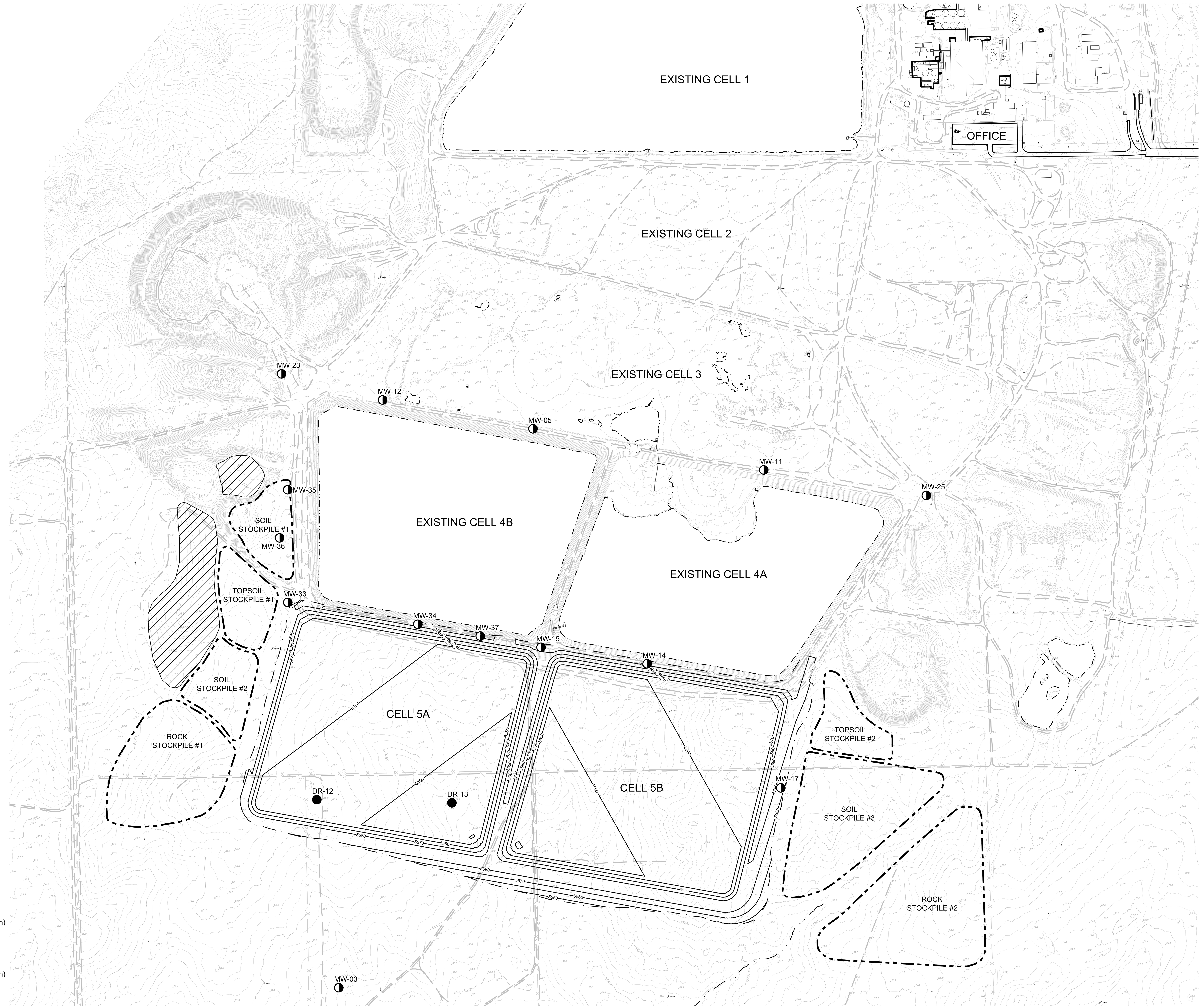
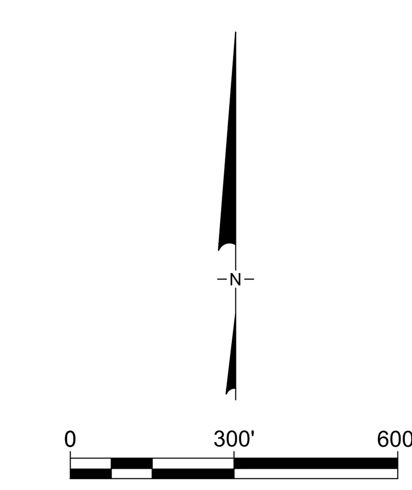


LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- SURFACE WATER BOUNDARY
- SURFACE WATER DRAINAGE
- PROPOSED GRADING MAJOR CONTOUR (10')
- PROPOSED GRADING LIMIT
- PROPOSED STOCKPILE BOUNDARIES
- KNOWN ARCHEOLOGICAL AREAS (SEE NOTE 6)
- DR-13 MW-12 EXISTING GROUNDWATER MONITORING WELLS

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. EXISTING WELLS, PIPING, AND OTHER SITE FEATURES SHALL BE PROTECTED IN PLACE, EXCEPT AS NOTED OTHERWISE.
3. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL, AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
4. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
5. CONSTRUCTION WATER TO BE PROVIDED BY OWNER AT NORTHEAST CORNER OF CELL 4A.
6. CONTRACTOR TO AVOID KNOWN ARCHEOLOGICAL AREAS. OWNER TO CLEAR ARCHEOLOGICAL AREAS WITHIN LIMITS OF WORK PRIOR TO BEGINNING EXCAVATION.



REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: SITE PLAN

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
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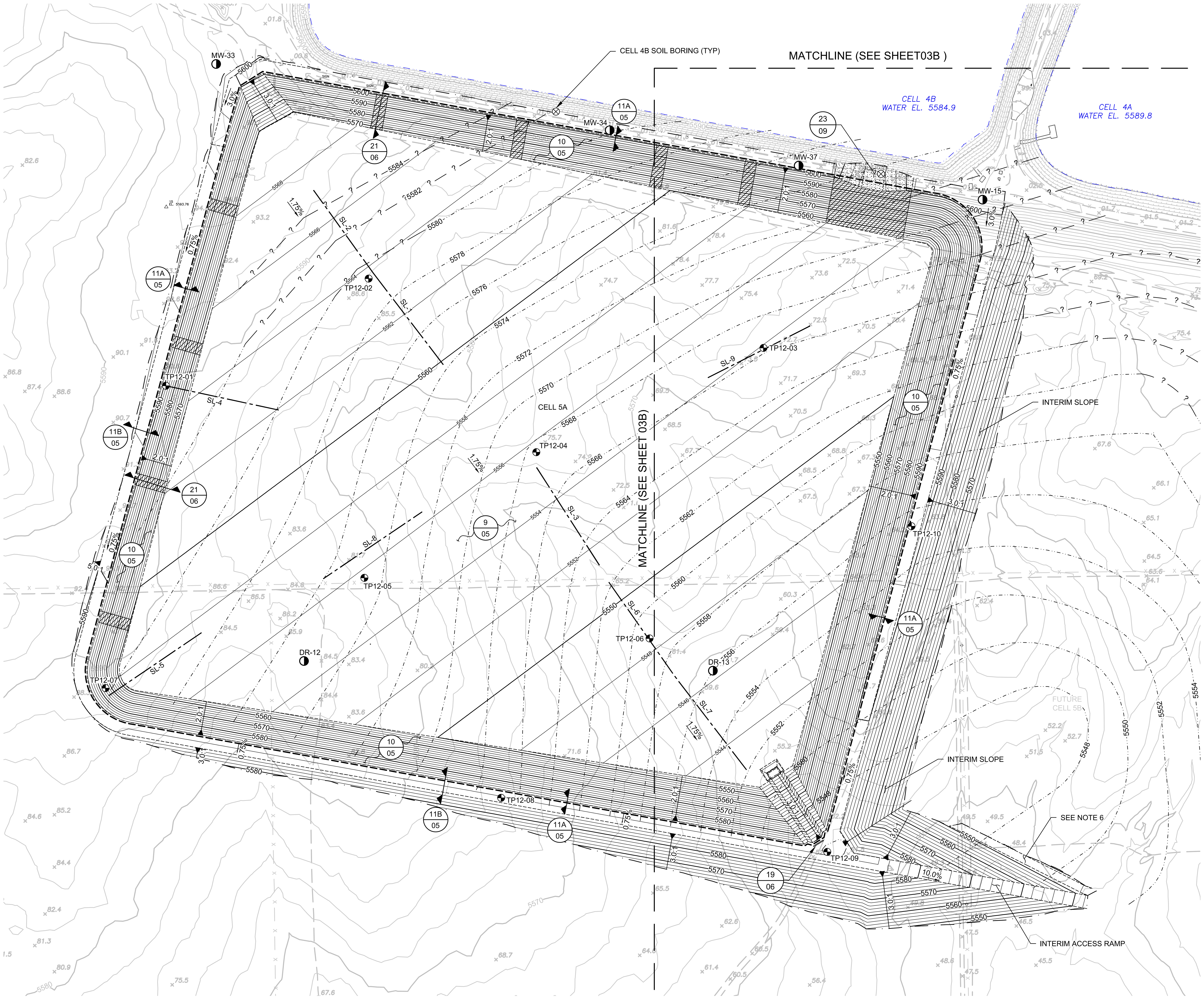
CHECKED BY:	RFO	FILE:	SC0634-02
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	02 OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

(1in) (2in) (3in) (4in)

P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\2018 REV\SC0634-02.dwg Last Edited by: SBerdy on 6/25/2018 3:16 PM



LEGEND

5570	JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
	EXISTING DIRT ROAD
x — x	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	PROPOSED GRADE BREAK
	LIMIT OF LINER SYSTEM
5570	APPROXIMATE TOP OF ROCK CONTOUR (1') (SEE NOTES 4 AND 5)
21/06	SPLASH PAD
TP12-03	EXPLORATORY TRENCH LOCATION
	SEISMIC LINE LOCATIONS (SEE NOTE 4)
⊗	CELL 4B SOIL BORINGS (SEE NOTE 4)
MW-33	EXISTING GROUNDWATER MONITOR WELL

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
4. SEISMIC LINE DATA AND CELL 4B BORINGS ARE PROVIDED IN SECTION 02200 OF THE TECHNICAL SPECIFICATIONS.
5. ROCK SURFACE IS APPROXIMATE AND BASED ON TRENCHES PERFORMED AT THE SITE. WHERE QUESTION MARKS ARE SHOWN, SURFACE IS ESTIMATED AND NOT BASED ON TRENCHES.
6. LOCALLY GRADE AREA NORTH OF BERM TO DRAIN AROUND BERM.

N

0 100' 200'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: CELL 5A PROPOSED GRADING

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

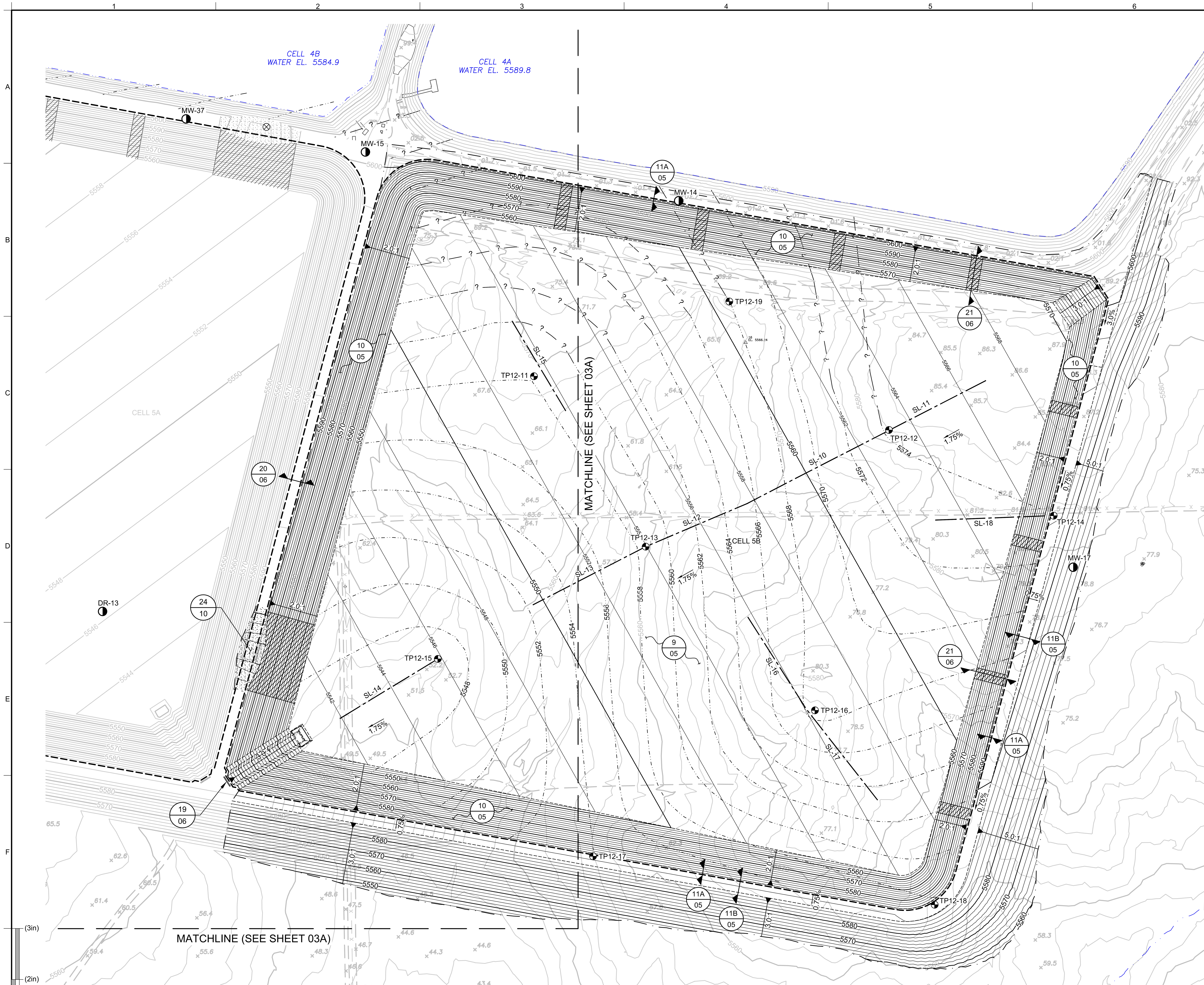
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	03A OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



LEGEND

5570	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
	EXISTING DIRT ROAD
x x	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	PROPOSED GRADE BREAK
	LIMIT OF LINER
5570	APPROXIMATE TOP OF ROCK CONTOUR (1') (SEE NOTES 4 AND 5)
	SPLASH PAD 21/06
TP12-03	EXPLORATORY TRENCH LOCATION
	SEISMIC LINE LOCATIONS (SEE NOTE 4)
⊗	CELL 4B SOIL BORINGS (SEE NOTE 4)
MW-33	EXISTING GROUNDWATER MONITORING WELL

NOTES

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3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
4. SEISMIC LINE DATA AND CELL 4B BORINGS ARE PROVIDED IN SECTION 02200 OF THE TECHNICAL SPECIFICATIONS.
5. ROCK SURFACE IS APPROXIMATE AND BASED ON TRENCHES PERFORMED AT THE SITE. WHERE QUESTION MARKS ARE SHOWN, SURFACE IS ESTIMATED AND NOT BASED ON TRENCHES.

N

0 100' 200'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: CELL 5B PROPOSED GRADING

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

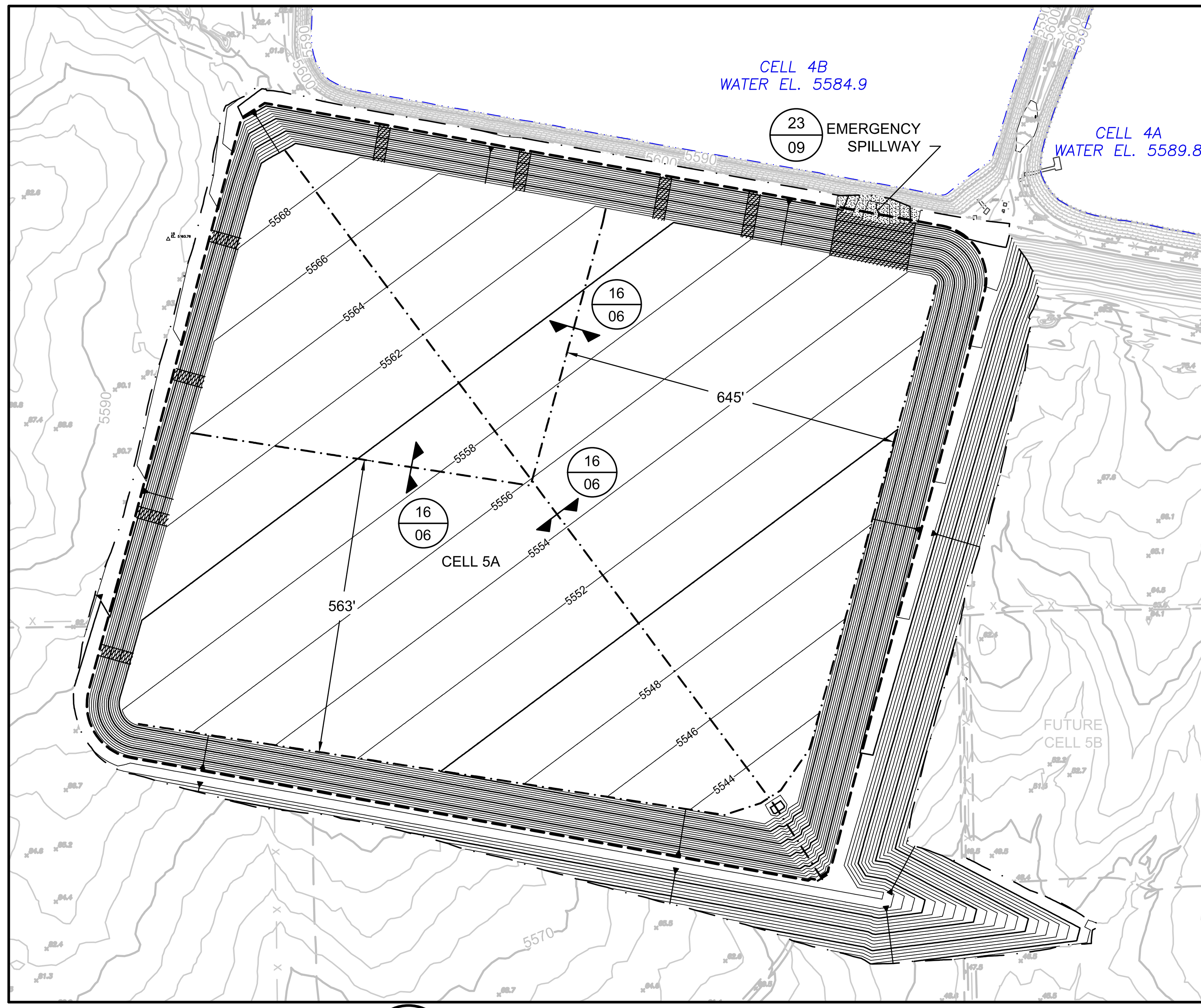
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

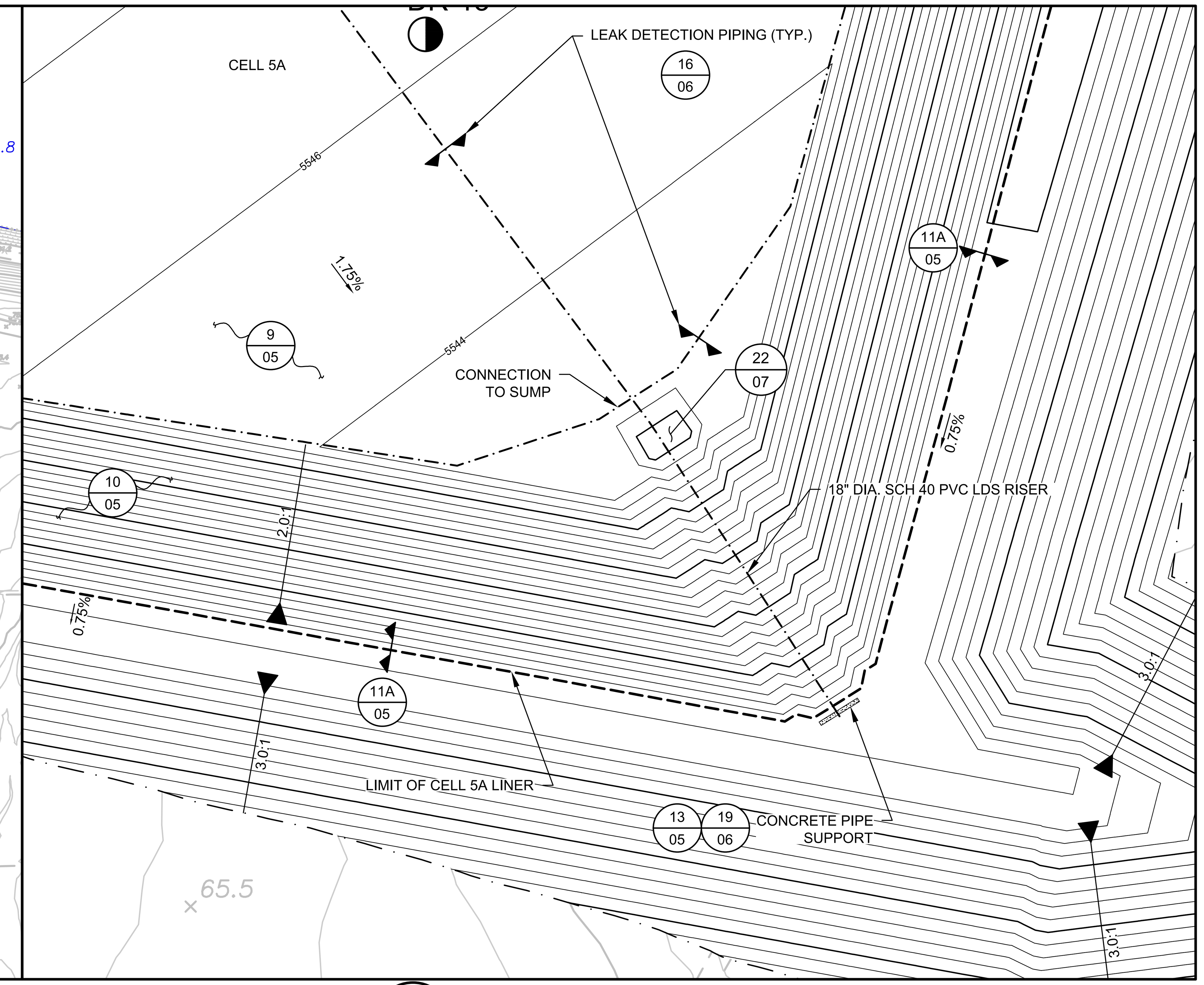
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	03B OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



1 PLAN
CELL 5A LEAK DETECTION SYSTEM
SCALE: 1" = 200'



2 DETAIL
CELL 5A LEAK DETECTION SYSTEM
SCALE: 1" = 50'

LEGEND

Symbol	Description
5570	JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
	EXISTING DIRT ROAD
x x	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	LIMIT OF LINER SYSTEM
	PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
	SLIMES DRAIN SYSTEM PIPING
	SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
DR-12	EXISTING GROUNDWATER MONITOR WELL
	SPLASH PAD 21 / 06

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BY ENERGY FUELS RESOURCES (USA) INC.
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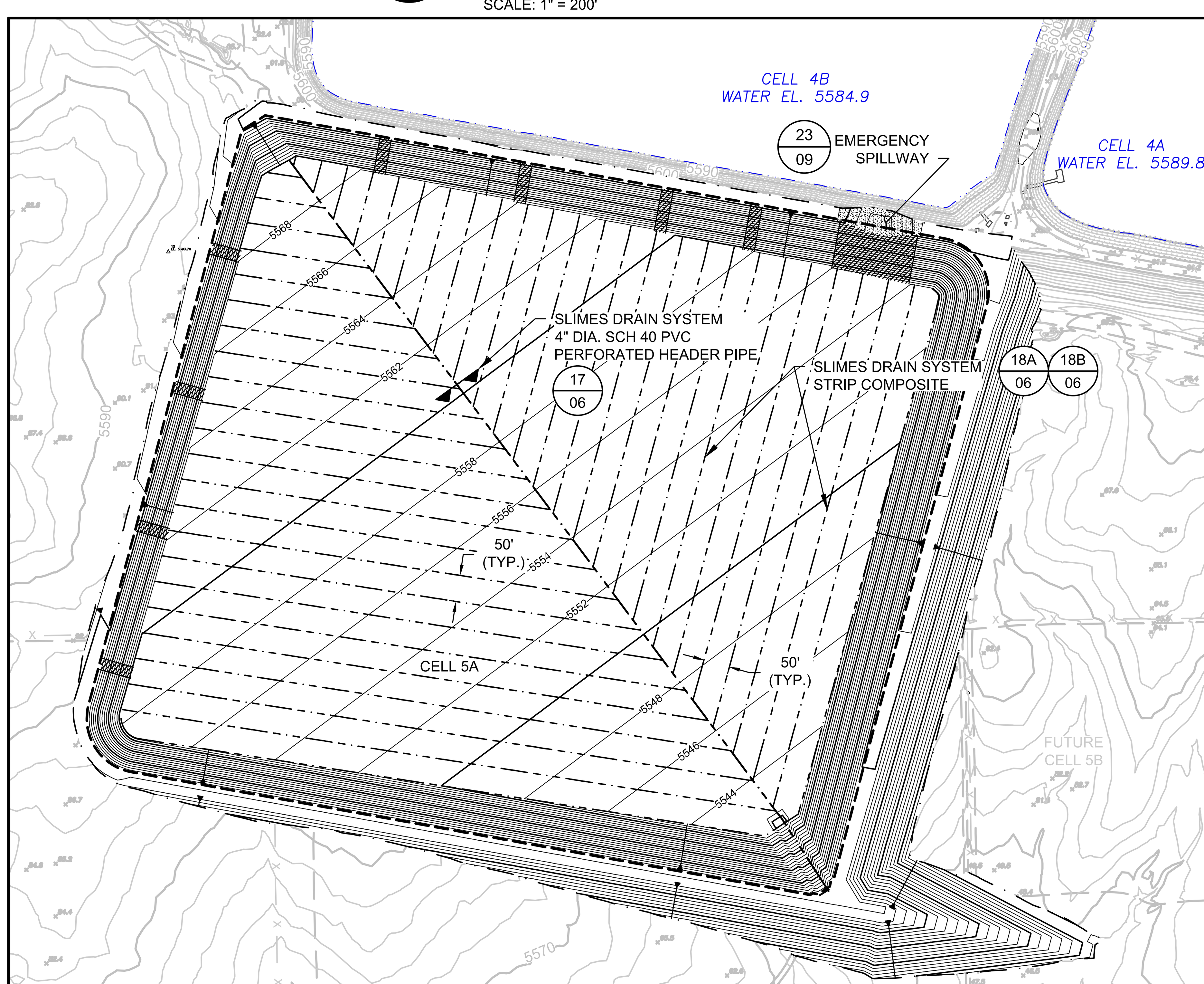
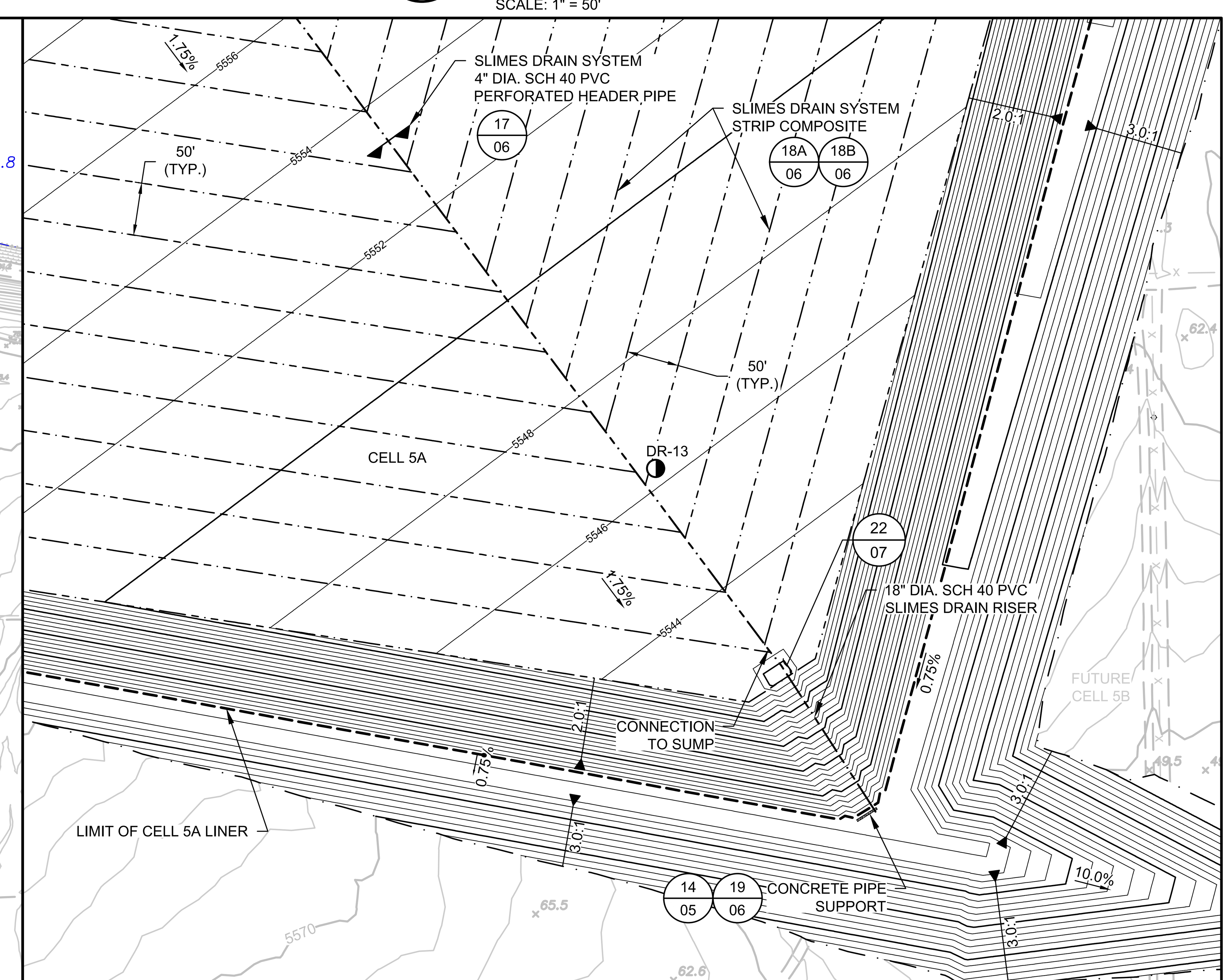


3 PLAN
CELL 5A SLIMES DRAIN SYSTEM
SCALE: 1" = 200'



4 DETAIL
CELL 5A SLIMES DRAIN SYSTEM
SCALE: 1" = 100'

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5A

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

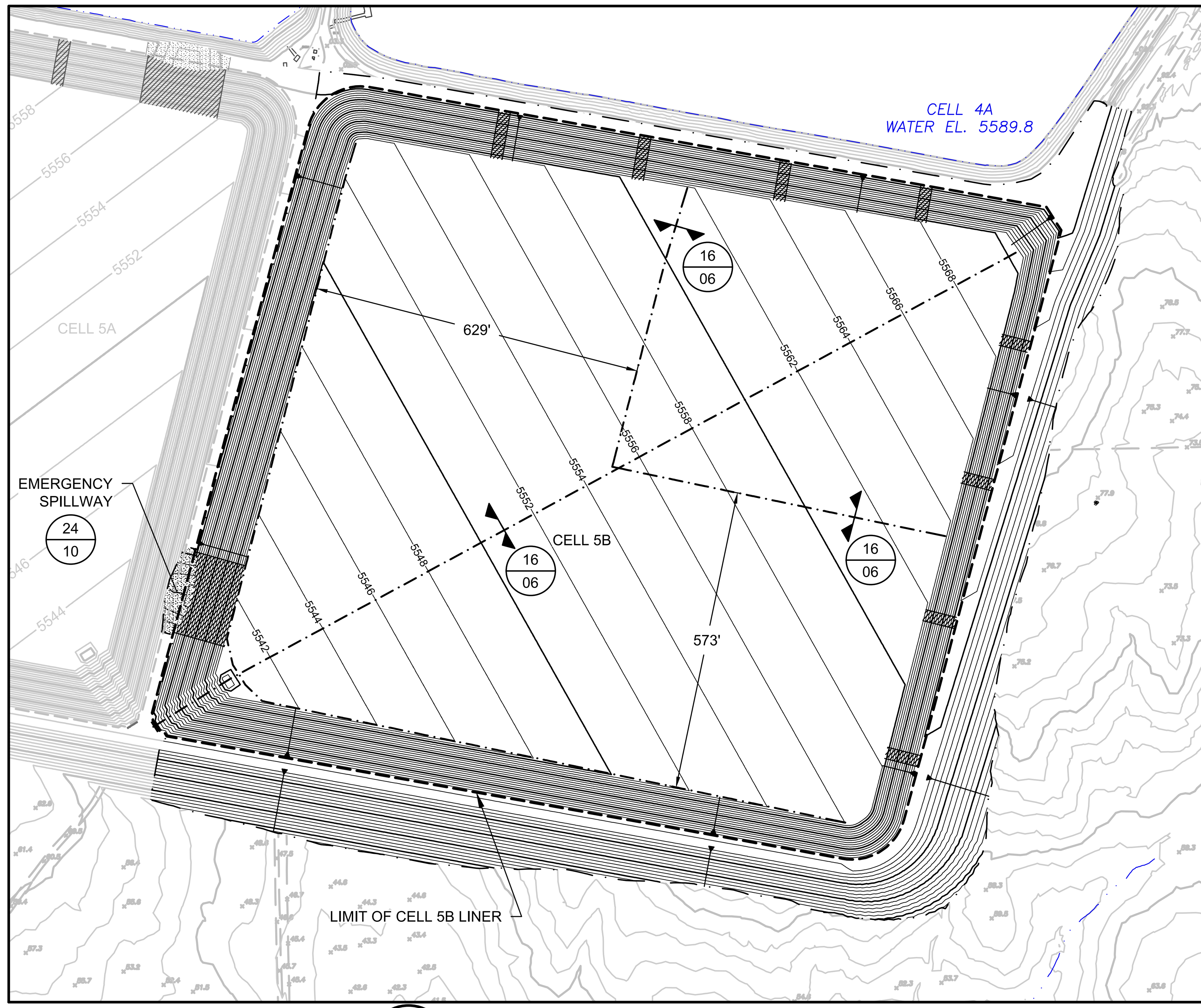
SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

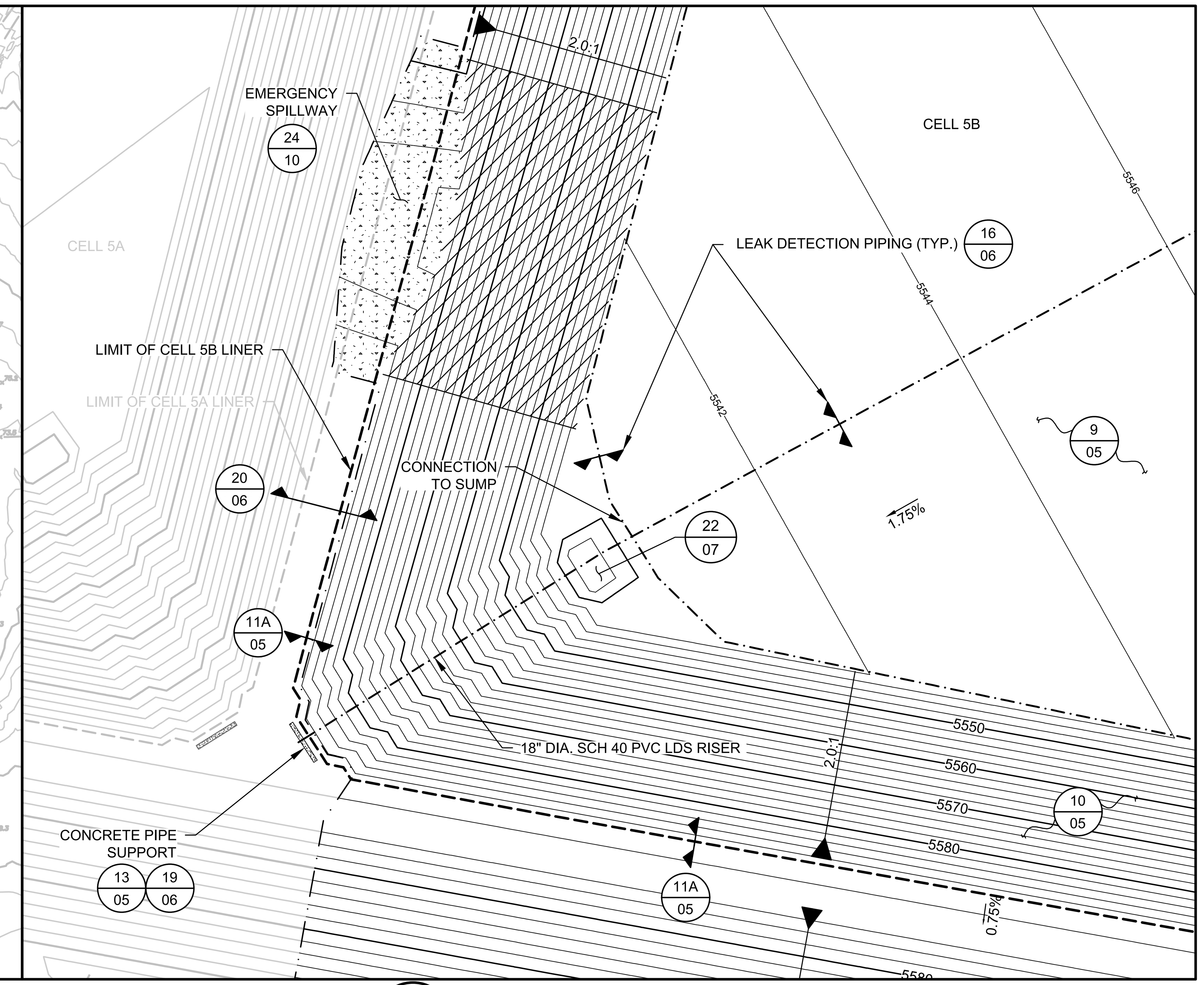
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

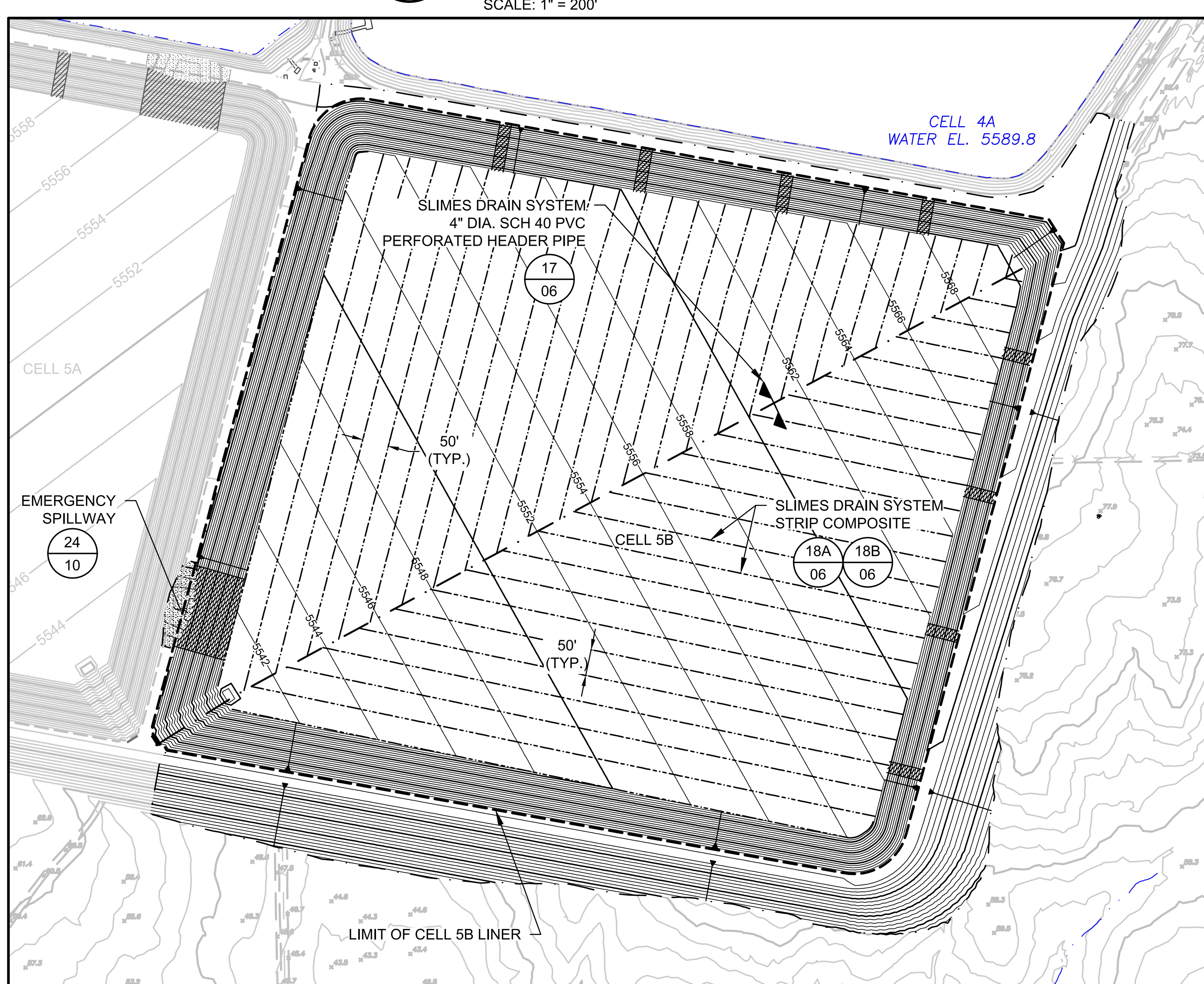
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	04A OF 10	



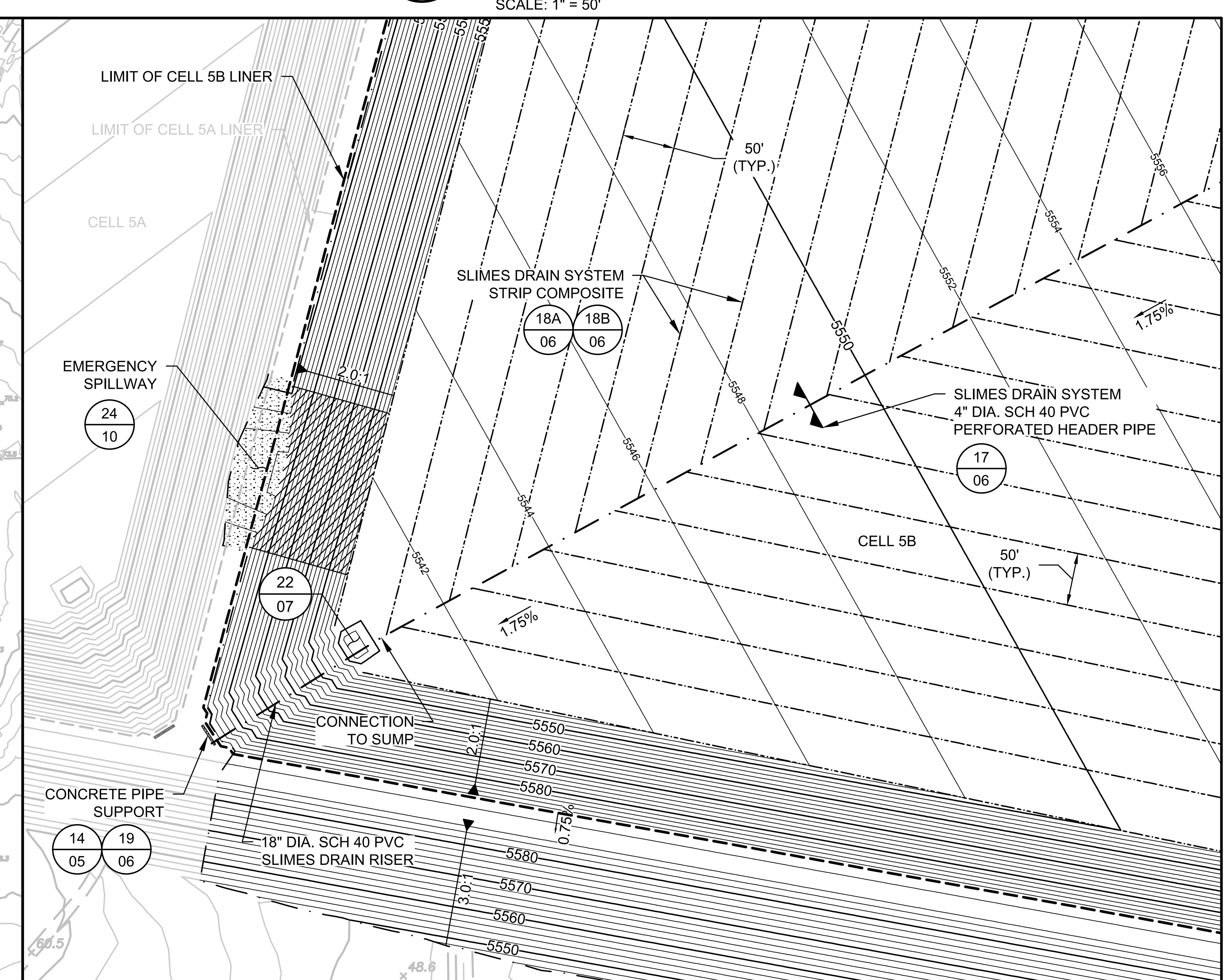
5 - PLAN
CELL 5B LEAK DETECTION SYSTEM
SCALE: 1" = 200'



6 - DETAIL
CELL 5B LEAK DETECTION SYSTEM
SCALE: 1" = 50'



7 - PLAN
CELL 5B SLIMES DRAIN SYSTEM
SCALE: 1" = 200'



8 - DETAIL
CELL 5B SLIMES DRAIN SYSTEM
SCALE: 1" = 100'

LEGEND

- 5570 — JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- x — x EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- 5602 — PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- LIMIT OF LINER SYSTEM
- PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- SPLASH PAD 21 / 06

NOTES

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REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5B

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

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SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	04B OF 10
APPROVED BY:	GTC		

PERMIT LEVEL DESIGN
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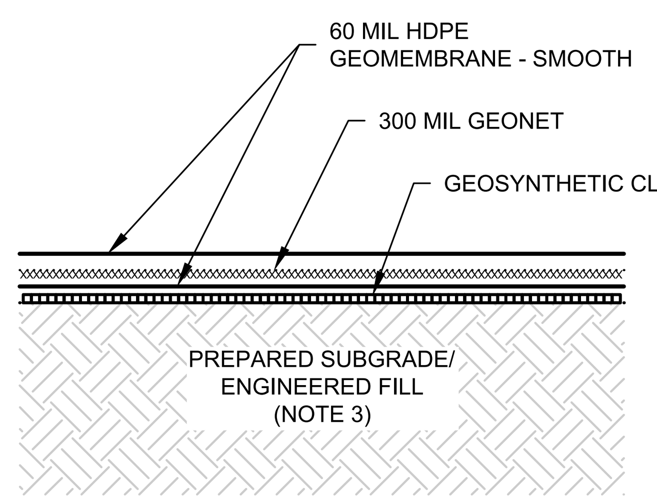
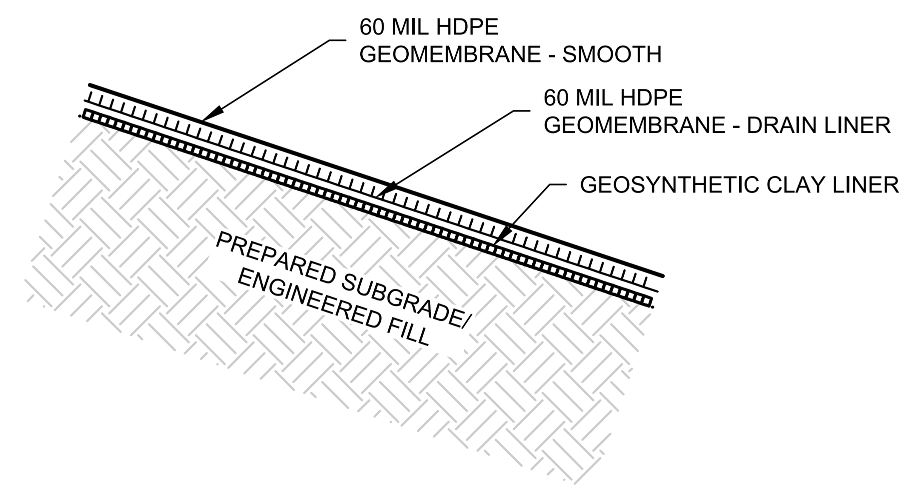
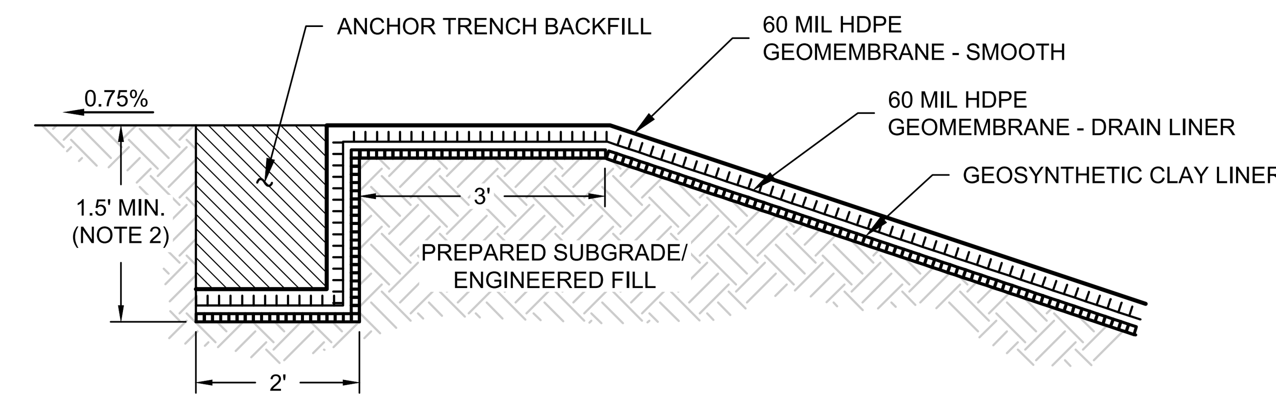


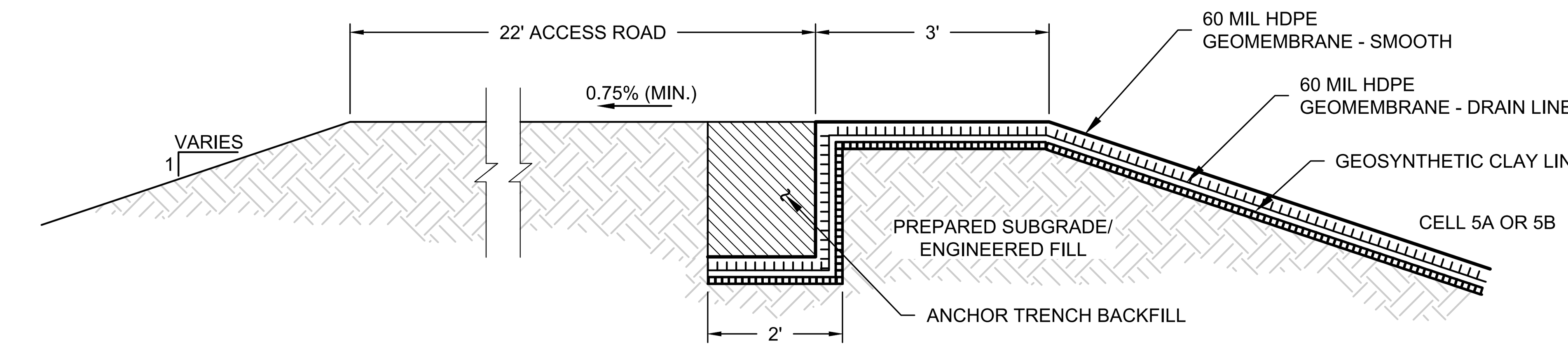
9 DETAIL
03A,03B,04A,04B BASE LINER SYSTEM
SCALE: 1" = 2'



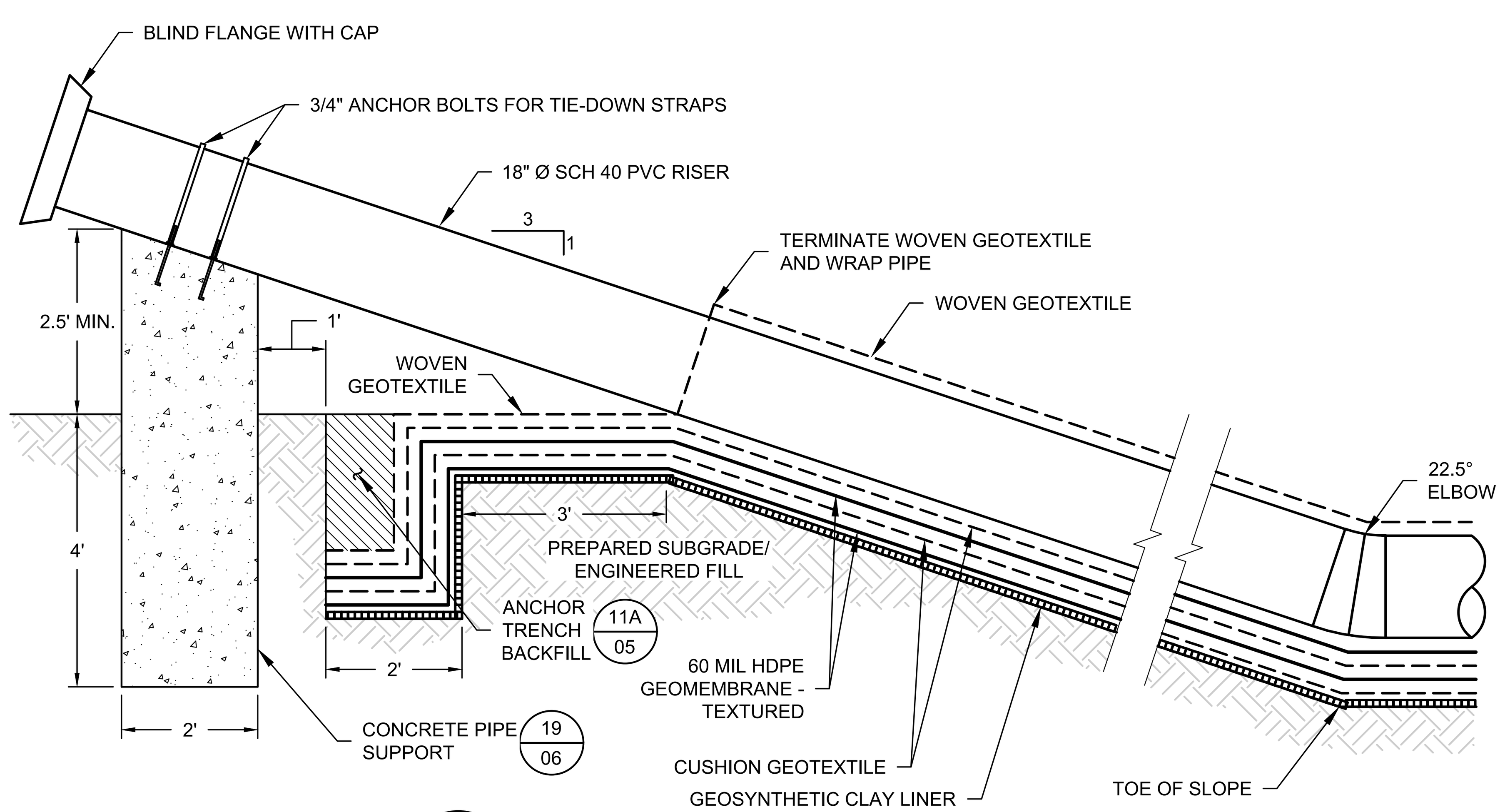
10 DETAIL
03A,03B,04A,04B SIDE SLOPE LINER SYSTEM
SCALE: 1" = 2'



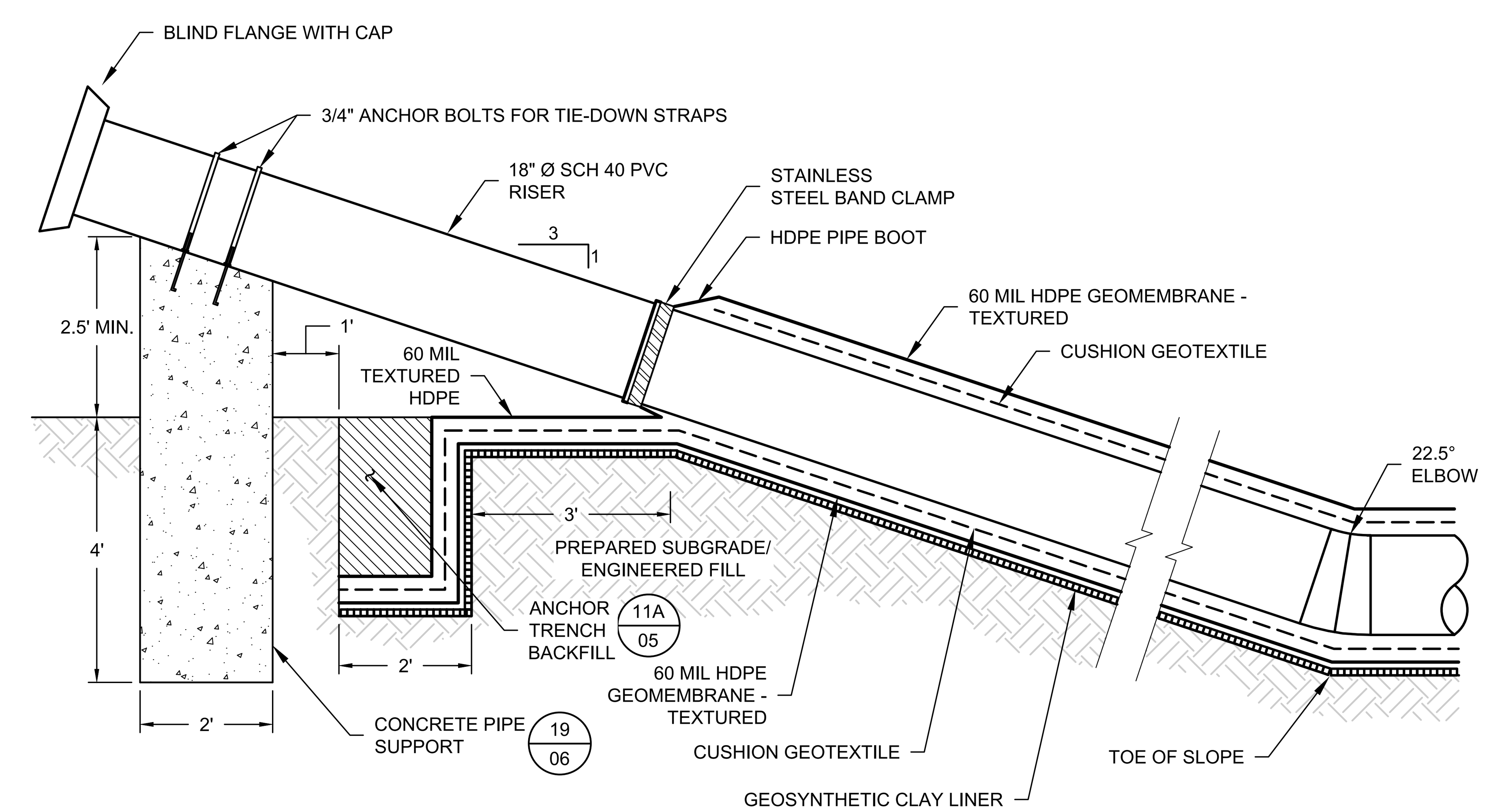
11A DETAIL
03A,03B,04A,04B,05,06,09 ANCHOR TRENCH
SCALE: 1" = 2'



11B DETAIL
03A,03B ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



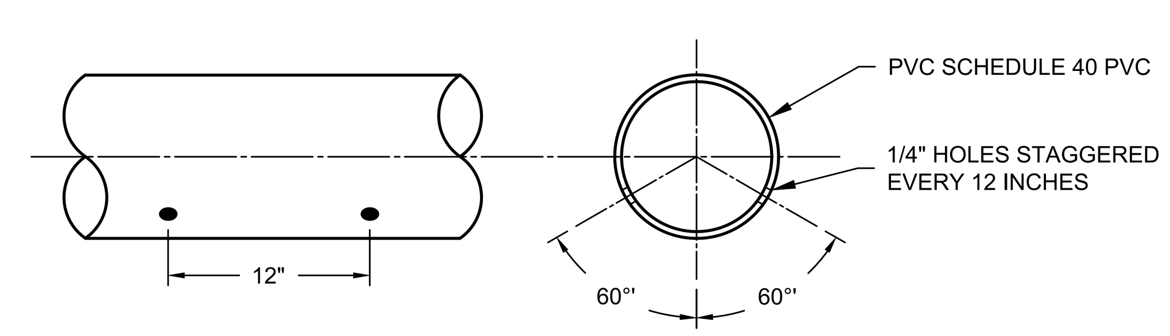
14 DETAIL
04A,04B SLIMES DRAIN RISER
PENETRATION
SCALE: 1" = 2'



13 DETAIL
04A,04B LEAK DETECTION SYSTEM
RISER PENETRATION
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. ANCHOR TRENCHES MAY BE CONSTRUCTED WITH A MAXIMUM DEPTH OF 3.5 FEET WITH UP TO 1 FOOT OF BACKFILL BETWEEN EACH GEOMEMBRANE IN BOTTOM OF ANCHOR TRENCH.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.



15 DETAIL
07,08 PERFORATED PIPE
SCALE: 1" = 1'

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS I

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

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SIGNATURE

06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER
No. 6020077-2202
GREGORY T. CORCORAN
STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	05 OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

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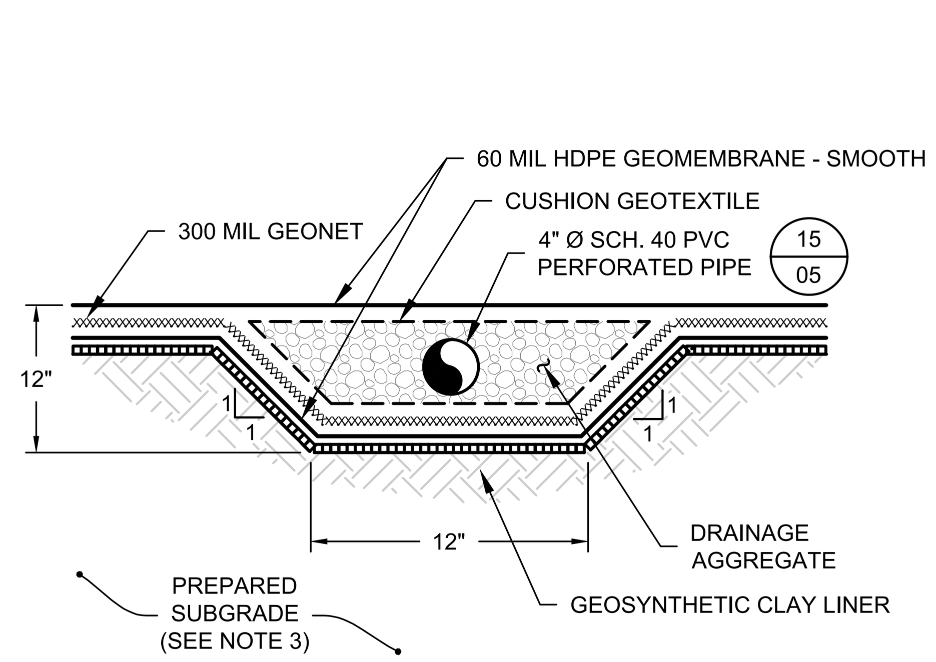
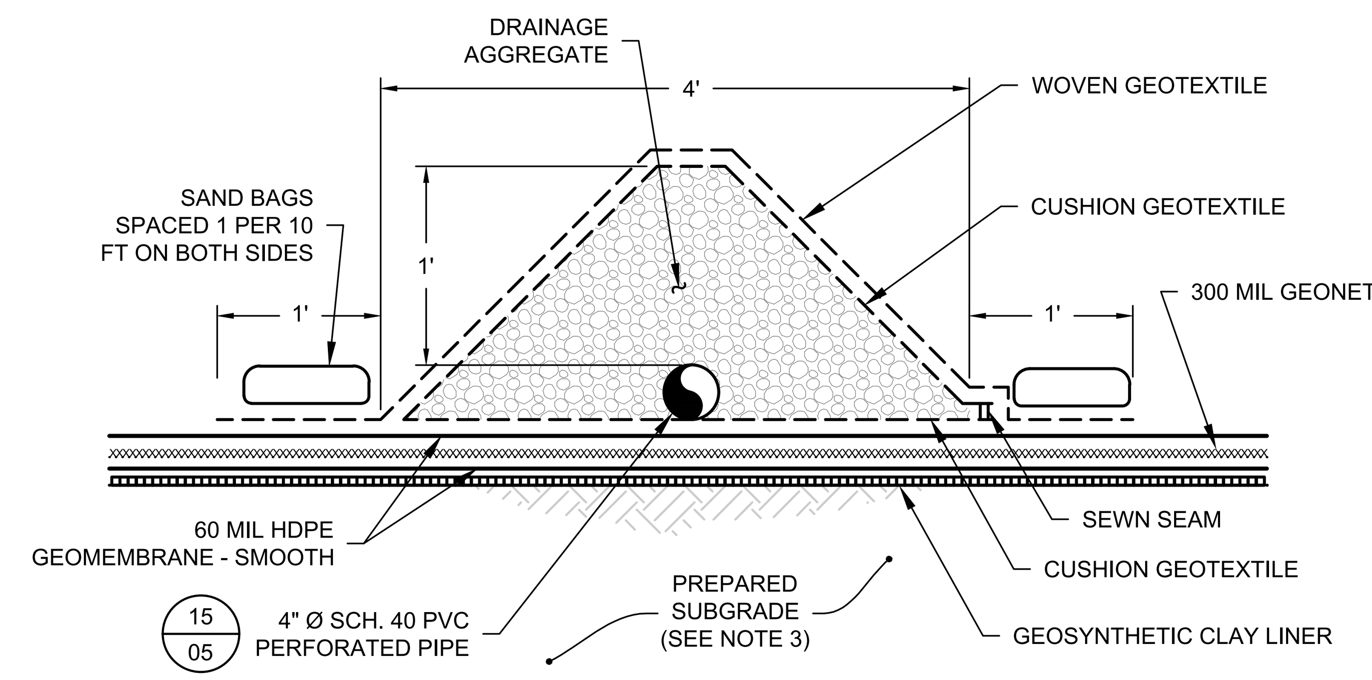
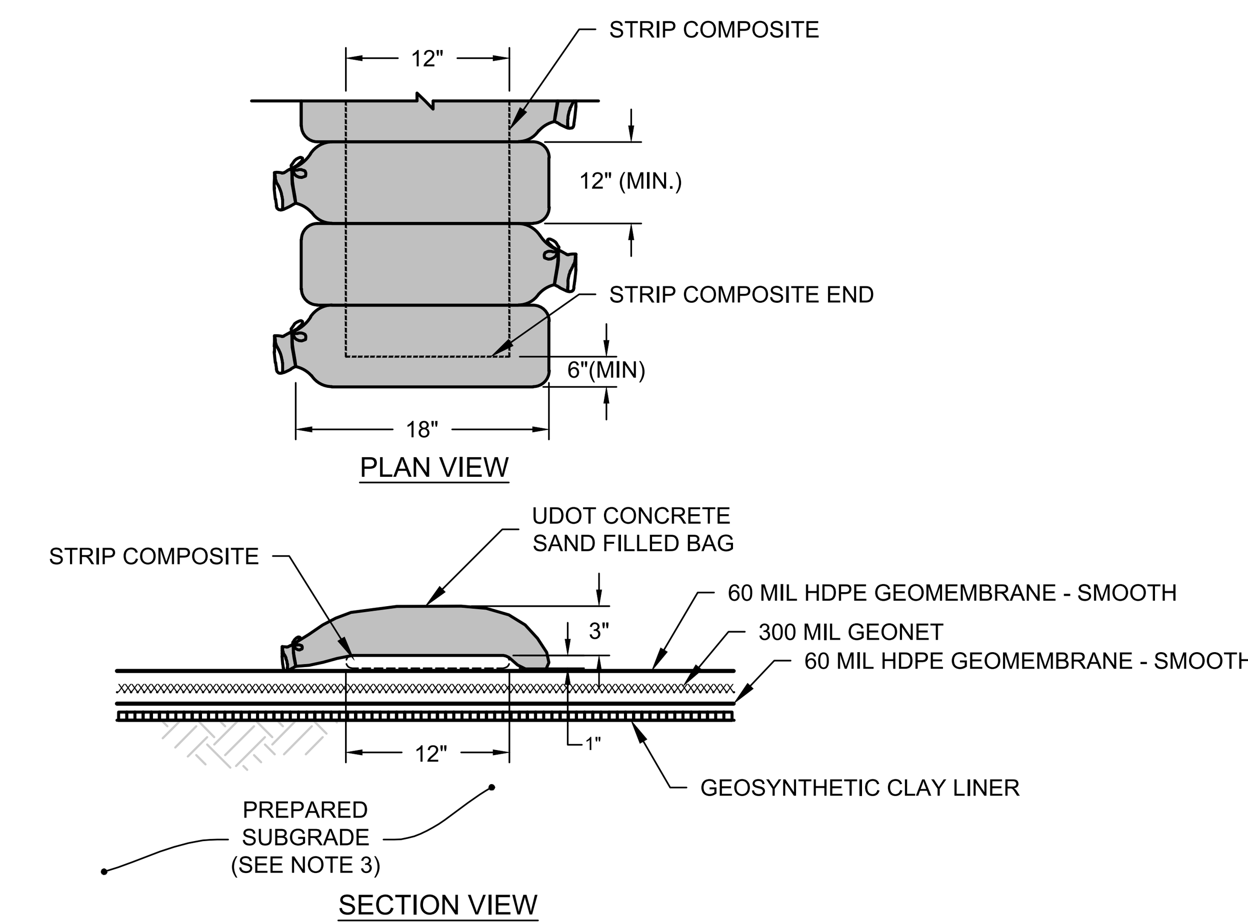


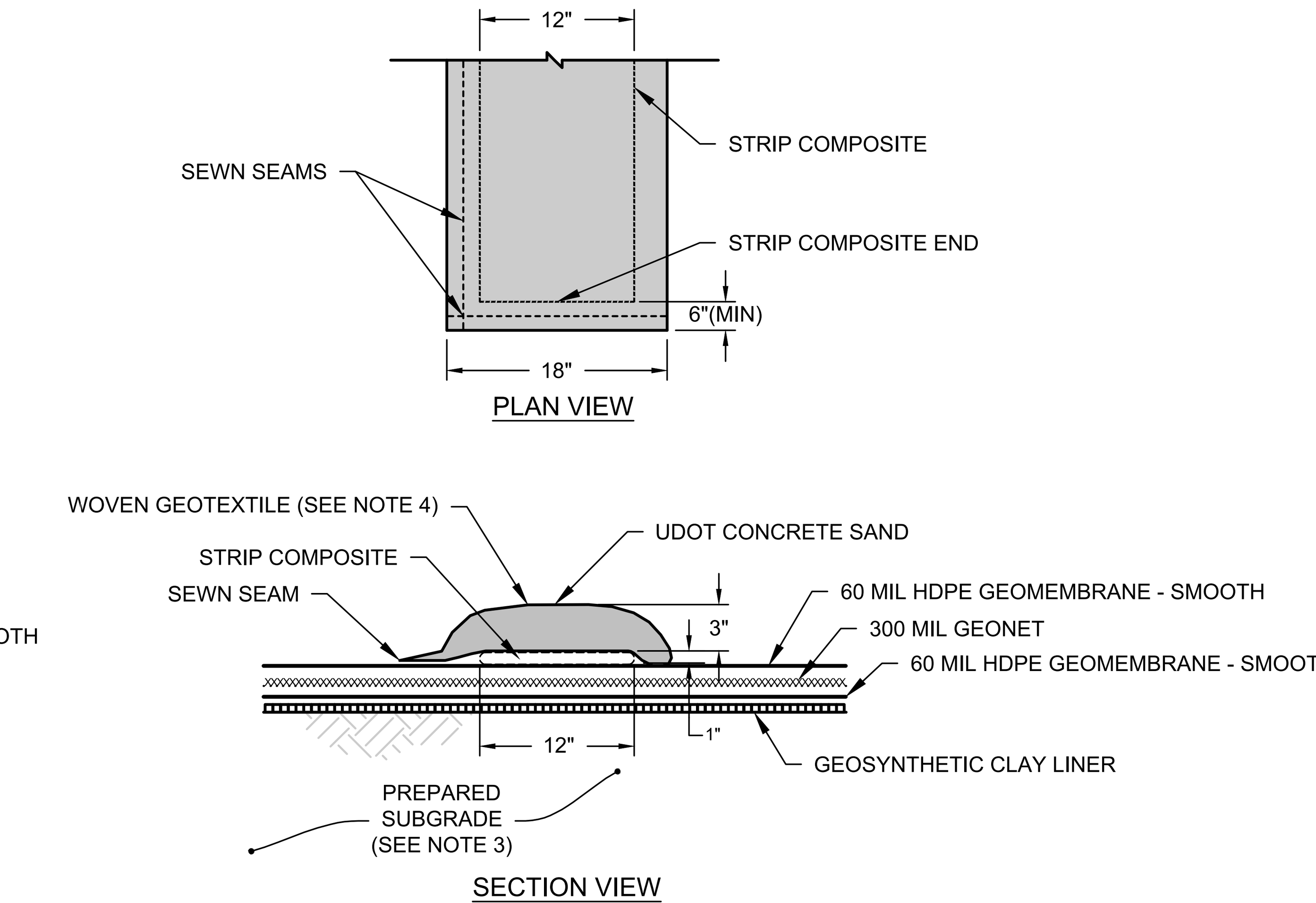
16 DETAIL
04A,04B
LEAK DETECTION SYSTEM TRENCH
SCALE: 1" = 1'



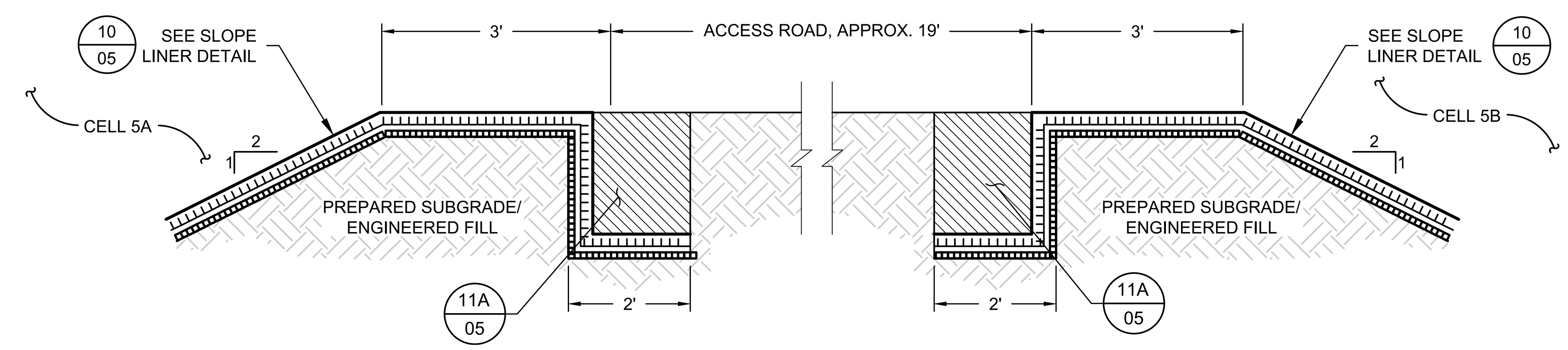
17 DETAIL
04A,04B
SLIMES DRAIN HEADER
SCALE: 1" = 1'



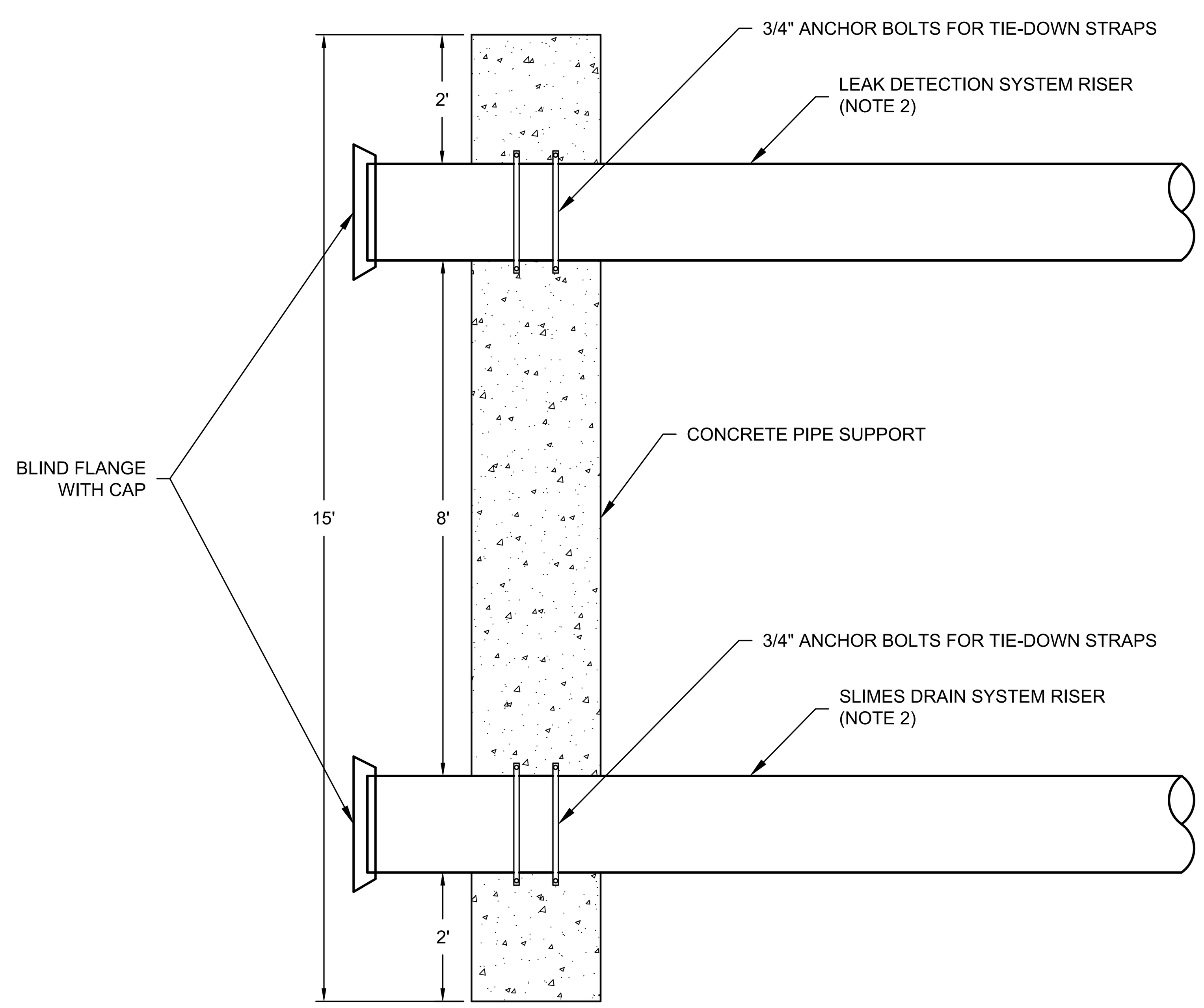
18A DETAIL
04A,04B
SLIMES DRAIN LATERAL - OPTION 1
SCALE: NTS



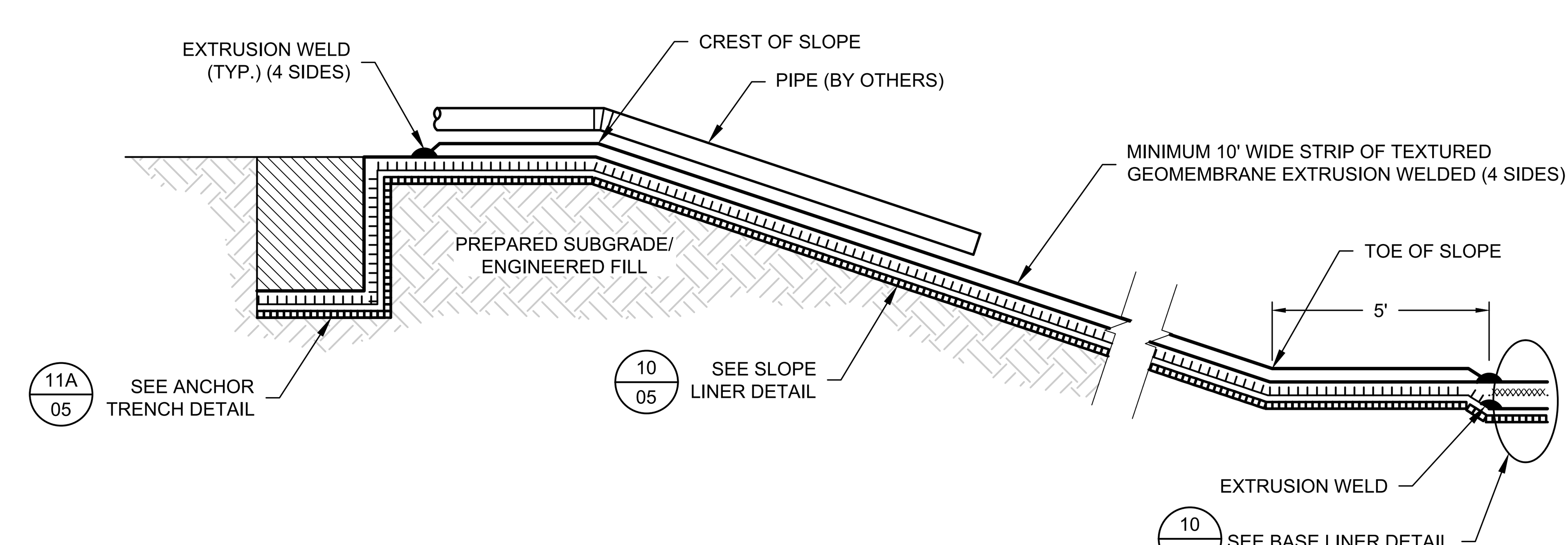
18B DETAIL
04A,04B
SLIMES DRAIN LATERAL - OPTION 2
SCALE: NTS



20 DETAIL
03B,04B
CELL 5A - CELL 5B ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



19 DETAIL
03A,03B,04A,04B
CONCRETE PIPE SUPPORT
SCALE: 1" = 2'



21 DETAIL
03A,03B,04A,04B,09,10
SPLASH PAD DETAIL
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. EXPOSED PVC PIPE SHALL BE PAINTED TO MINIMIZE DAMAGE DUE TO UV.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.
4. WOVEN GEOTEXTILE SHALL BE FOLDED OVER AND SEAMED. GEOTEXTILE SHALL BE FILLED WITH UDOT CONCRETE SAND TO CREATE A CONTINUOUS SANDBAG-LIKE STRUCTURE WITH A MINIMUM OF 3" OF SAND ABOVE STRIP COMPOSITE. ENDS SHALL BE SEAMED FOLLOWING SAND FILLING.

(3in) (2in) (1in)
(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS II

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.
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REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

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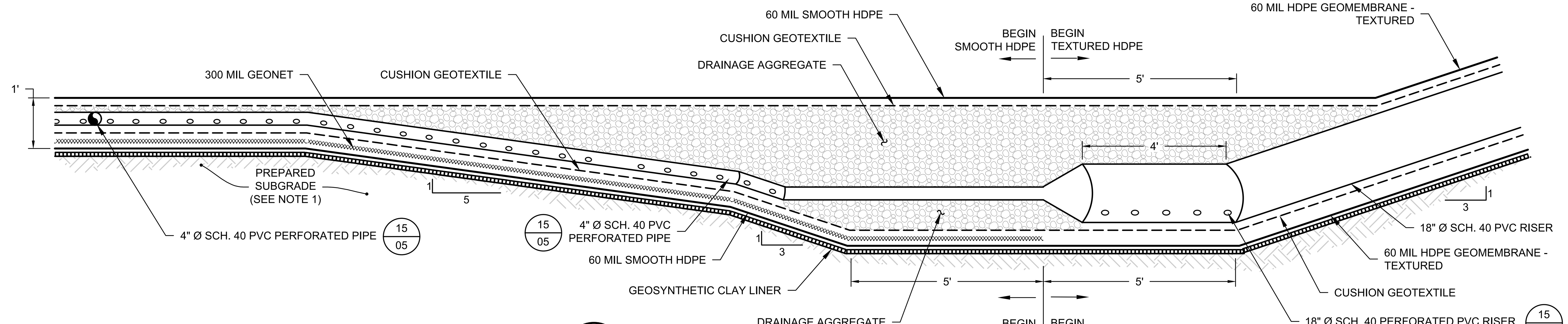
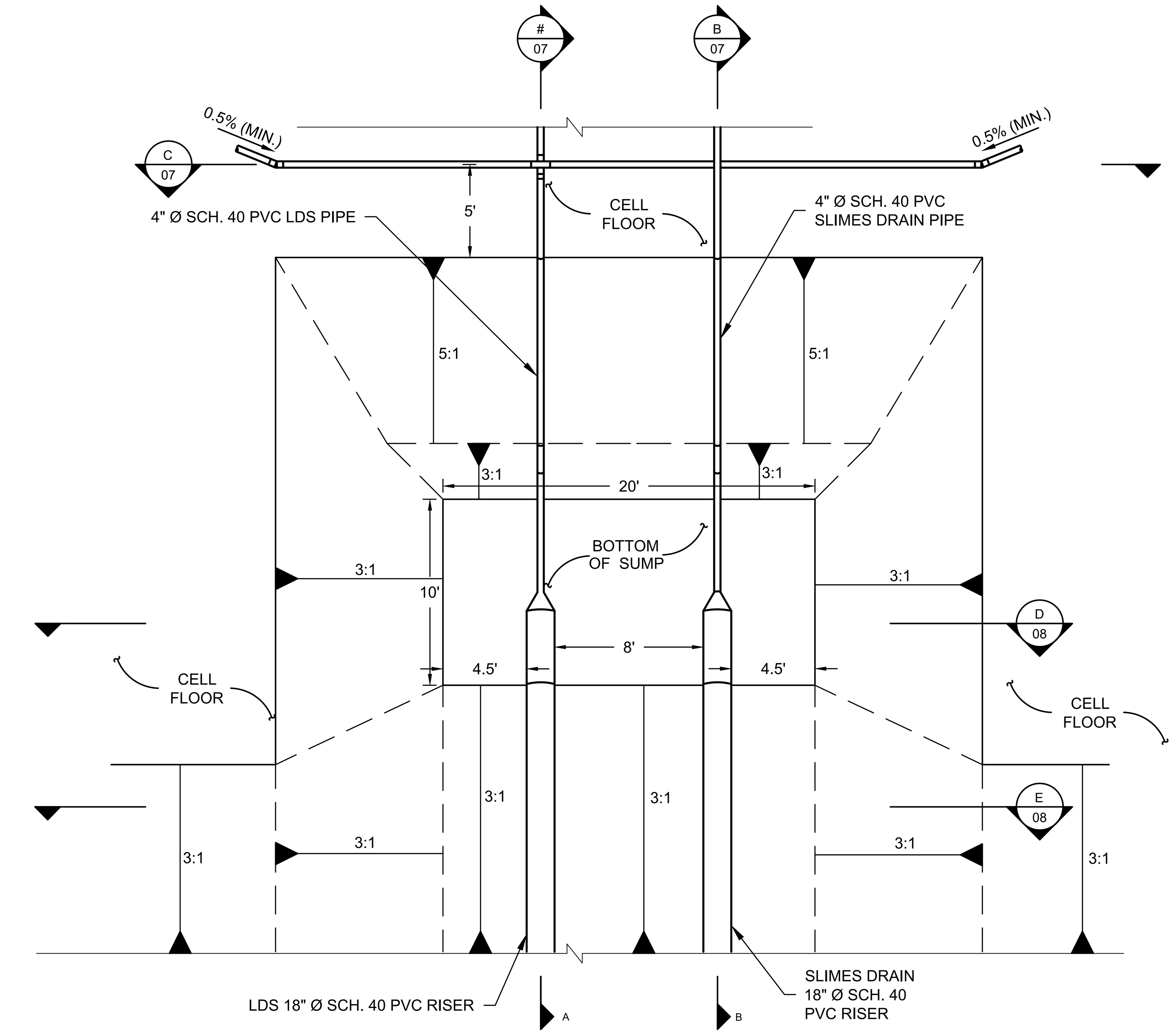
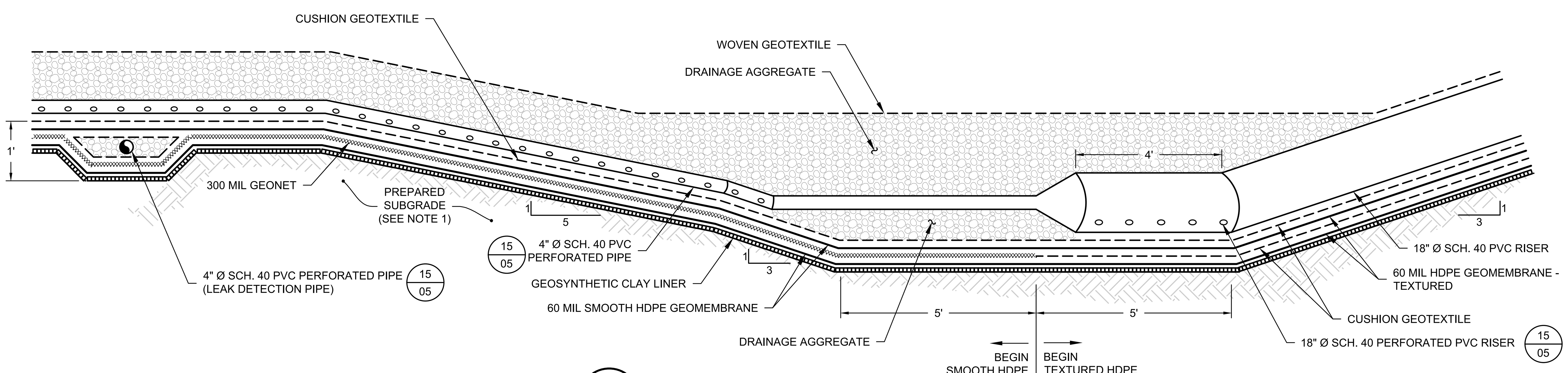
REVIEWED BY:	GTC	DRAWING NO.:	06 OF 10
APPROVED BY:	GTC		



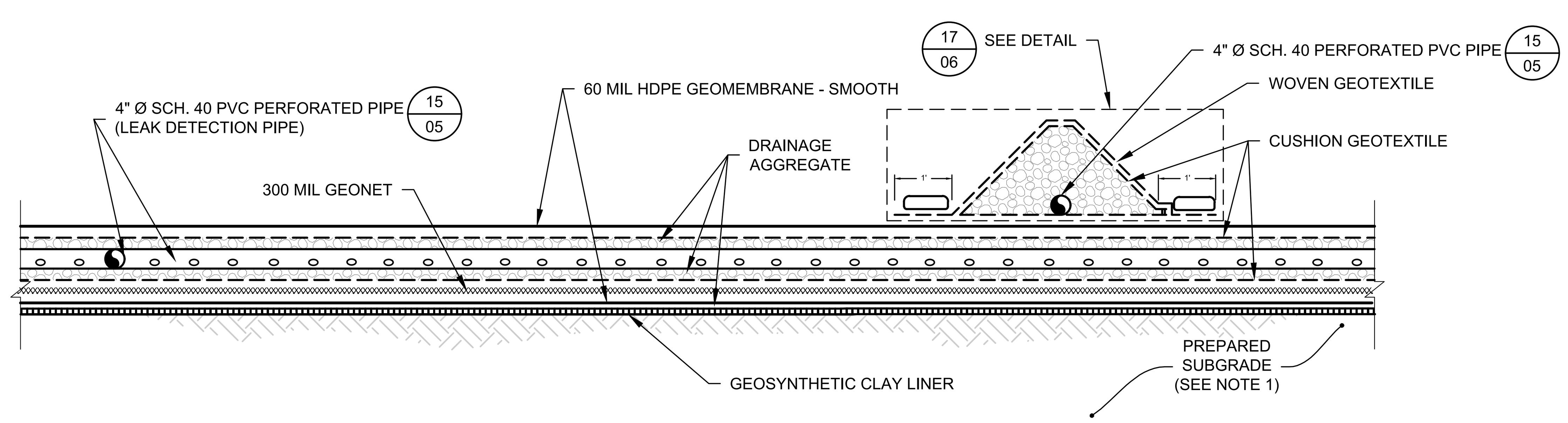
A / - SECTION
LEAK DETECTION SUMP
SCALE: 1" = 2'



22 / 04A,04B PLAN
SUMP PLAN VIEW
SCALE: 1" = 6'



B / - SECTION
SLIMES DRAIN SUMP
SCALE: 1" = 2'



C / - SECTION
SLIMES DRAIN AND LDS PIPING SECTION
SCALE: 1" = 2'

NOTES:

1. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. SOIL THICKNESSES ARE MINIMUMS.

(3in) (2in) (1in)
(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUITE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS III

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

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SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	07 OF 10	

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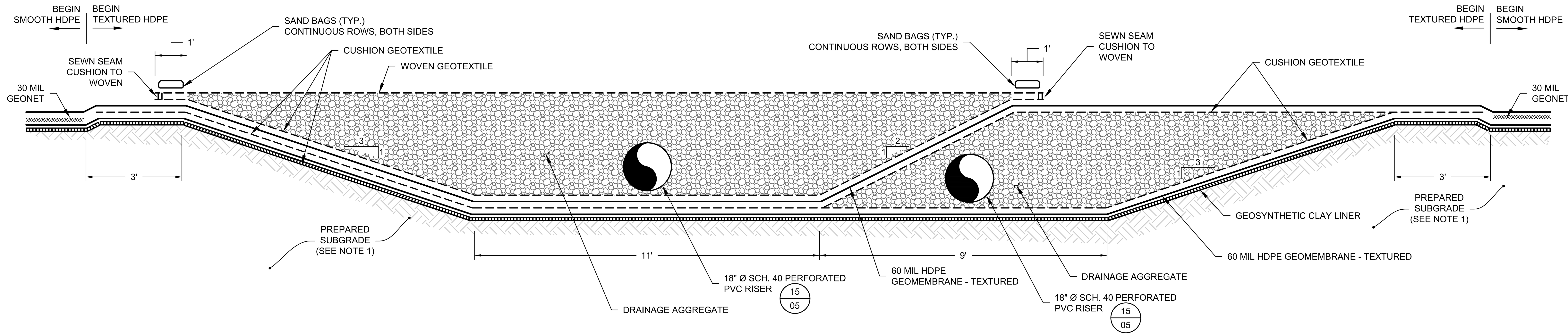
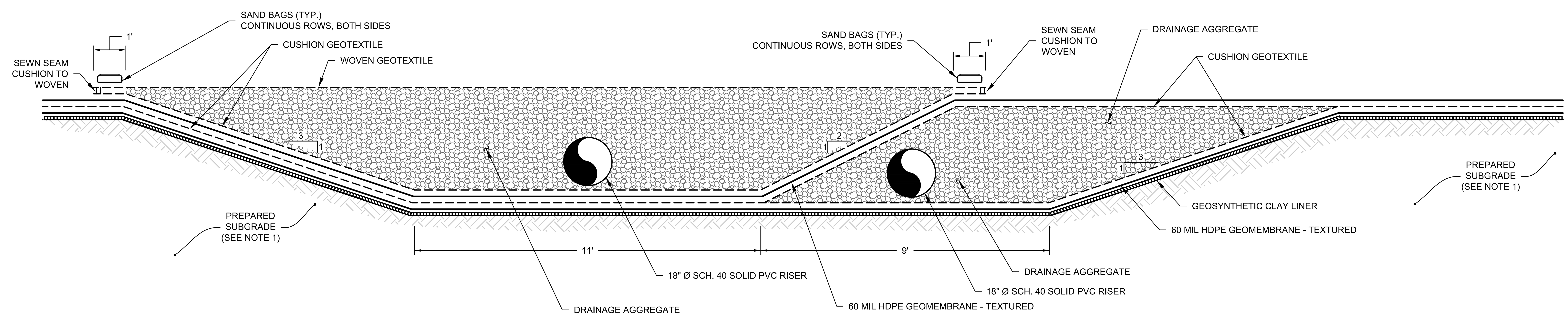


D / 07 SECTION
SUMP SECTION (FLOOR)
SCALE: 1" = 2'



E / 07 SECTION
SUMP SECTION (SLOPE)
SCALE: 1" = 2'

NOTES:

1. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.

2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. SOIL THICKNESSES ARE MINIMUMS.

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS IV

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

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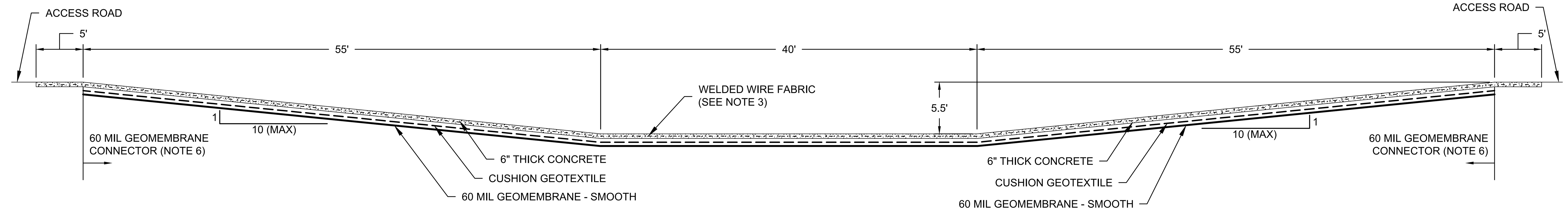
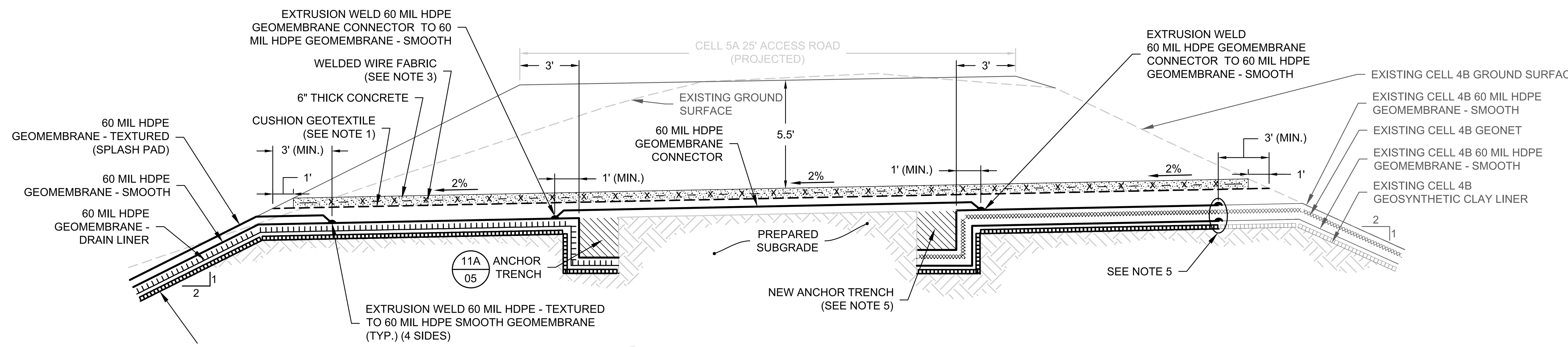
SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

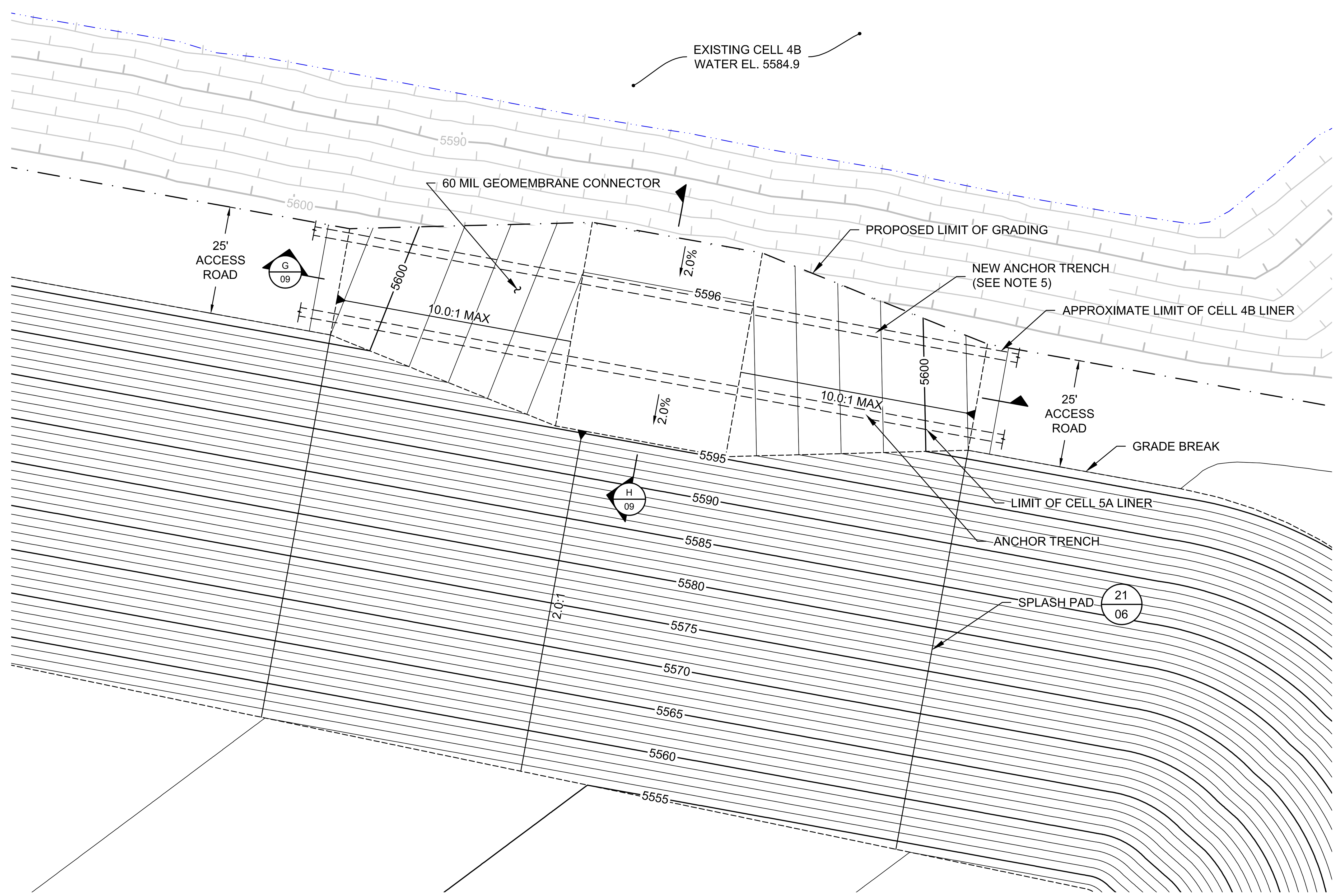
DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	08 OF 10
APPROVED BY:	GTC		



G
-
SECTION
SPILLWAY - SECTION-5A
SCALE: 1" = 8'



H
-
SECTION
SPILLWAY - SECTION 2-5A
SCALE: 1" = 4'



23
03A,04A
PLAN
SPILLWAY PLAN - 5A
SCALE: 1" = 20'

NOTES:

1. CUSHION GEOTEXTILE SHALL BE PLACED OVERLYING PRIMARY GEOMEMBRANE WHERE CONCRETE IS INSTALLED.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
3. WELDED WIRE FABRIC SHALL BE INSTALLED AT CENTER OF CONCRETE SLAB SECTION.
4. SPLASH PAD AT SPILLWAY SHALL BE 150' WIDE, SHALL EXTEND 5' ONTO THE FLOOR AND BE EXTRUSION WELDED ON ALL FOUR (4) SIDES TO PRIMARY GEOMEMBRANE.
5. CUT AND FOLD BACK EXISTING LINER SYSTEM GEOSYNTHETIC LAYERS (60 mil HDPE MEMBRANE, 300 mil GEONET, 60 mil HDPE GEOMEMBRANE, GCL) TO ALLOW EXCAVATION OF SPILLWAY. REPLACE LINER SYSTEM GEOSYNTHETICS LAYERS ONTO NEW SPILLWAY GRADES AND NEW ANCHOR TRENCH. NEW ANCHOR TRENCH SHALL BE TIED INTO EXISTING ANCHOR TRENCH.
6. ANCHOR 60 MIL GEOMEMBRANE CONNECTOR AT TOP OF 10H:1V SLOPE IN 12" DEEP ANCHOR TRENCH.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE:
DETAILS & SECTIONS V

PROJECT:
CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE:
WHITE MESA MILL
BLANDING, UTAH

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SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER
No. 6020077-2202
GREGORY T. CORCORAN
STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	09 OF 10	

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(1in) (2in) (3in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

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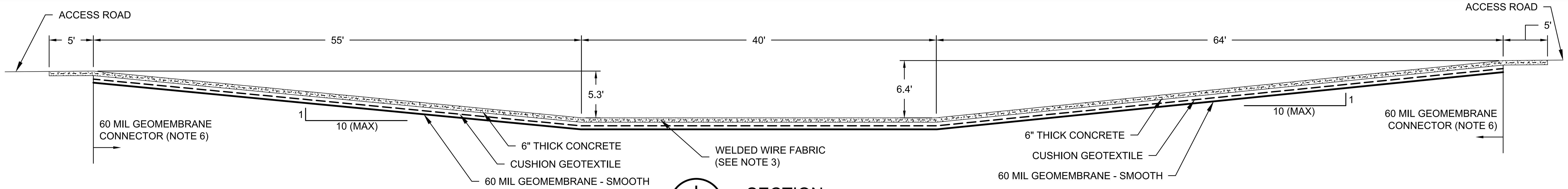
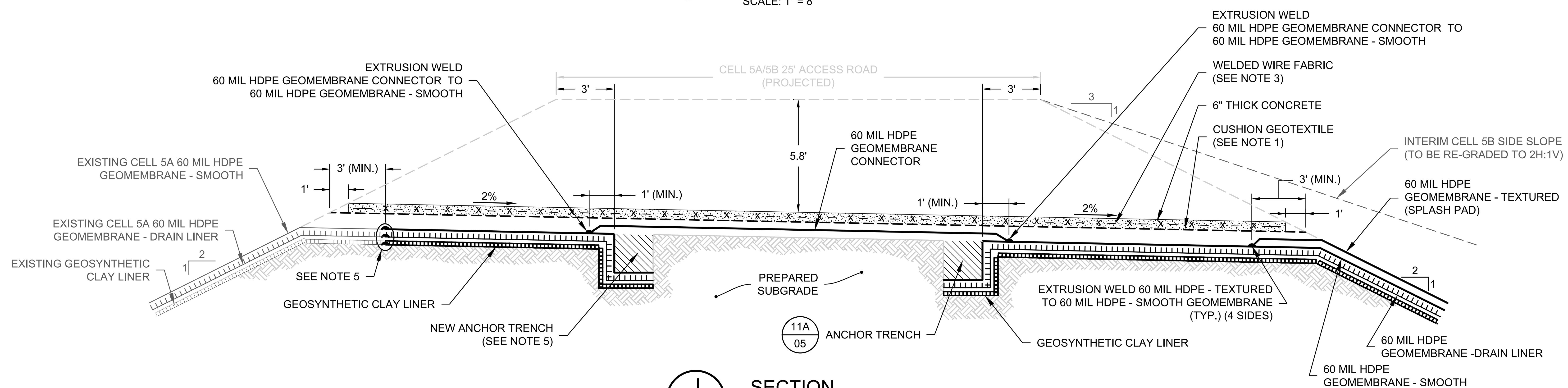
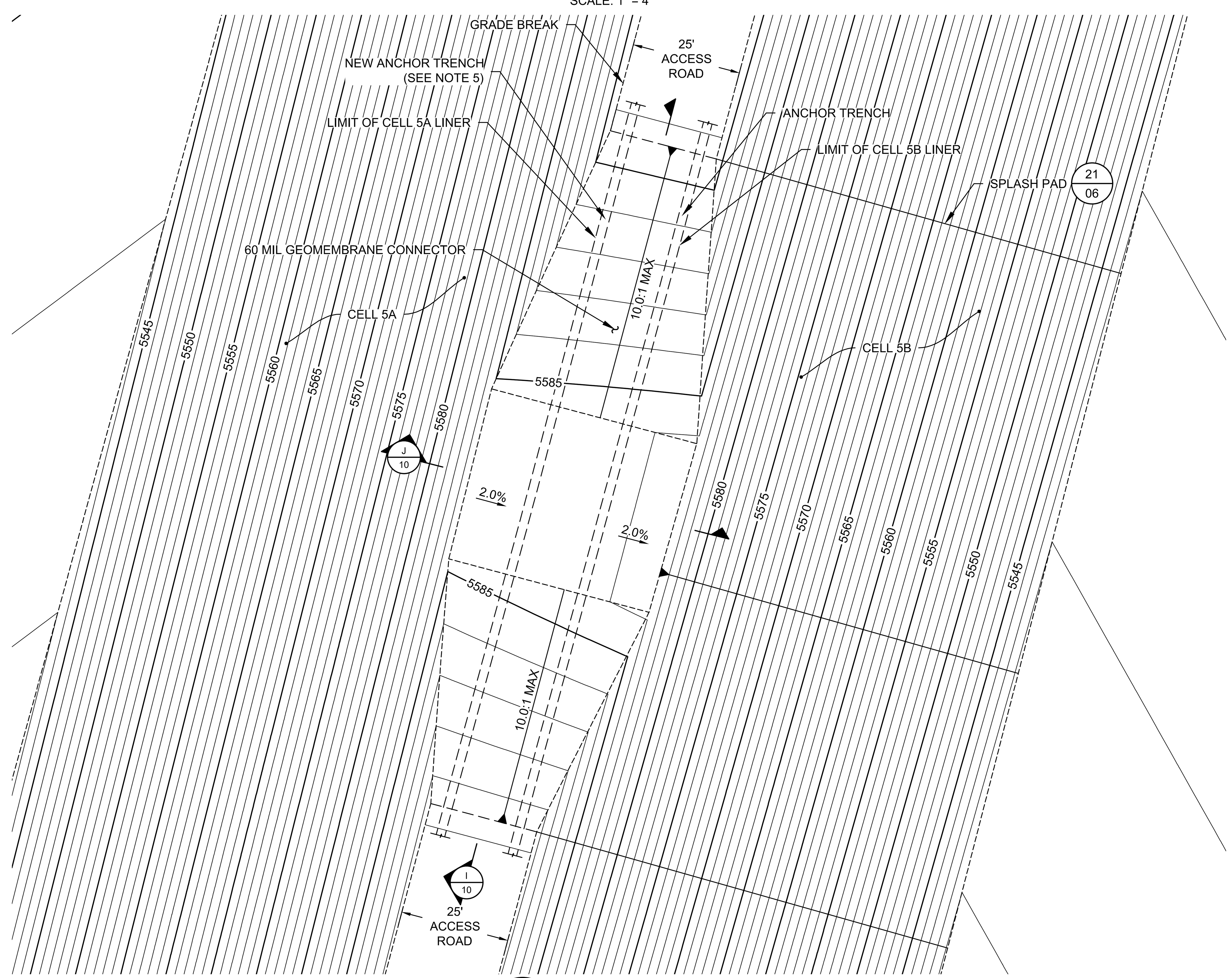


SECTION I - SPILLWAY - SECTION-5B
SCALE: 1" = 8'



SECTION J - SPILLWAY - SECTION 2 - 5B
SCALE: 1" = 4'



24 PLAN - SPILLWAY PLAN - 5B
03B,04B
SCALE: 1" = 20'

NOTES:

1. CUSHION GEOTEXTILE SHALL BE PLACED OVERLYING PRIMARY GEOMEMBRANE WHERE CONCRETE IS INSTALLED.
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
3. WELDED WIRE FABRIC SHALL BE INSTALLED AT CENTER OF CONCRETE SLAB SECTION.
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5. CUT AND FOLD BACK EXISTING LINER SYSTEM GEOSYNTHETIC LAYERS (60 mil HDPE MEMBRANE, 300 mil GEONET, 60 mil HDPE GEOMEMBRANE, GCL) TO ALLOW EXCAVATION OF SPILLWAY. REPLACE LINER SYSTEM GEOSYNTHETICS LAYERS ONTO NEW SPILLWAY GRADES AND NEW ANCHOR TRENCH. NEW ANCHOR TRENCH SHALL BE TIED INTO EXISTING ANCHOR TRENCH.
6. ANCHOR 60 MIL GEOMEMBRANE CONNECTOR AT TOP OF 10H:1V SLOPE IN 12" DEEP ANCHOR TRENCH.

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
16644 WEST BERNARDO DRIVE, SUTE 301
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: DETAILS & SECTIONS VI

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
OPTION B - DOUBLE LINER WITH GCL

SITE: WHITE MESA MILL
BLANDING, UTAH

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SIGNATURE
06-29-18
DATE

REGISTERED PROFESSIONAL ENGINEER No. 6020077-2202 GREGORY T. CORCORAN STATE OF UTAH

DESIGN BY:	GTC	DATE:	JUNE 2018
DRAWN BY:	MMC	PROJECT NO.:	SC0634A
CHECKED BY:	RFO	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	10 OF 10	

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APPENDIX B

Construction Quality Assurance Plan

Prepared for

Energy Fuels Resources (USA), Inc.
6425 S. Highway 191
P.O. Box 809
Blanding, UT 84511

CONSTRUCTION QUALITY ASSURANCE PLAN

CELLS 5A AND 5B

WHITE MESA MILL
BLANDING, UTAH

Prepared by

Geosyntec consultants

engineers | scientists | innovators

16644 West Bernardo Rd, Suite 301
San Diego, CA 92127

Project Number SC0634

June 2018

CERTIFICATION PAGE

CONSTRUCTION QUALITY ASSURANCE (CQA) PLAN FOR
CELLS 5A AND 5B CONSTRUCTION
ENERGY FUELS RESOURCES (USA), INC.
WHITE MESA MILL
BLANDING, UTAH

The Engineering material and data contained in this CQA Plan were prepared under the supervision and direction of the undersigned, whose seal as a registered Professional Engineer is affixed below.

Gregory T. Corcoran, P.E.
Engineer of Record

REGISTERED PROFESSIONAL ENGINEER
No. 6020077-2202
GREGORY T. CORCORAN
STATE OF UTAH

TABLE OF CONTENTS

TABLES

1. INTRODUCTION

1.1 Terms of Reference

Geosyntec Consultants (Geosyntec) has prepared this Construction Quality Assurance (CQA) Plan for the construction of liner systems associated with the Cells 5A and 5B Lining Systems Construction at the Energy Fuels Resources (USA), Inc. (Energy Fuels) White Mesa Mill Facility (site), located at 6425 South Highway 191, Blanding, Utah 84511. This CQA Plan was prepared by Ms. Rebecca Oliver, of Geosyntec, and was reviewed by Mr. Gregory T. Corcoran, P.E., also of Geosyntec, in general accordance with the peer review policies of the firm.

1.2 Purpose and Scope of the Construction Quality Assurance Plan

The purpose of the CQA Plan is to address the CQA procedures and monitoring requirements for construction of the project. The CQA Plan is intended to: (i) define the responsibilities of parties involved with the construction; (ii) provide guidance in the proper construction of the major components of the project; (iii) establish testing protocols; (iv) establish guidelines for construction documentation; and (v) provide the means for assuring that the project is constructed in conformance to the *Technical Specifications*, permit conditions, applicable regulatory requirements, and *Construction Drawings*.

This CQA Plan addresses the earthwork and geosynthetic components of the liner system for the project. Two alternative liner systems are proposed for the Cells: Option A – Triple Liner and Option B- Double Liner with Geosynthetic Clay Liner (GCL). These are described in detail in the Design Report prepared by Geosyntec in June 2018. The earthwork, geosynthetic, and appurtenant components include well abandonment, excavation, fill, prepared subgrade, geomembrane, geotextile, geosynthetic clay liner (GCL), geonet, drainage aggregate, and polyvinyl chloride (PVC) pipe. It should be emphasized that care and documentation are required in the placement of aggregate and in the production and installation of the geosynthetic materials installed during construction. This CQA Plan delineates procedures to be followed for monitoring construction utilizing these materials.

The CQA monitoring activities associated with the selection, evaluation, and placement of drainage aggregate are included in the scope of this plan. The CQA protocols applicable to manufacturing, shipping, handling, and installing all geosynthetic materials are also included. However, this CQA Plan does not specifically address either installation specifications or specification of soils and geosynthetic materials as these requirements are addressed in the *Technical Specifications*.

1.3 References

The CQA Plan includes references to test procedures in the latest editions of the ASTM International.

1.4 Organization of the Construction Quality Assurance Plan

The remainder of the CQA Plan is organized as follows:

- Section 2 presents definitions relating to CQA;
- Section 3 describes the CQA personnel and duties;
- Section 4 describes site and project control requirements;
- Section 5 presents CQA documentation;
- Section 6 presents CQA of well abandonment;
- Section 7 presents CQA of earthwork;
- Section 8 presents CQA of the drainage aggregate;
- Section 9 presents CQA of the pipe and fittings;
- Section 10 presents CQA of the geomembrane;
- Section 11 presents CQA of the geotextile;
- Section 12 presents CQA of the GCL;
- Section 13 presents CQA of the geonet;
- Section 14 presents CQA of the concrete spillway; and
- Section 15 presents CQA surveying.

2. DEFINITIONS RELATING TO CONSTRUCTION QUALITY ASSURANCE

This CQA Plan is devoted to Construction Quality Assurance. In the context of this document, Construction Quality Assurance and Construction Quality Control are defined as follows:

Construction Quality Assurance (CQA) - A planned and systematic pattern of means and actions designed to assure adequate confidence that materials or services meet contractual and regulatory requirements and will perform satisfactorily in service. CQA refers to means and actions employed by the CQA Consultant to assure conformity of the project "Work" with this CQA Plan, the *Construction Drawings*, and the *Technical Specifications*. CQA testing of aggregate, pipe, and geosynthetic components is provided by the CQA Consultant.

Construction Quality Control (CQC) - Actions which provide a means to measure and regulate the characteristics of an item or service in relation to contractual and regulatory requirements. Construction Quality Control refers to those actions taken by the Contractor, Manufacturer, or Geosynthetic Installer to verify that the materials and the workmanship meet the requirements of this CQA Plan, the *Construction Drawings*, and the *Technical Specifications*. In the case of the geosynthetic components and piping of the Work, CQC is provided by the Manufacturer, Geosynthetic Installer, and Contractor.

2.1 Owner

The Owner of this project is Energy Fuels Resources (USA), Inc. (Energy Fuels).

2.2 Construction Manager

Responsibilities

The Construction Manager is responsible for managing the construction and implementation of the *Construction Drawings* and *Technical Specifications* for the project work. The Construction Manager is selected/appointed by the Owner.

2.3 Design Engineer

Responsibilities

The Design Engineer is responsible for the design, *Construction Drawings*, and *Technical Specifications* for the project work. In this CQA Plan, the term "Design Engineer" refers to Geosyntec.

Qualifications

The Engineer of Record shall be a qualified engineer, registered as required by regulations in the State of Utah. The Design Engineer should have expertise, which demonstrates significant familiarity with piping, geosynthetics and soils, as appropriate, including design and construction experience related to liner systems.

2.4 Contractor

Responsibilities

In this CQA Plan, Contractor refers to an independent party or parties, contracted by the Owner, performing the work in accordance with this CQA Plan, the *Construction Drawings*, and the *Technical Specifications*. The Contractor will be responsible for the installation of the soils, pipe, drainage aggregate, and geosynthetic components of the liner systems. This work will include subgrade preparation, anchor trench excavation and backfill, placement of drainage aggregate for the slimes drain and two leak detection systems, installation of PVC piping, placement of cast-in-place concrete, and coordination of work with the Geosynthetic Installer and other subcontractors.

The Contractor will be responsible for constructing the liner system and appurtenant components in accordance with the *Construction Drawings* and complying with the quality control requirements specified in the *Technical Specifications*.

Qualifications

Qualifications of the Contractor are specific to the construction contract. The Contractor should have a demonstrated history of successful earthworks, piping, and liner system construction and shall maintain current state and federal licenses as appropriate.

2.5 Resin Supplier

Responsibilities

The Resin Supplier produces and delivers the resin to the Geosynthetics Manufacturer.

Qualifications

Qualifications of the Resin Supplier are specific to the Manufacturer's requirements. The Resin Supplier will have a demonstrated history of providing resin with consistent properties.

2.6 Manufacturers

Responsibilities

The Manufacturers are responsible for the production of finished material (geomembrane, geotextile, GCL, geonet, and pipe) from appropriate raw materials.

Qualifications

The Manufacturer(s) will be able to provide sufficient production capacity and qualified personnel to meet the demands of the project. The Manufacturer(s) must be a well-established firm(s) that meets the requirements identified in the *Technical Specifications*.

2.7 Geosynthetic Installer

Responsibilities

The Geosynthetic Installer is responsible for field handling, storage, placement, seaming, ballasting or anchoring against wind uplift, and other aspects of the geosynthetic material installation. The Geosynthetic Installer may also be responsible for specialized construction tasks (i.e., including construction of anchor trenches for the geosynthetic materials).

Qualifications

The Geosynthetic Installer will be trained and qualified to install the geosynthetic materials of the type specified for this project. The Geosynthetic Installer shall meet the qualification requirements identified in the *Technical Specifications*.

2.8 CQA Consultant

Responsibilities

The CQA Consultant is a party, independent from the Owner, Contractor, Manufacturer, and Geosynthetic Installer, who is responsible for observing, testing, and documenting activities related to the CQC and CQA of the earthwork, piping, and geosynthetic components used in the construction of the Project as required by this CQA Plan and the *Technical Specifications*. The CQA Consultant will also be responsible for issuing a CQA report at the completion of the Project construction, which documents construction and associated CQA activities. The CQA report will be signed and sealed by the CQA Engineer who will be a Professional Engineer registered in the State of Utah.

Qualifications

The CQA Consultant shall be a well-established firm specializing in geotechnical and geosynthetic engineering that possess the equipment, personnel, and licenses necessary to conduct the geotechnical and geosynthetic tests required by the project plans and *Technical Specifications*. The CQA Consultant will provide qualified staff for the project, as necessary, which will include, at a minimum, a CQA Engineer and a CQA Site Manager. The CQA Engineer will be a professionally licensed engineer as required by State of Utah regulations.

The CQA Consultant will be experienced with earthwork and installation of geosynthetic materials similar to those materials used in construction of the Project. The CQA Consultant will be experienced in the preparation of CQA documentation including CQA Plans, field documentation, field testing procedures, laboratory testing procedures, construction specifications, construction drawings, and CQA reports.

The CQA Site Manager will be specifically familiar with the construction of earthworks, piping, and geosynthetic lining systems. The CQA Site Manager will be trained by the CQA Consultant in the duties as CQA Site Manager.

2.9 Surveyor

Responsibilities

The Surveyor is a party, independent from the Contractor, Manufacturer, and Geosynthetic Installer, that is responsible for surveying, documenting, and verifying the location of all significant components of the Work. The Surveyor's work is coordinated and employed by the Contractor. The Surveyor is responsible for issuing *Record Drawings* of the construction.

Qualifications

The Surveyor will be a well-established surveying company with at least 3 years of surveying experience in the State of Utah. The Surveyor will be a licensed professional as required by the State of Utah regulations. The Surveyor shall be fully equipped and experienced in the use of total stations and the recent version of AutoCAD. All surveying will be performed under the direct supervision of the Contractor.

2.10 CQA Laboratory

Responsibilities

The CQA Laboratory is a party, independent from the Contractor, Manufacturer, and Geosynthetic Installer, that is responsible for conducting tests in accordance with ASTM and other applicable test standards on samples of geosynthetic materials and soil in either an onsite or offsite laboratory.

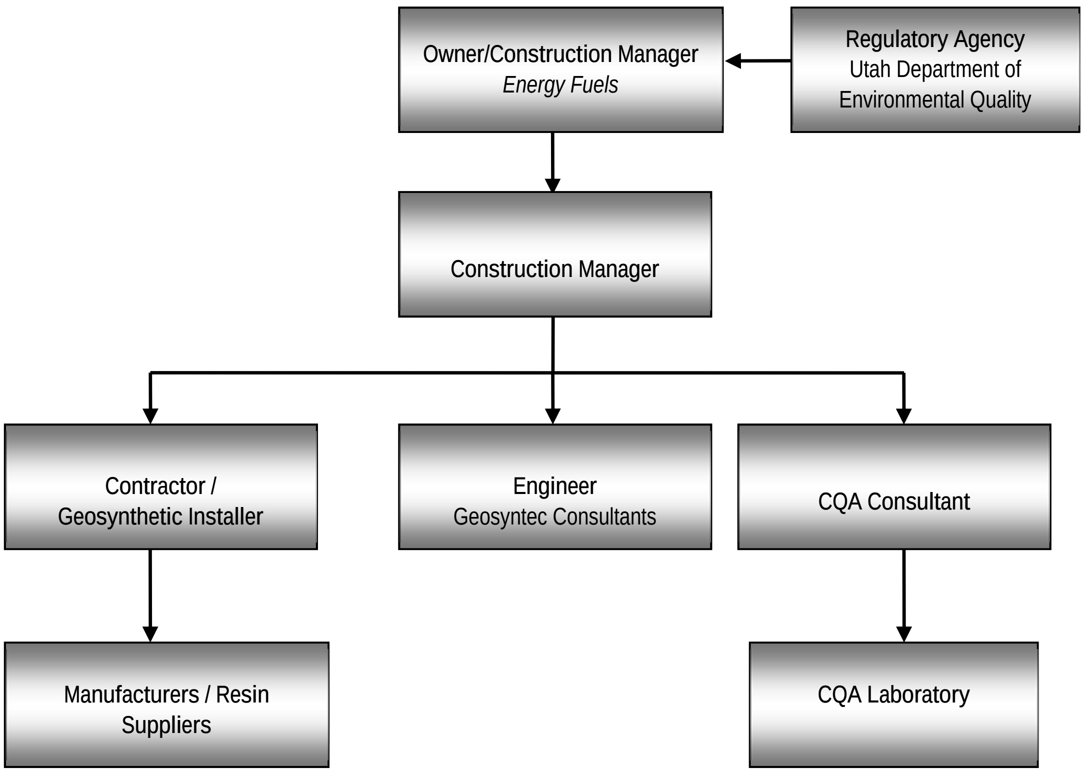
Qualifications

The CQA Laboratory will have experience in testing soils and geosynthetic materials and will be familiar with ASTM and other applicable test standards. The CQA Laboratory will be capable of providing test results within a maximum of seven days of receipt of samples and will maintain that capability throughout the duration of earthworks construction and geosynthetic materials installation. The CQA Laboratory will also be capable of transmitting geosynthetic destructive test results within 24 hours of receipt of samples and will maintain that capability throughout the duration of geosynthetic material installation.

2.11 Lines of Communication

The following organization chart indicates the lines of communication and authority related to this project.

Project Organization Chart
Energy Fuels
White Mesa Mill Cell 4B



2.12 Deficiency Identification and Rectification

If a defect is discovered in the work, the CQA Engineer will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Engineer will determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the CQA Engineer deems appropriate.

After evaluating the extent and nature of a defect, the CQA Engineer will notify the Construction Manager and schedule appropriate re-tests when the work deficiency is corrected by the Contractor.

The Contractor will correct the deficiency to the satisfaction of the CQA Engineer. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Engineer will develop and present to the Design Engineer suggested solutions for approval. Major modification to the *Construction Drawings*, *Technical Specifications*, or this CQA Plan must be provided to the regulatory agency for review prior to implementation.

Defect corrections will be monitored and documented by CQA personnel prior to subsequent work by the Contractor in the area of the deficiency.

3. CQA CONSULTANT'S PERSONNEL AND DUTIES

3.1 Overview

The CQA Engineer will provide supervision within the scope of work of the CQA Consultant. The scope of work for the CQA Consultant includes monitoring of construction activities including the following:

- earthwork;
- subgrade preparation;
- installation of GCL;
- installation of geomembrane;
- installation of geonet;
- installation of drainage aggregate;
- installation of piping; and
- installation of geotextile.

Duties of CQA personnel are discussed in the remainder of this section.

3.2 CQA Personnel

The CQA Consultant's personnel will include:

- the CQA Engineer, who works from the office of the CQA Consultant and who conducts periodic visits to the site as required; and
- the CQA Site Manager, who is located at the site.

3.3 CQA Engineer

The CQA Engineer shall supervise and be responsible for monitoring and CQA activities relating to the construction of the earthworks, piping, and installation of the geosynthetic materials of the Project. Specifically, the CQA Engineer:

- reviews the project design, this CQA Plan, *Construction Drawings*, and *Technical Specifications*;

- reviews other site-specific documentation; unless otherwise agreed, such reviews are for familiarization and for evaluation of constructability only, and hence the CQA Engineer and the CQA Consultant assume no responsibility for the liner system design;
- reviews and approves the Geosynthetic Installer's Quality Control (QC) Plan;
- attends Pre-Construction Meetings as needed;
- administers the CQA program (i.e., provides supervision of and manages onsite CQA personnel, reviews field reports, and provides engineering review of CQA related activities);
- provides quality control of CQA documentation and conducts site visits;
- reviews the *Record Drawings*; and
- with the CQA Site Manager, prepares the CQA report documenting that the project was constructed in accordance with the Construction Documents.

3.4 CQA Site Manager

The CQA Site Manager:

- acts as the onsite representative of the CQA Consultant;
- attends CQA-related meetings (e.g., pre-construction, daily, weekly (or designates a representative to attend the meetings));
- oversees the ongoing preparation of the *Record Drawings*;
- reviews test results provided by Contractor;
- assigns locations for testing and sampling;
- oversees the collection and shipping of laboratory test samples;
- reviews results of laboratory testing and makes appropriate recommendations;
- reviews the calibration and condition of onsite CQA equipment;
- prepares a daily summary report for the project;
- reviews the Manufacturer's Quality Control (MQC) documentation;
- reviews the Geosynthetic Installer's personnel Qualifications for conformance with those pre-approved for work on site;

- notes onsite activities in daily field reports and reports to the CQA Engineer and Construction Manager;
- reports unresolved deviations from the CQA Plan, *Construction Drawings*, and *Technical Specifications* to the Construction Manager; and
- assists with the preparation of the CQA report.

4. SITE AND PROJECT CONTROL

4.1 Project Coordination Meetings

Meetings of key project personnel are necessary to assure a high degree of quality during installation and to promote clear, open channels of communication. Therefore, Project Coordination Meetings are an essential element in the success of the project. Several types of Project Coordination Meetings are described below, including: (i) pre-construction meetings; (ii) progress meetings; and (iii) problem or work deficiency meetings.

4.1.1 Pre-Construction Meeting

A Pre-Construction Meeting will be held at the site prior to construction of the Project. At a minimum, the Pre-Construction Meeting will be attended by the Contractor, the Geosynthetic Installer's Superintendent, the CQA Consultant, and the Construction Manager.

Specific items for discussion at the Pre-Construction Meeting include the following:

- appropriate modifications or clarifications to the CQA Plan;
- the *Construction Drawings* and *Technical Specifications*;
- the responsibilities of each party;
- lines of authority and communication;
- methods for documenting and reporting, and for distributing documents and reports;
- acceptance and rejection criteria;
- protocols for testing;
- protocols for handling deficiencies, repairs, and re-testing;
- the time schedule for all operations;
- procedures for packaging and storing archive samples;
- panel layout and numbering systems for panels and seams;
- seaming procedures;
- repair procedures; and
- soil stockpiling locations.

The Construction Manager will conduct a site tour to observe the current site conditions and to review construction material and equipment storage locations. A person in attendance at the meeting will be appointed by the Construction Manager to record the discussions and decisions of the meeting in the form of meeting minutes. Copies of the meeting minutes will be distributed to all attendees.

4.1.2 Progress Meetings

Progress meetings will be held between the CQA Site Manager, the Contractor, Construction Manager, and other concerned parties participating in the construction of the project. This meeting will include discussions on the current progress of the project, planned activities for the next week, and revisions to the work plan or schedule. The meeting will be documented in meeting minutes prepared by a person designated by the Construction Manager at the beginning of the meeting. Within two working days of the meeting, draft minutes will be transmitted to representatives of parties in attendance for review and comment. Corrections or comments to the draft minutes shall be made within two working days of receipt of the draft minutes to be incorporated in the final meeting minutes.

4.1.3 Problem or Work Deficiency Meeting

A special meeting will be held when and if a problem or deficiency is present or likely to occur. The meeting will be attended by the Contractor, the Construction Manager, the CQA Site Manager, and other parties as appropriate. If the problem requires a design modification, the Design Engineer should either be present at, consulted prior to, or notified immediately upon conclusion of this meeting. The purpose of the work deficiency meeting is to define and resolve the problem or work deficiency as follows:

- define and discuss the problem or deficiency;
- review alternative solutions;
- select a suitable solution agreeable to all parties; and
- implement an action plan to resolve the problem or deficiency.

The Construction Manager will appoint one attendee to record the discussions and decisions of the meeting. The meeting record will be documented in the form of meeting minutes and copies will be distributed to all affected parties. A copy of the minutes will be retained in facility records.

5. DOCUMENTATION

5.1 Overview

An effective CQA Plan depends largely on recognition of all construction activities that should be monitored and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The CQA Consultant will document that quality assurance requirements have been addressed and satisfied.

The CQA Site Manager will provide the Construction Manager with signed descriptive remarks, data sheets, and logs to verify that monitoring activities have been carried out. The CQA Site Manager will also maintain, at the job site, a complete file of *Construction Drawings* and *Technical Specifications*, a CQA Plan, checklists, test procedures, daily logs, and other pertinent documents.

5.2 Daily Recordkeeping

Preparation of daily CQA documentation will consist of daily field reports prepared by the CQA Site Manager which may include CQA monitoring logs and testing data sheets. This information may be regularly submitted to and reviewed by the Construction Manager. Daily field reports will include documentation of the observed activities during each day of activity. The daily field reports may include monitoring logs and testing data sheets. At a minimum, these logs and data sheets will include the following information:

- the date, project name, location, and other identification;
- a summary of the weather conditions;
- a summary of locations where construction is occurring;
- equipment and personnel on the project;
- a summary of meetings held and attendees;
- a description of materials used and references of results of testing and documentation;
- identification of deficient work and materials;
- results of re-testing corrected "deficient work;"
- an identifying sheet number for cross referencing and document control;
- descriptions and locations of construction monitored;

- type of construction and monitoring performed;
- description of construction procedures and procedures used to evaluate construction;
- a summary of test data and results;
- calibrations or re-calibrations of test equipment and actions taken as a result of re-calibration;
- decisions made regarding acceptance of units of work or corrective actions to be taken in instances of substandard testing results;
- a discussion of agreements made between the interested parties which may affect the work; and
- signature of the respective CQA Site Manager.

5.3 Construction Problems and Resolution Data Sheets

Construction Problems and Resolution Data Sheets, to be submitted with the daily field reports prepared by the CQA Site Manager, describing special construction situations, will be cross-referenced with daily field reports, specific observation logs, and testing data sheets and will include the following information, where available:

- an identifying sheet number for cross-referencing and document control;
- a detailed description of the situation or deficiency;
- the location and probable cause of the situation or deficiency;
- how and when the situation or deficiency was found or located;
- documentation of the response to the situation or deficiency;
- final results of responses;
- measures taken to prevent a similar situation from occurring in the future; and
- signature of the CQA Site Manager and a signature indicating concurrence by the Construction Manager.

The Construction Manager will be made aware of significant recurring nonconformance with the *Construction Drawings*, *Technical Specifications*, or CQA Plan. The cause of the nonconformance will be determined and appropriate changes in procedures or specifications will be recommended. These changes will be submitted to the Construction Manager for approval. When this type of evaluation is made, the results will be documented and any revision to procedures or specifications will be approved by the Contractor and Design Engineer.

A summary of supporting data sheets, along with final testing results and the CQA Engineer's approval of the work, will be required upon completion of construction.

5.4 Photographic Documentation

Photographs will be taken and documented in order to serve as a pictorial record of work progress, problems, and mitigation activities. These records will be presented to the Construction Manager upon completion of the project. Photographic reporting data sheets, where used, will be cross-referenced with observation and testing data sheet(s), or Construction Problem and Resolution Data Sheet(s).

5.5 Design or Specifications Changes

Design or specifications changes may be required during construction. In such cases, the CQA Site Manager will notify the Design Engineer. Design or specification changes will be made with the written agreement of the Design Engineer and will take the form of an addendum to the *Construction Drawings* and *Technical Specifications*.

5.6 CQA Report

At the completion of the Project, the CQA Consultant will submit to the Owner a CQA report signed and sealed by a Professional Engineer licensed in the State of Utah. The CQA report will acknowledge: (i) that the work has been performed in compliance with the *Construction Drawings* and *Technical Specifications*; (ii) physical sampling and testing has been conducted at the appropriate frequencies; and (iii) that the summary document provides the necessary supporting information. At a minimum, this report will include:

- MQC documentation;
- a summary report describing the CQA activities and indicating compliance with the *Construction Drawings* and *Technical Specifications* which is signed and sealed by the CQA Engineer;
- a summary of CQA/CQC testing, including failures, corrective measures, and retest results;
- Contractor and Installer personnel resumes and qualifications as necessary;

- documentation that the geomembrane trial seams were performed in accordance with the CQA Plan and *Technical Specifications*;
- documentation that field seams were non-destructively tested using a method in accordance with the applicable test standards;
- documentation that nondestructive testing was monitored by the CQA Site Manager, that the CQA Site Manager informed the Geosynthetic Installer of any required repairs, and that the CQA Site Manager monitored the seaming and patching operations for uniformity and completeness;
- records of sample locations, the name of the individual conducting the tests, and the results of tests;
- *Record Drawings* as provided by the Surveyor; and
- daily field reports.

The *Record Drawings* will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., plan dimensions and appropriate elevations). *Record Drawings* and required base maps will be prepared by a qualified Professional Land Surveyor registered in the State of Utah. These documents will be reviewed by the CQA Consultant and included as part of the CQA Report.

6. WELL ABANDONMENT

6.1 Introduction

This section of the CQA Plan outlines the CQA activities to be performed for well abandonment. The CQA Site Manager will review and become familiar with the *Construction Documents* and any approved addenda or changes that pertain to work completed under this section.

The CQA Site Manager will monitor well abandonment operations. The CQA Engineer will review the contractor's submittals pertaining to CQA and provide recommendations to the Design Engineer. Monitored abandonment activities will be documented, as will deviations from the *Construction Drawings* and the *Technical Specifications*. Any non-conformance identified by the CQA Site Manager will be reported to the Construction Manager.

6.2 CQA Monitoring Activities

6.2.1 Materials

CQA activities provided for storing and handling of materials shall meet the requirements set forth in Section 02070 of the *Technical Specifications*.

6.2.2 Well Abandonment

The wells to be abandoned are indicated on the *Drawings*. Well abandonment shall be observed by the CQA Site Manager. Observed well abandonment activities shall be documented in daily field reports. The CQA Site Manager shall keep a detailed log for the abandoned well, including drilling procedure, total depth of abandonment, depth to groundwater (if applicable), final depth of boring, and well destruction details, including the depth of placement and quantities of all well abandonment materials.

6.2.3 Deficiencies

If a defect is discovered in the well abandonment, the CQA Site Manager will evaluate the extent and nature of the defect. The CQA Consultant will determine the extent of the deficient area by observations, a review of records, or other means that the CQA Consultant deems appropriate.

6.2.4 Notification

After observing a defect, the CQA Consultant will notify the Construction Manager and schedule appropriate re-evaluation after the work deficiency is corrected by the Contractor.

6.2.5 Repairs and Re-testing

The Contractor will correct the deficiency to the satisfaction of the CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Design Engineer suggested solutions for approval.

7. EARTHWORK

7.1 Introduction

This section prescribes the CQA activities to be performed to monitor that earthwork is constructed in accordance with *Construction Drawings* and *Technical Specifications*. The earthwork construction procedures to be monitored by the CQA Site Manager, if required, shall include:

- vegetation removal;
- subgrade preparation;
- engineered fill placement, moisture conditioning, and compaction; and
- anchor trench excavation and backfill.

7.2 Earthwork Testing Activities

Testing of earthwork to be used for engineered fill will be performed for material conformance. The CQA Laboratory will perform the conformance testing and CQC testing. Soil testing will be conducted in accordance with the current versions of the corresponding ASTM test procedures. The test methods indicated in Tables 1A and 1B are those that will be used for this testing unless the test methods are updated or revised prior to construction. Revisions to the test methods will be reviewed and approved by the Design Engineer and the CQA Consultant prior to their usage.

7.2.1 Sample Frequency

The frequency of subgrade soil testing for material qualification and material conformance will conform to the minimum frequencies presented in Table 1A. The frequency of soil testing shall conform to the minimum frequencies presented in Table 1B. The actual frequency of testing required will be increased by the CQA Site Manager, as necessary, if variability of materials is noted at the site, during adverse conditions, or to isolate failing areas of the construction.

7.2.2 Sample Selection

Sampling locations will be selected by the CQA Site Manager. Conformance samples will be obtained from borrow pits or stockpiles of material. The Contractor must plan the work and make soil available for sampling in a timely and organized manner so that the test results can be obtained before the material is installed. The CQA Site Manager must document sample locations so that failing areas can be immediately isolated. The CQA Site Manager will follow standard sampling procedures to obtain representative samples of the proposed soil materials.

7.3 CQA Monitoring Activities

7.3.1 Vegetation Removal

The CQA Site Manager will monitor and document that vegetation is sufficiently cleared and grubbed in areas where engineered fill is to be placed. Vegetation removal shall be performed as described in the *Technical Specifications* and the *Construction Drawings*.

7.3.2 Topsoil Removal

The CQA Site Manager will monitor and document that topsoil is sufficiently excavated in areas where engineered fill is to be placed. Topsoil removal shall be performed as described in the *Technical Specifications* and the *Construction Drawings*.

7.3.3 Engineered Fill

During construction, the CQA Site Manager will monitor engineered fill placement and compaction to confirm it is consistent with the requirements specified in the *Technical Specifications* and the *Construction Drawings*. The CQA Site Manager will monitor, at a minimum, that:

- the fill material is free of debris and other undesirable materials and that particles are no larger than 6-inches in longest dimension;
- the fill is constructed to the lines and grades shown on the *Construction Drawings*; and
- fill compaction requirements are met as specified in the *Technical Specifications.*

7.3.4 Subgrade Soil

During construction, the CQA Site Manager will monitor the subgrade soil placement and compaction methods are consistent with the requirements specified in the *Technical Specifications* and the *Construction Drawings*. The CQA Site Manager will monitor, at a minimum, that:

- the subgrade soil is free of protrusions larger than 0.7-inches and particles are to be no larger than 3-inches in longest dimension;
- the subgrade soil is constructed to the lines and grades shown on the *Construction Drawings*; and
- compaction requirements are met as specified in the *Technical Specifications.*

7.3.5 Fine Grading

The CQA Site Manager shall monitor and document that site re-grading performed meets the requirements of the *Technical Specifications* and the *Construction Drawings*. At a minimum, the CQA Site Manager shall monitor that:

- the subgrade surface is free of sharp rocks, debris, and other undesirable materials;
- the subgrade surface is smooth and uniform; and
- the subgrade surface meets the lines and grades shown on the *Construction Drawings*.

7.3.6 Anchor Trench Construction

During construction, the CQA Site Manager will monitor the anchor trench excavation and backfill methods are consistent with the requirements specified in the *Technical Specifications* and the *Construction Drawings*. The CQA Site Manager will monitor, at a minimum, that:

- the anchor trench is free of debris and other undesirable materials;
- the anchor trench is constructed to the lines and grades shown on the *Construction Drawings*; and
- compaction requirements are met, through visual observations, as specified in the *Technical Specifications.*

7.4 <u>Deficiencies</u>

If a defect is discovered in the earthwork product, the CQA Site Manager will immediately determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Consultant will determine the extent of the defective area by additional tests, observations, a review of records, or other means that the CQA Consultant deems appropriate. If the defect is related to adverse site conditions, such as overly wet soils or non-conforming particle sizes, the CQA Site Manager will define the limits and nature of the defect.

7.4.1 Notification

After evaluating the extent and nature of a defect, the CQA Consultant will notify the Construction Manager and Contractor and schedule appropriate re-evaluation when the work deficiency is to be corrected.

7.4.2 Repairs and Re-Testing

The Contractor will correct deficiencies to the satisfaction of the CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Construction Manager suggested solutions for his approval.

Re-evaluations by the CQA Site Manager shall continue until it is verified that defects have been corrected before any additional work is performed by the Contractor in the area of the deficiency.

8. DRAINAGE AGGREGATE

8.1 Introduction

This section prescribes the CQA activities to be performed to monitor that drainage aggregates are constructed in accordance with *Construction Drawings* and *Technical Specifications*. The drainage aggregates construction procedures to be monitored by the CQA Site Manager include drainage aggregate placement.

8.2 Testing Activities

Aggregate testing will be performed for material qualification and material conformance. These two stages of testing are defined as follows:

- Material qualification tests are used to evaluate the conformance of a proposed aggregate source with the *Technical Specifications* for qualification of the source prior to construction.
- Aggregate conformance testing is used to evaluate the conformance of a particular batch of aggregate from a qualified source to the *Technical Specifications* prior to installation of the aggregate.

The Contractor will be responsible for submitting material qualification test results to the Construction Manager and to the CQA Consultant for review. The CQA Laboratory will perform the conformance testing and CQC testing. Aggregate testing will be conducted in accordance with the current versions of the corresponding ASTM test procedures. The test methods indicated in Tables 2A and 2B are those that will be used for this testing unless the test methods are updated or revised prior to construction. Revisions to the test methods will be reviewed and approved by the Design Engineer and the CQA Consultant prior to their usage.

8.2.1 Sample Frequency

The frequency of aggregate testing for material qualification and material conformance will conform to the minimum frequencies presented in Table 2A. The frequency of aggregate testing shall conform to the minimum frequencies presented in Table 2B. The actual frequency of testing required will be increased by the CQA Site Manager, as necessary, if variability of materials is noted at the site, during adverse conditions, or to isolate failing areas of the construction.

8.2.2 Sample Selection

With the exception of qualification samples, sampling locations will be selected by the CQA Site Manager. Conformance samples will be obtained from borrow pits or stockpiles of material. The Contractor must plan the work and make aggregate available for sampling in a timely and organized manner so that the test results can be obtained before the material is installed. The CQA Site Manager must document sample locations so that failing areas can be immediately isolated. The CQA Site Manager will follow standard sampling procedures to obtain representative samples of the proposed aggregate materials.

8.3 CQA Monitoring Activities

8.3.1 Drainage Aggregate

The CQA Site Manager will monitor and document the installation of the drainage aggregates. In general, monitoring of the installation of drainage aggregate includes the following activities:

- reviewing documentation of the material qualification test results provided by the Contractor;
- sampling and testing for conformance of the materials to the *Technical Specifications*;
- documenting that the drainage aggregates are installed using the specified equipment and procedures;
- documenting that the drainage aggregates are constructed to the lines and grades shown on the *Construction Drawings*; and
- monitoring that the construction activities do not cause damage to underlying geosynthetic materials.

8.4 Deficiencies

If a defect is discovered in the drainage aggregates, the CQA Site Manager will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Consultant will determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the CQA Consultant deems appropriate.

8.4.1 Notification

After evaluating the extent and nature of a defect, the CQA Consultant will notify the Construction Manager and Contractor and schedule appropriate re-tests when the work deficiency is to be corrected.

8.4.2 Repairs and Re-testing

The Contractor will correct the deficiency to the satisfaction of the CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Construction Manager suggested solutions for approval.

Re-tests recommended by the CQA Site Manager shall continue until it is verified that the defect has been corrected before any additional work is performed by the Contractor in the area of the deficiency. The CQA Site Manager will also verify that installation requirements are met and that submittals are provided.

9. POLYVINYL CHLORIDE (PVC) PIPE AND STRIP COMPOSITE

9.1 Material Requirements

PVC pipe, fittings, and strip composite must conform to the requirements of the *Technical Specifications*. The CQA Consultant will document that the PVC pipe, fittings, and strip composite meet those requirements.

9.2 Manufacturer

9.2.1 Submittals

Prior to the installation of PVC pipe and strip composite, the Manufacturer will provide to the CQA Consultant:

- a properties' sheet including, at a minimum, all specified properties, measured using test methods indicated in the *Technical Specifications*, or equivalent; and

The CQA Consultant will document that:

- the property values certified by the Manufacturer meet the *Technical Specifications*; and
- the measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

9.3 Handling and Laying

Care will be taken during transportation of the pipe such that it will not be cut, kinked, or otherwise damaged. Ropes, fabric, or rubber-protected slings and straps will be used when handling pipes. Chains, cables, or hooks inserted into the pipe ends will not be used. Two slings spread apart will be used for lifting each length of pipe. Pipe or fittings will not be dropped onto rocky or unprepared ground.

Pipes will be handled and stored in accordance with the Manufacturer's recommendation. The handling of joined pipe will be in such a manner that the pipe is not damaged by dragging it over sharp and cutting objects. Slings for handling the pipe will not be positioned at joints. Sections of the pipes with deep cuts and gouges will be removed and the ends of the pipe rejoined.

9.4 Perforations

The CQA Site Manager shall monitor and document that the perforations of the PVC pipe conform to the requirements of the *Construction Drawings* and the *Technical Specifications*.

9.5 Joints

The CQA Monitor shall monitor and document that pipe and fittings are joined by the methods indicated in the *Technical Specifications*.

9.6 Strip Composite

The CQA Site Monitor shall monitor and document that the strip composite and sandbags meet and are installed in accordance with the requirements outlined on the drawings and in the *Technical Specifications.*

10. GEOMEMBRANE

10.1 General

This section discusses and outlines the CQA activities to be performed for high density polyethylene (HDPE) smooth, textured, and Drain Liner™ geomembrane installation. The CQA Site Manager will review the *Construction Drawings*, *Technical Specifications,* and any approved Addenda regarding this material.

10.2 Geomembrane Material Conformance

10.2.1 Introduction

The CQA Site Manager will document that the geomembrane delivered to the site meets the requirements of the *Technical Specifications* prior to installation. The CQA Site Manager will:

- review the manufacturer's submittals for compliance with the *Technical Specifications*;
- document the delivery and proper storage of geomembrane rolls; and
- conduct conformance testing of the rolls before the geomembrane is installed.

The following sections describe the CQA activities required to verify the conformance of geomembrane.

10.2.2 Review of Quality Control

10.2.2.1 Material Properties Certification

The Manufacturer will provide the Construction Manager and the CQA Consultant with the following:

- property data sheets, including, at a minimum, all specified properties, measured using test methods indicated in the *Technical Specifications*, or equivalent; and
- sampling procedures and results of testing.

The CQA Consultant will document that:

- the property values certified by the Manufacturer meet all of the requirements of the *Technical Specifications*; and
- the measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.

10.2.2.2 Geomembrane Roll MQC Certification

Prior to shipment, the Manufacturer will provide the Construction Manager and the CQA Consultant with MQC certificates for every roll of geomembrane provided. The MQC certificates will be signed by a responsible party employed by the Geomembrane Manufacturer, such as the production manager. The MQC certificates shall include:

- roll numbers and identification; and
- results of MQC tests; as a minimum, results will be given for thickness, specific gravity, carbon black content, carbon black dispersion, tensile properties, and puncture resistance evaluated in accordance with the methods indicated in the *Technical Specifications* or equivalent methods approved by the Construction Manager.

The CQA Consultant will document that:

- that MQC certificates have been provided at the specified frequency, and that the certificates identify the rolls related to the roll represented by the test results; and
- review the MQC certificates and monitor that the certified roll properties meet the specifications.

10.2.3 Conformance Testing

The CQA Consultant shall obtain conformance samples (at the manufacturing facility or site) at the specified frequency and forward them to the Geosynthetics CQA Laboratory for testing to monitor conformance to both the *Technical Specifications* and the list of properties certified by the Manufacturer. The test procedures will be as indicated in Table 3. Where optional procedures are noted in the test method, the requirements of the *Technical Specifications* will prevail.

Samples will be taken across the width of the roll and will not include the first linear 3 feet of material. Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Consultant will mark the machine direction on the samples with an arrow along with the date and roll number. The required minimum sampling frequencies are provided in Table 3.

The CQA Consultant will examine results from laboratory conformance testing and will report any non-conformance to the Construction Manager and the Geosynthetic Installer. The procedures prescribed in the *Technical Specifications* will be followed in the event of a failing conformance test.

10.3 Delivery

10.3.1 Transportation and Handling

The CQA Consultant will document that the transportation and handling does not pose a risk of damage to the geomembrane.

Upon delivery of the rolls of geomembrane, the CQA Site Manager will document that the rolls are unloaded and stored on site as required by the *Technical Specifications*. Damage caused by unloading will be documented by the CQA Site Manager and the damaged material shall not be installed.

10.3.2 Storage

The Geosynthetic Installer will be responsible for the storage of the geomembrane on site. The Contractor will provide storage space in a location (or several locations) such that onsite transportation and handling are optimized, if possible, to limit potential damage.

The CQA Site Manager will document that storage of the geomembrane provides adequate protection against sources of damage.

10.4 Geomembrane Installation

10.4.1 Introduction

The CQA Site Manager will document that the geomembrane installation is carried out in accordance with the *Construction Drawings, Technical Specifications,* and Manufacturer's recommendations.

10.4.2 Earthwork[1]

10.4.2.1 Surface Preparation

The CQA Site Manager will document that:

- the prepared subgrade meets the requirements of the *Technical Specifications* and has been approved; and
- placement of the overlying materials does not damage, create large wrinkles, or induce excessive tensile stress in any underlying geosynthetic materials.

The Geosynthetic Installer will certify in writing that the surface on which the geosynthetics will be installed is acceptable. The Certificate of Acceptance, as presented in the *Technical Specifications*, will be signed by the Geosynthetic Installer and given to the CQA Site Manager prior to commencement of geosynthetics installation in the area under consideration.

After the subgrade has been accepted by the Geosynthetic Installer, it will be the Geosynthetic Installer's responsibility to indicate to the Construction Manager any change in the subgrade soil condition that may require repair work. If the CQA Site Manager concurs with the Geosynthetic Installer, then the CQA Site Manager shall monitor and document that the subgrade soil is repaired before geosynthetic installation begins.

At any time before and during the geomembrane installation, the CQA Site Manager will indicate to the Construction Manager locations that may not provide adequate support to the geomembrane.

10.4.2.2 Geosynthetic Termination

The CQA Site Manager will document that the geosynthetic terminations (Anchor Trench) have been constructed in accordance with the *Construction Drawings*. Backfilling above the terminations will be conducted in accordance with the *Technical Specifications*.

10.4.3 Geomembrane Placement

10.4.3.1 Panel Identification

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[1] For Option A, geomembrane will be installed over subgrade; for Option B, geomembrane will be installed over GCL

A field panel is the unit area of geomembrane which is to be seamed in the field, i.e., a field panel is a roll or a portion of roll cut in the field. It will be the responsibility of the CQA Site Manager to document that each field panel is given an "identification code" (number or letter-number) consistent with the Panel Layout Drawing. This identification code will be agreed upon by the Construction Manager, Geosynthetic Installer and CQA Site Manager. This field panel identification code will be as simple and logical as possible. Roll numbers established in the manufacturing plant must be traceable to the field panel identification code.

The CQA Site Manager will establish documentation showing correspondence between roll numbers and field panel identification codes. The field panel identification code will be used for all CQA records.

10.4.3.2 Field Panel Placement

Location

The CQA Site Manager will document that field panels are installed at the location indicated in the Geosynthetic Installer's Panel Layout Drawing, as approved or modified by the Construction Manager.

Installation Schedule

Field panels may be installed using one of the following schedules:

- all field panels are placed prior to field seaming in order to protect the subgrade from erosion by rain;
- field panels are placed one at a time and each field panel is seamed after its placement (in order to minimize the number of unseamed field panels exposed to wind); and
- any combination of the above.

If a decision is reached to place all field panels prior to field seaming, it is usually beneficial to begin at the high point area and proceed toward the low point with "shingle" overlaps to facilitate drainage in the event of precipitation. It is also usually beneficial to proceed in the direction of prevailing winds. Accordingly, an early decision regarding installation scheduling should be made if and only if weather conditions can be predicted with reasonable certainty. Otherwise, scheduling decisions must be made during installation, in accordance with varying conditions. In any event, the Geosynthetic Installer is fully responsible for the decision made regarding placement procedures.

The CQA Site Manager will evaluate every change in the schedule proposed by the Geosynthetic Installer and advise the Construction Manager on the acceptability of that change. The CQA Site Manager will document that the condition of the subgrade soil has not changed detrimentally during installation.

The CQA Site Manager will record the identification code, location, and date of installation of each field panel.

Weather Conditions

Geomembrane placement will not proceed unless otherwise authorized when the ambient temperature is below 32°F or above 122°F. In addition, wind speeds and direction will be monitored for potential impact to geosynthetic installation. Geomembrane placement will not be performed during any precipitation, in the presence of excessive moisture (e.g., fog, dew), or in an area of ponded water.

The CQA Site Manager will document that the above conditions are fulfilled. Additionally, the CQA Site Manager will document that the subgrade soil has not been damaged by weather conditions. The Geosynthetics Installer will inform the Construction Manager if the above conditions are not fulfilled.

Method of Placement

The CQA Site Manager will document the following:

- equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons or other means;
- the surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement;
- geosynthetics are oriented in accordance with the requirements of the *Technical Specifications*;
- excessive dust and/or dirt is not within the Drain Liner™ studs which could result in clogging and/or damage to the adjacent materials;

- geosynthetic elements immediately underlying the geomembrane are clean and free of debris;
- personnel working on the geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane;
- the method used to unroll the panels does not cause scratches or crimps in the geomembrane and does not damage the supporting soil;
- the method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels); and
- adequate temporary loading or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind (in case of high winds, continuous loading, e.g., by adjacent sand bags, is recommended along edges of panels to minimize risk of wind flow under the panels).

The CQA Site Manager will inform the Construction Manager if the above conditions are not fulfilled.

Damaged panels or portions of damaged panels that have been rejected will be marked and their removal from the work area recorded by the CQA Site Manager. Repairs will be made in accordance with procedures described in Section 9.4.5.

10.4.4 Field Seaming

This section details CQA procedures to document that seams are properly constructed and tested in accordance with the Manufacturer's specifications and industry standards.

10.4.4.1 Requirements of Personnel

All personnel performing seaming operations will be qualified by experience or by successfully passing seaming tests, as outlined in the *Technical Specifications*. The most experienced seamer, the "master seamer", will provide direct supervision over less experienced seamers.

The Geosynthetic Installer will provide the Construction Manager and the CQA Consultant with a list of proposed seaming personnel and their experience records. These documents will be reviewed by the Construction Manager and the Geosynthetics CQA Consultant.

10.4.4.2 Seaming Equipment and Products

Approved processes for field seaming are fillet extrusion welding and double-track fusion welding.

Fillet Extrusion Process

The fillet extrusion-welding apparatus will be equipped with gauges giving the temperature in the apparatus.

The Geosynthetic Installer will provide documentation regarding the extrusion welding rod to the CQA Site Manager, and will certify that the extrusion welding rod is compatible with the *Technical Specification*, and in any event, is comprised of the same resin as the geomembrane.

The CQA Site Manager will log apparatus temperatures, ambient temperatures, and geomembrane surface temperatures at appropriate intervals.

The CQA Site Manager will document that:

- the Geosynthetic Installer maintains, on site, the number of spare operable seaming apparatus decided at the Pre-construction Meeting;
- equipment used for seaming is not likely to damage the geomembrane;
- the extruder is purged prior to beginning a seam until all heat-degraded extrudate has been removed from the barrel;
- the electric generator is placed on a smooth base such that no damage occurs to the geomembrane;
- a smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and
- the geomembrane is protected from damage in heavily trafficked areas.

Fusion Process

The fusion-welding apparatus must be automated vehicular-mounted devices. The fusion-welding apparatus will be equipped with gauges giving the applicable temperatures and pressures.

The CQA Site Manager will log ambient, seaming apparatus, and geomembrane surface temperatures as well as seaming apparatus speeds.

The CQA Site Manager will also document that:

- the Geosynthetic Installer maintains on site the number of spare operable seaming apparatus decided at the Pre-construction Meeting;
- equipment used for seaming is not likely to damage the geomembrane;
- for cross seams, the edge of the cross seam is ground to a smooth incline (top and bottom) prior to welding;
- the electric generator is placed on a smooth cushioning base such that no damage occurs to the geomembrane from ground pressure or fuel leaks;
- a smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage; and
- the geomembrane is protected from damage in heavily trafficked areas.

10.4.4.3 Seam Preparation

The CQA Site Manager will document that:

- prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris, and foreign material;
- horizontal seams are not present on slopes greater than 10H:1V;
- Drain Liner™ studs are removed and grind depth does not exceed 10 percent of the core geomembrane thickness; and
- seams are aligned with the fewest possible number of wrinkles and "fishmouths."

10.4.4.4 Weather Conditions for Seaming

The normally required weather conditions for seaming are as follows unless authorized in writing by the Design Engineer:

- seaming will only be approved between ambient temperatures of 32°F and 122°F.

If the Geosynthetic Installer wishes to use methods that may allow seaming at ambient temperatures below 32°F or above 122°F, the Geosynthetic Installer will demonstrate and certify that such methods produce seams which are entirely equivalent to seams produced within acceptable temperature, and that the overall quality of the geomembrane is not adversely affected.

The CQA Site Manager will document that these seaming conditions are fulfilled and will advise the Geosynthetics Installer if they are not.

10.4.4.5 Overlapping and Temporary Bonding

The CQA Site Manager will document that:

- the panels of geomembrane have a finished overlap of a minimum of 3 inches for both extrusion and fusion welding;
- no solvent or adhesive bonding materials are used; and
- the procedures utilized to temporarily bond adjacent panels together does not damage the geomembrane.

The CQA Site Manager will log appropriate temperatures and conditions, and will log and report non-compliances to the Construction Manager.

10.4.4.6 Trial Seams

Trial seams shall be prepared with the procedures and dimensions as indicated in the *Technical Specifications*. The CQA Site Manager will observe trial seam procedures and will document the results of trial seams on trial seam logs. Each trial seam samples will be assigned a number. The CQA Site Manager, will log the date, time, machine temperature(s), seaming unit identification, name of the seamer, and pass or fail description for each trial seam sample tested.

Separate trial seaming logs shall be maintained for fusion welded and extrusion welded trial seams.

10.4.4.7 General Seaming Procedure

Unless otherwise specified, the general production seaming procedure used by the Geosynthetic Installer will be as follows:

- fusion-welded seams are continuous, commencing at one end to the seam and ending at the opposite end;
- cleaning, overlap, and shingling requirements shall be maintained;

- if seaming operations are carried out at night, adequate illumination will be provided at the Geosynthetic Installer's expense; and
- seaming will extend to the outside edge of panels to be placed in the anchor trench.

The CQA Site Manager shall document geomembrane seaming operations on seaming logs. Seaming logs shall include, at a minimum:

- seam identifications (typically associated with panels being joined);
- seam starting time and date;
- seam ending time and date;
- seam length;
- identification of person performing seam; and
- identification of seaming equipment.

Separate logs shall be maintained for fusion and extrusion welded seams. In addition, the CQA Site Manager shall monitor during seaming that:

- fusion-welded seams are continuous, commencing at one end of the seam and ending at the opposite end; and
- cleaning, overlap, and shingling requirements are maintained.

10.4.4.8 Nondestructive Seam Continuity Testing

Concept

The Geosynthetic Installer will non-destructively test field seams over their length using a vacuum test unit, air pressure test (for double fusion seams only), or other method approved by the Construction Manager. The purpose of nondestructive tests is to check the continuity of seams. It does not provide information on seam strength. Continuity testing will be carried out as the seaming work progresses, not at the completion of field seaming.

The CQA Site Manager will:

- observe continuity testing;

- record location, date, name of person conducting the test, and the results of tests; and
- inform the Geosynthetic Installer of required repairs.

The Geosynthetic Installer will complete any required repairs in accordance with Section 10.4.5.

The CQA Site Manager will:

- observe the repair and re-testing of the repair;
- mark on the geomembrane that the repair has been made; and
- document the results.

The following procedures will apply to locations where seams cannot be non-destructively tested:

All such seams will be cap-stripped with the same geomembrane.

- If the seam is accessible to testing equipment prior to final installation, the seam will be non-destructively tested prior to final installation.
- If the seam cannot be tested prior to final installation, the seaming and cap-stripping operations will be observed by the CQA Site Manager and Geosynthetic Installer for uniformity and completeness.

The seam number, date of observation, name of tester, and outcome of the test or observation will be recorded by the CQA Site Manager.

Vacuum Testing

Vacuum testing shall be performed utilizing the equipment and procedures specified in the Technical Specifications. The CQA Site Manager shall observe the vacuum testing procedures and document that they are performed in accordance with the *Technical Specifications*. The result of vacuum testing shall be recorded on the CQA seaming logs. Results shall include, at a minimum, the personnel performing the vacuum test and the result of the test (pass or fail), and the test date. Seams failing the vacuum test shall be repaired in accordance with the procedures listed in the *Technical Specifications*. The CQA Site Manager shall document seam repairs in the seaming logs.

Air Pressure Testing

Air channel pressure testing shall be performed on double-track seams created with a fusion welding device, utilizing the equipment and procedures specified in the *Technical Specifications*. The CQA Site Manager shall observe the air pressure testing procedures and document that they are performed in accordance with the *Technical Specifications*. The result of air channel pressure testing shall be recorded on the CQA seaming logs. Results shall include, at a minimum, personnel performing the air pressure test, the starting air pressure and time, the final air pressure and time, the drop in psi during the test, and the result of the test (pass or fail). Seams failing the air pressure test shall be repaired in accordance with the procedures listed in the *Technical Specifications*. The CQA Site Manager shall document seam repairs in the seaming logs.

10.4.4.9 Destructive Testing

Concept

Destructive seam testing will be performed on site and at the independent CQA laboratory in accordance with the *Construction Drawings* and the *Technical Specifications*. Destructive seam tests will be performed at selected locations. The purpose of these tests is to evaluate seam strength. Seam strength testing will be done as the seaming work progresses, not at the completion of all field seaming.

Location and Frequency

The CQA Site Manager will select locations where seam samples will be cut out for laboratory testing. Those locations will be established as follows.

- The frequency of geomembrane seam testing is a minimum of one destructive sample per 500 feet of weld. If after a total of 50 samples have been tested and no more than one sample has failed, the frequency can be increased to one per 1,000 feet.
- A minimum of one test per seaming machine over the duration of the project.
- Additional test locations may be selected during seaming at the CQA Site Manager's discretion. Selection of such locations may be prompted by suspicion of excess crystallinity, contamination, offset welds, or any other potential cause of imperfect welding.

The Geosynthetic Installer will not be informed in advance of the locations where the seam samples will be taken.

Sampling Procedure

Samples will be marked by the CQA Site Manager following the procedures listed in the *Technical Specifications*. Preliminary samples will be taken from either side of the marked sample and tested before obtaining the full sample per the requirements of the *Technical Specifications*. Samples shall be obtained by the Geosynthetic Installer. Samples shall be obtained as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material. The CQA Site Manager will:

- observe sample cutting and monitor that corners are rounded;
- assign a number to each sample, and mark it accordingly;
- record sample location on the Panel Layout Drawing; and
- record reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).

Holes in the geomembrane resulting from destructive seam sampling will be immediately repaired in accordance with repair procedures described in Section 10.4.5. The continuity of the new seams in the repaired area will be tested in accordance with Section 10.4.4.8.

Size and Distribution of Samples

The destructive sample will be 12 inches (0.3 meters) wide by 42 inches (1.1 meters) long with the seam centered lengthwise. The sample will be cut into three parts and distributed as follows:

- one portion, measuring 12 inches by 12 inches (30 centimeters (cm) by 30 cm), to the Geosynthetic Installer for field testing;
- one portion, measuring 12 inches by 18 inches (30 cm by 45 cm), for CQA Laboratory testing; and
- one portion, measuring 12 inches by 12 inches (30 cm by 30 cm), to the Construction Manager for archive storage.

Final evaluation of the destructive sample sizes and distribution will be made at the Pre-Construction Meeting.

Field Testing

Field testing will be performed by the Geosynthetic Installer using a gauged tensiometer. Prior to field testing the Geosynthetic Installer shall submit a calibration certificate for gauge tensiometer to the CQA Consultant for review. Calibration must have been performed within one year of use on the current project. The destructive sample shall be tested according to the requirements of the *Technical Specifications*. The specimens shall not fail in the seam and shall meet the strength requirements outlined in the *Technical Specifications*. If any field test specimen fails, then the procedures outlined in *Procedures for Destructive Test Failures* of this section will be followed.

The CQA Site Manager will witness field tests and mark samples and portions with their number. The CQA Site Manager will also document the date and time, ambient temperature, number of seaming unit, name of seamer, welding apparatus temperatures and pressures, and pass or fail description.

CQA Laboratory Testing

Destructive test samples will be packaged and shipped, if necessary, under the responsibility of the CQA Site Manager in a manner that will not damage the test sample. The Construction Manager will be responsible for storing the archive samples. This procedure will be outlined at the Pre-construction Meeting. Samples will be tested by the CQA Laboratory. The CQA Laboratory will be selected by the CQA Consultant with the concurrence of the Design Engineer.

Testing will include “Bonded Seam Strength” and “Peel Adhesion.” The minimum acceptable values to be obtained in these tests are given in the *Technical Specifications*. At least five specimens will be tested for each test method. Specimens will be selected alternately, by test, from the samples (i.e., peel, shear, peel, shear, and so on). A passing test will meet the minimum required values in at least four out of five specimens.

The CQA Laboratory will provide test results no more than 24 hours after they receive the samples. The CQA Consultant will review laboratory test results as soon as they become available, and make appropriate recommendations to the Construction Manager.

Geosynthetic Installer's Laboratory Testing

The Geosynthetic Installer's laboratory test results will be presented to the Construction Manager and the CQA Consultant for comments.

Procedures for Destructive Test Failure

The following procedures will apply whenever a sample fails a destructive test, whether that test conducted by the CQA Laboratory, the Geosynthetic Installer's laboratory, or by gauged tensiometer in the field. The Geosynthetic Installer has two options:

- The Geosynthetic Installer can reconstruct the seam between two passed test locations.
- The Geosynthetic Installer can trace the welding path to an intermediate location at 10 feet (3 meters) minimum from the point of the failed test in each direction and take a small sample for an additional field test at each location. If these additional samples pass the test, then full laboratory samples are taken. If these laboratory samples pass the tests, then the seam is reconstructed between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be reconstructed.

Acceptable seams must be bounded by two locations from which samples passing laboratory destructive tests have been taken. Repairs will be made in accordance with Section 10.4.5.

The CQA Site Manager will document actions taken in conjunction with destructive test failures.

10.4.5 Defects and Repairs

This section prescribes CQA activities to document that defects, tears, rips, punctures, damage, or failing seams shall be repaired.

10.4.5.1 Identification

Seams and non-seam areas of the geomembrane shall be examined by the CQA Site Manager for identification of defects, holes, blisters, undispersed raw materials and signs of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of examination.

10.4.5.2 Evaluation

Potentially flawed locations, both in seam and non-seam areas, shall be non-destructively tested using the methods described in Section 10.4.4.8 as appropriate. Each location that fails the nondestructive testing will be marked by the CQA Site Manager and repaired by the Geosynthetic Installer. Work will not proceed with any materials that will cover locations which have been repaired until laboratory test results with passing values are available.

10.4.5.3 Repair Procedures

Portions of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, will be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure will be at the discretion of the CQA Consultant with input from the Construction Manager and Geosynthetic Installer. The procedures available include:

- patching, used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter;
- grinding and re-welding, used to repair small sections of extruded seams;
- spot welding or seaming, used to repair small tears, pinholes, or other minor, localized flaws;
- capping, used to repair large lengths of failed seams; and
- removing a bad seam and replacing with a strip of new material welded into place (used with large lengths of fusion seams).

In addition, the following provisions will be satisfied:

- surfaces of the geomembrane which are to be repaired will be abraded no more than 20 minutes prior to the repair;
- surfaces must be clean and dry at the time of the repair;
- all seaming equipment used in repairing procedures must be approved;
- the repair procedures, materials, and techniques will be approved in advance by the CQA Consultant with input from the Design Engineer and Geosynthetic Installer;

- patches or caps will extend at least 6 inches (150 millimeters (mm)) beyond the edge of the defect, and all corners of patches will be rounded with a radius of at least 3 inches (75 mm);
- cuts and holes to be patched shall have rounded corners; and
- the geomembrane below large caps should be appropriately cut to avoid water or gas collection between the two sheets.

10.4.5.4 Verification of Repairs

The CQA Site Manager shall monitor and document repairs. Records of repairs shall be maintained on repair logs. Repair logs shall include, at a minimum:

- panel containing repair and approximate location on panel;
- approximate dimensions of repair;
- repair type, i.e. fusion weld or extrusion weld
- date of repair;
- seamer making the repair; and
- results of repair non-destructive testing (pass or fail).

Each repair will be non-destructively tested using the methods described herein, as appropriate. Repairs that pass the non-destructive test will be taken as an indication of an adequate repair. Large caps may be of sufficient extent to require destructive test sampling, per the requirements of the *Technical Specifications*. Failed tests shall be redone and re-tested until passing test results are observed.

10.4.5.5 Large Wrinkles

When seaming of the geomembrane is completed (or when seaming of a large area of the geomembrane liner is completed) and prior to placing overlying materials, the CQA Site Manager will observe the geomembrane wrinkles. The CQA Site Manager will indicate to the Geosynthetic Installer which wrinkles should be cut and re-seamed. The seam thus produced will be tested like any other seam.

10.4.6 Lining System Acceptance

The Geosynthetic Installer and the Manufacturer(s) will retain all responsibility for the geosynthetic materials in the liner system until acceptance by the Construction Manager.

The geosynthetic liner system will be accepted by the Construction Manager when:

- the installation is finished;
- verification of the adequacy of all seams and repairs, including associated testing, is complete;
- all documentation of installation is completed including the CQA Engineer's acceptance report and appropriate warranties; and
- CQA report, including "as built" drawing(s), sealed by a registered professional engineer has been received by the Construction Manager.

The CQA Site Manager will document that installation proceeded in accordance with the *Technical Specifications* for the project.

11. GEOTEXTILE

11.1 Introduction

This section of the CQA Plan outlines the CQA activities to be performed for the geotextile installation. The CQA Consultant will review the *Construction Drawings*, and the *Technical Specifications*, and any approved addenda or changes.

11.2 Manufacturing

The Manufacturer will provide the Construction Manager with a list of guaranteed "minimum average roll value" properties (defined as the mean less two standard deviations), for each type of geotextile to be delivered. The Manufacturer will also provide the Construction Manager with a written quality control certification signed by a responsible party employed by the Manufacturer that the materials actually delivered have property "minimum average roll values" which meet or exceed all property values guaranteed for that type of geotextile.

The quality control certificates will include:

- roll identification numbers; and
- results of MQC testing.

The Manufacturer will provide, as a minimum, test results for the following:

- mass per unit area;
- grab strength;
- tear strength;
- puncture strength;
- permittivity; and
- apparent opening size.

MQC tests shall be performed at the frequency listed in the *Technical Specifications*. CQA tests on geotextile produced for the project shall be performed according to the test methods specified and frequencies presented in Table 4.

The CQA Consultant will examine Manufacturer certifications to evaluate that the property values listed on the certifications meet or exceed those specified for the particular type of geotextile and the measurements of properties by the Manufacturer are properly documented, test methods acceptable and the certificates have been provided at the specified frequency properly identifying the rolls related to testing. Deviations will be reported to the Construction Manager.

11.3 Labeling

The Manufacturer will identify all rolls of geotextile with the following:

- manufacturer's name;
- product identification;
- lot number;
- roll number; and
- roll dimensions.

The CQA Site Manager will examine rolls upon delivery and deviation from the above requirements will be reported to the Construction Manager.

11.4 Shipment and Storage

During shipment and storage, the geotextile will be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions. To that effect, geotextile rolls will be shipped and stored in relatively opaque and watertight wrappings.

Protective wrappings will be removed less than one hour prior to unrolling the geotextile. After the wrapping has been removed, a nonwoven geotextile will not be exposed to sunlight for more than 15 days, except for UV protection geotextile, unless otherwise specified and guaranteed by the Manufacturer.

The CQA Site Manager will observe rolls upon delivery at the site and deviation from the above requirements will be reported to the Geosynthetic Installer.

11.5 Conformance Testing

11.5.1 Tests

The CQA Consultant will sample the geotextile either during production at the manufacturing facility or after delivery to the construction site. The samples will be forwarded to the Geosynthetics CQA Laboratory for testing to assess conformance with the *Technical Specifications*. The test methods and minimum testing frequencies are indicated in Table 4.

11.5.2 Sampling Procedures

Samples will be taken across the width of the roll and will not include the first 3 feet. Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Consultant will mark the machine direction on the samples with an arrow.

Unless otherwise specified, samples will be taken at a rate as indicated in Table 4 for geotextiles.

11.5.3 Test Results

The CQA Consultant will examine results from laboratory conformance testing and will report non-conformance with the *Technical Specifications* and this CQA Plan to the Construction Manager.

11.5.4 Conformance Sample Failure

The following procedure will apply whenever a sample fails a conformance test that is conducted by the CQA Laboratory:

- The Manufacturer will replace every roll of geotextile that is in nonconformance with the *Technical Specifications* with a roll(s) that meets *Technical Specifications*; or
- The Geosynthetic Installer will remove conformance samples for testing by the CQA Laboratory from the closest numerical rolls on both sides of the failed roll. These two samples must conform to the *Technical Specifications*. If either of these samples fail, the numerically closest rolls on the side of the failed sample will be tested by the CQA Laboratory. These samples must conform to the *Technical Specifications*. If any of these samples fail, every roll of geotextile on site from this lot and every subsequently delivered roll that is from the same lot must be tested by the CQA Laboratory for conformance to the *Technical Specifications*. This additional conformance testing will be at the expense of the Manufacturer.

The CQA Site Manager will document actions taken in conjunction with conformance test failures.

11.6 Handling and Placement

The Geosynthetic Installer will handle all geotextiles in such a manner as to document they are not damaged in any way, and the following will be complied with:

- In the presence of wind, all geotextiles will be weighted with sandbags or the equivalent. Such sandbags will be installed during placement and will remain until replaced with earth cover material.
- Geotextiles will be cut using an approved geotextile cutter only. If in place, special care must be taken to protect other materials from damage, which could be caused by the cutting of the geotextiles.
- The Geosynthetic Installer will take all necessary precautions to prevent damage to underlying layers during placement of the geotextile.
- During placement of geotextiles, care will be taken not to entrap in the geotextile stones, excessive dust, or moisture that could damage the geotextile, generate clogging of drains or filters, or hamper subsequent seaming.
- A visual examination of the geotextile will be carried out over the entire surface, after installation, to document that no potentially harmful foreign objects, such as needles, are present.

The CQA Site Manager will note non-compliance and report it to the Construction Manager.

11.7 Seams and Overlaps

Geotextiles will be continuously sewn. No horizontal seams will be allowed on side slopes (i.e. seams will be along, not across, the slope), except as part of a patch.

Seams will be sewn using polymeric thread with chemical and ultraviolet resistance properties equal to or exceeding those of the geotextile.

11.8 Repair

Holes or tears in the geotextile will be repaired as follows:

- On slopes: A patch made from the same geotextile will be double seamed into place. Should a tear exceed 10 percent of the width of the roll, that roll will be removed from the slope and replaced.
- Non-slopes: A patch made from the same geotextile will be spot-seamed in place with a minimum of 6 inches (0.60 meters) overlap in all directions.

Care will be taken to remove any soil or other material that may have penetrated the torn geotextile.

The CQA Site Manager will observe any repair, note any non-compliance with the above requirements and report them to the Construction Manager.

11.9 Placement of Soil or Aggregate Materials

The Contractor will place all soil or aggregate materials located on top of a geotextile, in such a manner as to document:

- no damage of the geotextile;
- minimal slippage of the geotextile on underlying layers; and
- no excess tensile stresses in the geotextile.

Non-compliance will be noted by the CQA Site Manager and reported to the Construction Manager.

12. GEOSYNTHETIC CLAY LINER (GCL)

12.1 Introduction

This section of the CQA Plan outlines the CQA activities to be performed for the GCL installation. The CQA Consultant will review the *Construction Drawings*, *Technical Specifications*, and approved addenda or changes.

12.2 Manufacturing

The Manufacturer will provide the Construction Manager with a list of guaranteed "minimum average roll value" properties (defined as the mean less two standard deviations), for the GCL to be delivered. The Manufacturer will also provide the Construction Manager with a written quality control certification signed by a responsible party employed by the Manufacturer that the materials actually delivered have property "minimum average roll values" which meet or exceed all property values guaranteed for that GCL.

The quality control certificates will include:

- roll identification numbers; and
- results of quality control testing.

The Manufacturer will provide, as a minimum, test results for the following:

- mass per unit area (bentonite content); and
- index flux.

Quality control tests must be performed, in accordance with the test methods specified in Table 5, on GCL produced for the project.

The CQA Consultant will examine Manufacturer certifications to verify that the property values listed on the certifications meet or exceed those specified for the GCL and the measurements of properties by the Manufacturer are properly documented, test methods acceptable and the certificates have been provided at the specified frequency properly identifying the rolls related to testing. Deviations will be reported to the Construction Manager.

12.3 Labeling

The Manufacturer will identify all rolls of GCL with the following:

- manufacturer's name;
- product identification;
- lot number;
- roll number; and
- roll dimensions.

The CQA Site Manager will examine rolls upon delivery and deviation from the above requirements will be reported to the Construction Manager.

12.4 Shipment and Storage

During shipment and storage, the GCL will be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, and cutting or any other damaging or deleterious conditions. To that effect, GCL rolls will be shipped and stored in relatively opaque and watertight wrappings.

The CQA Site Manager will observe rolls upon delivery at the site and any deviation from the above requirements will be reported to the Construction Manager.

12.5 Conformance Testing

12.5.1 Tests

The CQA Consultant will sample the GCL either during production at the manufacturing facility or after delivery to the construction site. The samples will be forwarded to the Geosynthetics CQA Laboratory for testing to assess conformance with the *Technical Specifications*. The test methods and minimum testing frequencies are indicated in Table 5.

Samples will be taken across the width of the roll and will not include the first 3 ft if the sample is cut on site. Unless otherwise specified, samples will be 3 ft long by the roll width. The CQA Consultant will mark the machine direction with an arrow and the manufacturer's roll number on each sample.

During GCL installation, the CQA Site Manager will deploy a small container to collect water as it is being applied to the surface of the GCL. The depth of water within the container will be measured and compared to the requirements outlined in the Technical Specifications. In addition, the CQA Site Manager will collect 6 inch square samples of the hydrated GCL for testing of moisture content. Samples will be collected once the overlying secondary geomembrane is in place and taken from within a destructive sample location. The test methods and minimum testing frequencies are indicated in Table 5.

The CQA Site Manager will examine results from laboratory conformance testing and will report non-conformance to the Construction Manager.

12.5.2 Conformance Sample Failure

The following procedure will apply whenever a sample fails a conformance test that is conducted by the CQA Laboratory:

- The Manufacturer will replace every roll of GCL that is in nonconformance with the *Technical Specifications* with a roll(s) that meets *Technical Specifications*; or
- The Geosynthetic Installer will remove conformance samples for testing by the CQA Laboratory from the closest numerical rolls on both sides of the failed roll. These two samples must conform to the *Technical Specifications*. If either of these samples fail, the numerically closest rolls on the side of the failed sample will be tested by the CQA Laboratory. These samples must conform to the *Technical Specifications*. If any of these samples fail, every roll of GCL on site from this lot and every subsequently delivered roll that is from the same lot must be tested by the CQA Laboratory for conformance to the *Technical Specifications*. This additional conformance testing will be at the expense of the Manufacturer.

The CQA Site Manager will document actions taken in conjunction with conformance test failures.

12.6 GCL Delivery and Storage

Upon delivery to the site, the CQA Site Manager will check the GCL rolls for defects (e.g., tears, holes) and for damage. The CQA Site Manager will report to the Construction Manager and the Geosynthetics Installer:

- any rolls, or portions thereof, which should be rejected and removed from the site because they have severe flaws; and
- any rolls which include minor repairable flaws.

The GCL rolls delivered to the site will be checked by the CQA Site Manager to document that the roll numbers correspond to those on the approved Manufacturer's quality control certificate of compliance.

12.6.1 Earthwork[2]

12.6.1.1 Surface Preparation

The CQA Site Manager will document that:

- the prepared subgrade meets the requirements of the *Technical Specifications* and has been approved; and
- placement of the overlying materials does not damage, create large wrinkles, or induce excessive tensile stress in any underlying geosynthetic materials.

The Geosynthetic Installer will certify in writing that the surface on which the geosynthetics will be installed is acceptable. The Certificate of Acceptance, as presented in the *Technical Specifications*, will be signed by the Geosynthetic Installer and given to the CQA Site Manager prior to commencement of geosynthetics installation in the area under consideration.

After the subgrade has been accepted by the Geosynthetic Installer, it will be the Geosynthetic Installer's responsibility to indicate to the Construction Manager any change in the subgrade soil condition that may require repair work. If the CQA Site Manager concurs with the Geosynthetic Installer, then the CQA Site Manager shall monitor and document that the subgrade soil is repaired before geosynthetic installation begins.

At any time before and during the geomembrane installation, the CQA Site Manager will indicate to the Construction Manager locations that may not provide adequate support to the geomembrane.

12.7 <u>GCL Installation</u>

[2] For Option A, geomembrane will be installed over subgrade and no GCL will be installed; for Option B, GCL will be installed over subgrade

The CQA Site Manager will monitor and document that the GCL is installed in accordance with the *Drawings* and the *Technical Specifications*. The Geosynthetics Installer shall provide the CQA Site Manager a certificate of subgrade acceptance prior to the installation of the GCL as outlined in the *Technical Specifications*. The GCL installation activities to be monitored and documented by the CQA Site Manager include:

- monitoring that the GCL rolls are stored and handled in a manner which does not result in any damage to the GCL;
- monitoring that the GCL is not exposed to UV radiation for extended periods of time without prior approval;
- monitoring that the GCL are seamed in accordance with the *Technical Specifications* and the Manufacturer's recommendations;
- monitoring and documenting that the GCL is installed on an approved subgrade, free of debris, protrusions, or uneven surfaces;
- monitoring that the subgrade surface is moist to within a minimum of 1 inch from the subgrade surface;
- monitoring that the GCL is hydrated prior to installation of the overlying geomembrane; and
- monitoring that any damage to the GCL is repaired as outlined in the *Technical Specifications*.

The CQA Site Manager will note non-compliance and report it to the Construction Manager.

13. GEONET

13.1 Introduction

This section of the CQA Plan outlines the CQA activities to be performed for the geonet installation. The CQA Consultant will review the *Construction Drawings*, *Technical Specifications*, and any approved addenda or changes.

13.2 Manufacturing

The Manufacturer will provide the CQA Consultant with a list of certified "minimum average roll value" properties for the type of geonet to be delivered. The Manufacturer will also provide the CQA Consultant with a written certification signed by a responsible representative of the Manufacturer that the geonet actually delivered have "minimum average roll values" properties which meet or exceed all certified property values for that type of geonet.

The CQA Consultant will examine the Manufacturers' certifications to document that the property values listed on the certifications meet or exceed those specified for the particular type of geonet. Deviations will be reported to the Construction Manager.

13.3 Labeling

The Manufacturer will identify all rolls of geonet with the following:

- Manufacturer's name;
- product identification;
- lot number;
- roll number; and
- roll dimensions.

The CQA Site Manager will examine rolls upon delivery and deviation from the above requirements will be reported to the Construction Manager.

13.4 Shipment and Storage

During shipment and storage, the geonet will be protected from mud, dirt, dust, puncture, cutting or any other damaging or deleterious conditions. The CQA Site Manager will observe rolls upon delivery to the site and deviation from the above requirements will be reported to the Construction Manager. Damaged rolls will be rejected and replaced.

The CQA Site Manager will observe that geonet is free of dirt and dust just before installation. The CQA Site Manager will report the outcome of this observation to the Construction Manager, and if the geonet is judged dirty or dusty, they will be cleaned by the Geosynthetic Installer prior to installation.

13.5 Conformance Testing

13.5.1 Tests

The geonet material will be tested for transmissivity (ASTM D 4716) and for thickness (ASTM D 5199) at the frequencies presented in Table 6.

13.5.2 Sampling Procedures

The CQA Consultant will sample the geonet either during production at the manufacturing facility or after delivery to the construction site. The samples will be forwarded to the Geosynthetics CQA Laboratory for testing to assess conformance with the *Technical Specifications*.

Samples will be taken across the width of the roll and will not include the first 3 linear feet. Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Consultant will mark the machine direction on the samples with an arrow.

13.5.3 Test Results

The CQA Consultant will examine results from laboratory conformance testing and compare results to the *Technical Specifications*. The criteria used to evaluate acceptability are presented in the *Technical Specifications*. The CQA Consultant will report any nonconformance to the Construction Manager.

13.5.4 Conformance Test Failure

The following procedure will apply whenever a sample fails a conformance test that is conducted by the CQA Laboratory:

- The Manufacturer will replace every roll of geonet that is in nonconformance with the *Technical Specifications* with a roll that meets specifications; or

- The Geosynthetic Installer will remove conformance samples for testing by the CQA Laboratory from the closest numerical rolls on both sides of the failed roll. These two samples must conform to the *Technical Specifications*. If either of these samples fail, the numerically closest rolls on the side of the failed sample that is not tested, will be tested by the CQA Laboratory. These samples must conform to the *Technical Specifications*. If any of these samples fail, every roll of geonet on site from this lot and every subsequently delivered roll that is from the same lot must be tested by the CQA Laboratory for conformance to the *Technical Specifications*.

The CQA Site Manager will document actions taken in conjunction with conformance test failures.

13.6 Handling and Placement

The Geosynthetic Installer will handle all geonet in such a manner as to document they are not damaged in any way. The Geosynthetic Installer will comply with the following:

- If in place, special care must be taken to protect other materials from damage, which could be caused by the cutting of the geonet.
- The Geosynthetic Installer will take any necessary precautions to prevent damage to underlying layers during placement of the geonet.
- During placement of geonet, care will be taken to prevent entrapment of dirt or excessive dust that could cause clogging of the drainage system, or stones that could damage the adjacent geomembrane. If dirt or excessive dust is entrapped in the geonet, it should be cleaned prior to placement of the next material on top of it. In this regard, care should be taken with the handling or sandbags, to prevent rupture or damage of the sandbag.
- A visual examination of the geonet will be carried out over the entire surface, after installation to document that no potentially harmful foreign objects are present.

The CQA Site Manager will note noncompliance and report it to the Construction Manager.

13.7 Geonet Seams and Overlaps

Adjacent geonet panels will be joined in accordance with *Construction Drawings* and *Technical Specifications*. As a minimum, the adjacent rolls will be overlapped by at least 4 inches and secured by tying, in accordance with the *Technical Specifications*.

The CQA Site Manager will note any noncompliance and report it to the Construction Manager.

13.8 Repair

Holes or tears in the geonet will be repaired by placing a patch extending 2 feet beyond edges of the hole or tear. The patch will be secured by tying with approved tying devices every 6 inches If the hole or tear width across the roll is more than 50 percent of the width of the roll, the damaged area will be cut out and the two portions of the geonet will be joined in accordance with Section 13.7.

The CQA Site Manager will observe repairs, note non-compliances with the above requirements and report them to the Construction Manager.

14. CONCRETE SPILLWAY

14.1 Introduction

This section prescribes the CQA activities to be performed to monitor that the concrete spillway is constructed in accordance with *Construction Drawings* and *Technical Specifications*. The concrete spillway construction procedures to be monitored by the CQA Site Manager, if required, shall include:

- subgrade preparation;
- liner system and cushion geotextile installation;
- welded wire reinforcement installation; and
- concrete placement and finishing.

14.2 CQA Monitoring Activities

14.2.1 Subgrade Preparation

The CQA Site Manager will monitor and document that the subgrade is prepared in accordance with the *Technical Specifications* and the *Construction Drawings*.

14.2.2 Liner System and Cushion Geotextile Installation

The CQA Site Manager shall monitor and document that the liner system components, along with the anchor trench and cushion geotextile, are installed in accordance with the requirements of the *Technical Specifications* and the *Construction Drawings*.

14.2.3 Welded Wire Reinforcement Installation

The CQA Site Manager shall monitor and document that the welded wire fabric reinforcement is installed in accordance with the requirements of the *Technical Specifications* and the *Construction Drawings*.

14.2.4 Concrete Installation

The CQA Site Manager shall test, monitor, and document that the concrete is installed in accordance with the requirements of the *Technical Specifications* and the *Construction Drawings*. At a minimum, the CQA Site Manager shall review the concrete tickets prior to installing the concrete to monitor that the concrete meets the requirements outlined in the *Technical Specifications*.

14.2.5 Conformance Testing

The Contractor shall facilitate the CQA Site Manager in the collection of samples required for testing. Compression test specimens shall be prepared by the CQA Site Manager by the following method:

- compression test cylinders from fresh concrete in accordance with ASTM C 172 and C 31.

Compression testing shall be completed on one cylinder at 7 days, one cylinder at 14 days, and two (2) cylinders at the 28 day strength. The CQA Consultant will examine results from laboratory conformance testing and will report any non-conformance with the requirements outlined in the *Technical Specifications* to the Construction Manager.

14.3 Deficiencies

If a defect is discovered in the concrete spillway, the CQA Site Manager will immediately determine the extent and nature of the defect. The CQA Site Manager will determine the extent of the defective area by additional observations, a review of records, or other means that the CQA Site Manager deems appropriate.

14.3.1 Notification

After evaluating the extent and nature of a defect, the CQA Site Manager will notify the Construction Manager and Contractor and schedule appropriate re-evaluation when the work deficiency is to be corrected.

14.3.2 Repairs

The Contractor will correct deficiencies to the satisfaction of the CQA Consultant. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the CQA Consultant will develop and present to the Construction Manager suggested solutions for his approval.

Re-evaluations by the CQA Site Manager shall continue until the defects have been corrected before any additional work is performed by the Contractor in the area of the deficiency.

15. SURVEYING

15.1 Survey Control

Survey control will be performed by the Surveyor as needed. A permanent benchmark will be established for the site(s) in a location convenient for daily tie--in. The vertical and horizontal control for this benchmark will be established within normal land surveying standards.

15.2 Precision and Accuracy

A wide variety of survey equipment is available for the surveying requirements for these projects. The survey instruments used for this work should be sufficiently precise and accurate to meet the needs of the projects.

15.3 Lines and Grades

The following structures will be surveyed to verify and document the lines and grades achieved during construction of the Project:

- geomembrane terminations; and
- centerlines of pipes.

15.4 Frequency and Spacing

A line of survey points no further than 100 feet apart must be taken at the top of pipes or other appurtenances to the liner.

15.5 Documentation

Field survey notes should be retained by the Land Surveyor. The findings from the field surveys should be documented on a set of Survey *Record Drawings*, which shall be provided to the Construction Manager in AutoCAD format or other suitable format as directed by the Construction Manager.

TABLE 1A

TEST PROCEDURES FOR THE EVALUATION OF EARTHWORK

TEST METHOD	DESCRIPTION	TEST STANDARD
Sieve Analysis	Particle Size Distribution	ASTM D 422
Modified Proctor	Moisture Density Relationship	ASTM D 1557

TABLE 1B

MINIMUM EARTHWORK TESTING FREQUENCIES

TEST	TEST METHOD	FILL
Sieve Analysis	ASTM D 422	1 per 20,000 CY or 1 per material type
Modified Proctor	ASTM D 1557	1 per 20,000 CY or 1 per material type
Nuclear Densometer – In-situ Moisture/Density	ASTM D 6938	1 per 500 yd^3

TABLE 2A

TEST PROCEDURES FOR THE EVALUATION OF AGGREGATE

TEST METHOD	DESCRIPTION	TEST STANDARD
Sieve Analysis	Particle Size Distribution of Fine and Coarse Aggregates	ASTM C 136
Hydraulic Conductivity (Rigid Wall Permeameter)	Permeability of Aggregates	ASTM D 2434
Insoluable Residue	Insoluable Residue in Carbonate Aggregates	ASTM D 3042

TABLE 2B

MINIMUM AGGREGATE TESTING FREQUENCIES FOR CONFORMANCE TESTING

TEST	TEST METHOD	DRAINAGE AGGREGATE
Sieve Analysis	ASTM C 136	1 per project
Hydraulic Conductivity	ASTM D 2434	1 per project
Insoluable Residue	Insoluable Residue in Carbonate Aggregates	1 per project

TABLE 3

GEOMEMBRANE CONFORMANCE TESTING REQUIREMENTS

TEST NAME	TEST METHOD	FREQUENCY[4]
Specific Gravity	ASTM D 792	200,000 ft^2
Thickness	ASTM D 5199 or ASTM D 5994	200,000 ft^2
Tensile Strength at Yield	ASTM D 6693	200,000 ft^2
Tensile Strength at Break	ASTM D 6693	200,000 ft^2
Elongation at Yield	ASTM D 6693	200,000 ft^2
Elongation at Break	ASTM D 6693	200,000 ft^2
Carbon Black Content	ASTM D 4218	200,000 ft^2
Carbon Black Dispersion	ASTM D 5596	200,000 ft^2
Interface Shear Strength[1,2,3]	ASTM D 5321	1 per project

Notes:
1. To be performed at normal stresses of 10, 20, and 40 psi between smooth geomembrane and Drain Liner™
2. To be performed at normal stresses of 10, 20, and 40 psi between smooth geomembrane and 300-mil geonet
3. To be performed at normal stresses of 100, 200, and 400 psf between textured geomembrane and nonwoven geotexile.
4. Frequency does not include material intended for splash pads.

TABLE 4

GEOTEXTILE CONFORMANCE TESTING REQUIREMENTS

TEST NAME	TEST METHOD	MINIMUM FREQUENCY
Mass per Unit Area	ASTM D 5261	1 test per 260,000 ft^2
Grab Strength	ASTM D 4632	1 test per 260,000 ft^2
Puncture Resistance	ASTM D 6241	1 test per 260,000 ft^2
Permittivity	ASTM D 4491	1 test per 260,000 ft^2
Apparent Opening Size	ASTM D 4751	1 test per 260,000 ft^2

Notes:
1. Nonwoven geotextile only.

TABLE 5

GCL CONFORMANCE TESTING REQUIREMENTS

TEST NAME	TEST METHOD	MINIMUM FREQUENCY
Mass per Unit Area	ASTM D 5993	1 test per 100,000 ft^2
Index Flux	ASTM D 5887	1 test per 400,000 ft^2
Bentonite Moisture Content – Post Field Hydration	ASTM D 2216	1 test per 4 secondary geomembrane destructive samples

Note: Hydraulic index flux testing shall be performed under an effective confining stress of 5 pounds per square inch.

TABLE 6

GEONET CONFORMANCE TESTING REQUIREMENTS

TEST NAME	TEST METHOD	MINIMUM FREQUENCY
Thickness	ASTM D 5199	1 test per 200,000 ft^2
Hydraulic Transmissivity	ASTM D 4716	1 test per 400,000 ft^2

Note: Transmissivity shall be measured using water at 68°F with a gradient of 0.1 under a confining pressure of 7,000 lb/ft^2. The geonet shall be placed in the testing device between 60-mil smooth geomembrane. Measurements are taken one hour after application of confining pressure.

APPENDIX C

Project Technical Specifications

Prepared for

Energy Fuels Resources (USA), Inc.
6425 S. Highway 191
P.O. Box 809
Blanding, UT 84511

TECHNICAL SPECIFICATIONS

CELLS 5A AND 5B

WHITE MESA MILL
BLANDING, UTAH

Prepared by

Geosyntec consultants

engineers | scientists | innovators

16644 West Bernardo Drive, Suite 301
San Diego, CA 92127

Project Number SC0634

June 2018

CERTIFICATION PAGE

TECHNICAL SPECIFICATIONS
CELLS 5A AND 5B CONSTRUCTION
ENERGY FUELS RESOURCES (USA), INC.
WHITE MESA MILL
BLANDING, UTAH

The Engineering material and data contained in these Technical Specifications were prepared under the supervision and direction of the undersigned, whose seal as a registered Professional Engineer is affixed below.

Gregory T. Corcoran, P.E.
Engineer of Record

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SECTION 01010

SUMMARY OF WORK

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Work consists of constructing Cells 5A and 5B under separate contracts and at separate times. Cell 5A will be constructed first, followed by Cell 5B in subsequent years. These Technical Specifications are to be used for both Projects.

B. The Work generally involves the excavation or soil and rock, placement and compaction of fill, preparation of subgrade, installation of geosynthetic liner system, and installation of associated piping and concrete.

C. These Technical Specifications consist of requirements related to both Option A – Triple Liner and Option B – Double Liner with Geosynthetic Clay Liner (GCL). Applicability of specifications, specifically GCL, is dependent on Option selected for construction. The Owner will direct the Contractor as to which liner system option will be constructed.

D. The Work will generally consist of:

1. Initial topographic survey;
2. Mass excavation and fill placement and compaction;
3. Subgrade preparation;
4. Anchor trench and leak detection system trench and sump excavation;
5. Installation of either (see Drawings, Option A or Option B for specific differences):
    a. Option A - 130-mil high density polyethylene (HDPE) tertiary Drain Liner™ geomembrane and textured 60-mil HDPE geomembrane in the sump side slope riser trench; or
    b. Option B - Geosynthetic clay liner (GCL).
6. Option A only - Installation of secondary leak detection system, cushion geotextile, drainage aggregate, and 4-inch and 18-inch polyvinyl chloride (PVC) pipe and fittings;
7. Installation of smooth 60-mil HDPE secondary geomembrane on the bottom of the Cell, 130-mil HDPE Drain Liner ™ geomembrane on the side slopes and 60-mil textured geomembrane on the sump side slope riser trench;
8. Installation of primary leak detection system, cushion geotextile, drainage aggregate, and 4-inch and 18-inch polyvinyl chloride (PVC) pipe and fittings;
9. Installation of 300-mil geonet on the bottom of the cell;
10. Installation of smooth 60-mil HDPE primary geomembrane and textured 60-mil HDPE geomembrane in the sump side slope riser trench;
11. Installation of 16 oz./SY nonwoven geotextile cushion;
12. Installation of slimes drain 4-inch and 18-inch PVC pipe and fittings;
13. Installation of drainage aggregate around slimes drain and within sump;
14. Installation of woven geotextile;

15. Installation of 60-mil HDPE geomembrane splash pads;
16. Backfill and compaction of anchor trenches;
17. Construction of concrete spillway and pipe support at the side slope riser termination; and
18. Installation of strip composite drainage layer, including sand bags.

1.02 CONTRACTOR'S RESPONSIBILITIES

A. Start, layout, construct, and complete the construction of the lining system (the Project) in accordance with the Technical Specifications, CQA Plan, and Drawings (Contract Documents).

B. Provide a competent site superintendent, capable of reading and understanding the Construction Documents, who shall receive instructions from the Construction Manager. Site superintendent shall have successfully completed projects of similar scope (excavation of soil and rock, fill placement and compaction, finish work to close tolerances to lines and grades, and geosynthetic liner installation).

C. Establish means, techniques, and procedures for constructing and otherwise executing the Work.

D. Establish and maintain proper Health and Safety practices for the duration of the Project.

E. Except as otherwise specified, furnish the following and pay the cost thereof:

1. Labor, superintendent, and products.
2. Construction supplies, equipment, tools, and machinery.
3. Electricity and other utilities required for construction.
4. Other facilities and services necessary to properly execute and complete the Work.
5. A Registered Land Surveyor, licensed in the State of Utah, to survey and layout the Work, and to certify as-built Record Drawings.

F. Pay cost of legally required sales, consumer, use taxes and governmental fees.

G. Perform Work in accordance with codes, ordinances, rules, regulations, orders, and other legal requirements of governmental bodies and public agencies bearing on performance of the Work.

H. Forward submittals and communications to the Construction Manager. Where applicable, the Construction Manager will coordinate submittals and communications with the representatives who will give approvals and directions through the Construction Manager.

I. Maintain order, safe practices, and proper conduct at all times among Contractor's employees. The Owner, and its authorized representative, may require that disciplinary action be taken against an employee of the Contractor for disorderly, improper, or unsafe conduct. Should an employee of the Contractor be dismissed from his duties for misconduct, incompetence, or unsafe practice, or combination thereof, that employee shall not be rehired for the duration of the Work.

J. Coordinate the Work with the utilities, private utilities, and/or other parties performing work on or adjacent to the Site. Eliminate or minimize delays in the Work and conflicts with those utilities or contractors. Coordinate activities with the Construction Manager. Schedule private utility and public utility work relying on survey points, lines, and grades established by the Contractor to occur immediately after those points, lines, and grades have been established.

K. Coordinate activities of the several trades, suppliers, and subcontractors, if any, performing the Work.

1.03 NOTIFICATION

A. The Contractor shall notify the Construction Manager in writing if he elects to subcontract, sublet, or reassign any portion of the Work. This shall be done at the time the bid is submitted. The written statement shall describe the portion of the Work to be performed by the Subcontractor and shall include an indication, by reference if desired by the Construction Manager, that the Subcontractor is particularly experienced and equipped to perform that portion of the Work. No portion of the Work shall be subcontracted, sublet, or reassigned without written permission of the Construction Manager. Consent to subcontract, sublet, or reassign any portion of the Work by the Construction Manager shall not be considered as a testimony of the Construction Manager as to the qualifications of the Subcontractor and shall not be construed to relieve the Contractor of any responsibilities for completion of the Work.

1.04 CONFORMANCE

A. Work shall conform to the Technical Specifications, Construction Quality Assurance (CQA) Plan, and Drawings that form a part of these Contract Documents.

B. Omissions from the Technical Specifications, CQA Plan, and Drawings or the misdescription of details of the Work which are necessary to carry out the intent of the Contract Documents, are customarily performed and shall not relieve the Contractor from performing such omitted or misdescribed details of the Work, but they shall be performed as if fully and correctly set forth and described in the Technical Specifications, CQA Plan, and Drawings.

1.05 DEFINITIONS

A. **OWNER** – The term Owner means Energy Fuels Resources (USA), Inc. for whom the Work is to be provided.

B. **CONSTRUCTION MANAGER** – The term Construction Manager means the firm responsible for project administration and project documentation control. All formal documents will be submitted to the Construction Manager for proper distribution and/or review. During the period of Work the Construction Manager will act as an authorized representative of the Owner.

C. **DESIGN ENGINEER** – The term Design Engineer means the firm responsible for the design and preparation of the Construction Documents. The Design Engineer is responsible for approving all design changes, modifications, or clarifications encountered during construction. The Design Engineer reports directly to the Owner.

D. **CQA CONSULTANT** – The term CQA Consultant refers to the firm responsible for CQA related monitoring and testing activities. The CQA Consultant's authorized personnel will include CQA Engineer-of-Record and CQA Site Manager. The CQA Consultant may also perform construction quality control (CQC) work as appropriate.

E. **CONTRACTOR** – The term Contractor means the firm that is responsible for the Work. The Contractor's responsibilities include the Work of any and all of the subcontractors and suppliers. The Contractor reports directly to the Construction Manager. All subcontractors report directly to the Contractor.

F. **SURVEYOR** – The term Surveyor means the firm that will perform the survey and provide as-built Record Drawings for the Work. The Surveyor shall be a Registered Land Surveyor, licensed to practice in the State of Utah. The Surveyor is employed by and reports directly to the Contractor.

G. **SITE** – The term Site refers to all approved staging areas, and all areas where the Work is to be performed, both public and private owned.

H. **WORK** – The term Work means the entire completed construction, or various separately identifiable parts thereof, required to be furnished under the Contract Documents. Work includes any and all labor, services, materials, equipment, tools, supplies, and facilities required by the Contract Documents and necessary for the completion of the project. Work is the result of performing services, furnishing labor, and furnishing and incorporating materials and equipment into the construction, all as required by the Contract Documents.

I. **DAY** – A calendar day on which weather and other conditions not under the control of the Contractor will permit construction operations to proceed for the major part of the day (greater than 4 hours) with the normal working force engaged in performing the controlling item or items of Work which would be in progress at that time.

J. **CONTRACT DOCUMENTS** – Contract Documents consist of the Technical Specifications, CQA Plan, and Drawings.

1.06 CONTRACT TIMES

A. The time stated for completion and substantial completion shall be in accordance with the Contract Times specified in the Agreement. No claims for damages shall be made by the Contractor for delays.

B. Contractor shall adhere to the schedule provided in the Contract. Unapproved extensions to the schedule will result in the Contractor paying liquidated damages in the amount of $4,000 per day to cover costs associated with Construction Management and construction oversight.

1.07 CONTRACTOR USE OF WORK SITE

A. Confine Site operations to areas permitted by law, ordinances, permits, and the Contract Documents. The Contractor shall ensure that all persons under his control (including Subcontractors and their workers and agents) are kept within the boundaries of the Site and shall be responsible for any acts of trespass or damage to property by persons who are under his control. Consider the safety of the Work, and that of people and property on and adjacent to work Site, when determining amount, location, movement, and use of materials and equipment on work Site.

B. The Contractor shall be responsible for protecting private and public property including pavements, drainage culverts, electricity, highway, telephone, and similar property and shall make good of, or pay for, all damage caused thereto. Control of erosion throughout the project is of prime importance and is the responsibility of the Contractor. The Contractor shall provide and maintain all necessary measures to control erosion during progress of the Work to the satisfaction of the Construction Manager and all applicable laws and regulations, and shall remove such measures and collected debris upon completion of the project. All provisions for erosion and sedimentation control apply equally to all areas of the Work.

C. The Contractor shall promptly notify the Construction Manager in writing of any subsurface or latent physical conditions at the Site that differ materially from those indicated or referred to in the Contract Documents. Construction Manager will promptly review those conditions and advise Owner in writing if further investigations or tests are necessary. If the Construction Manager finds that the results of such investigations or tests indicate that there are subsurface and latent physical conditions which differ materially from those intended in the Contract Documents, and which could not reasonably have been anticipated by Contractor, a Change Order shall be issued incorporating the necessary revisions.

D. At no time shall the Contractor interfere with operations of businesses on or in the vicinity of the Site. Should the Contractor need to work outside the regular working hours, the Contractor is required to submit a written request and obtain approval by the Construction Manager.

1.08 PRESERVATION OF SCIENTIFIC INFORMATION

A. Federal and State legislation provides for the protection, preservation, and collection of data having scientific, prehistoric, historical, or archaeological value (including relics and specimens) that might otherwise be lost due to alteration of the terrain as a result of any construction work. If evidence of such information is discovered during the course of the Work, the Contractor shall notify the Construction Manager immediately, giving the location and nature of the findings. Written confirmation shall be forwarded within two (2) working days.

B. The Contractor shall exercise care so as not to damage artifacts uncovered during excavation operations, and shall provide such cooperation and assistance as may be necessary to preserve the findings for removal or other disposition by the Construction Manager or Government agency.

C. Where appropriate, by reason of a discovery, the Construction Manager may order delays in the time of performance, or changes in the Work, or both. If such delays, or changes, or both, are ordered, the time of performance and contract price shall be adjusted in accordance with the applicable clauses of the Contract.

1.09 MEASUREMENT AND PAYMENT

A. Measurement for Work will be according to the work items listed in Section 01025 of these Specifications.

1.10 EXISTING UTILITIES

A. The Contractor shall be responsible for locating, uncovering, protecting, flagging, and identifying all existing utilities encountered while performing the Work. The Contractor shall request that Underground Service Alert (USA) locate and identify the existing utilities. The request shall be made 48 hours in advance.

B. Costs resulting from damage to utilities shall be borne by the Contractor. Costs of damage shall include repair and compensation for incidental costs resulting from the unscheduled loss of utility service to affected parties.

C. The Contractor shall immediately stop work and notify the Construction Manager of all utilities encountered and damaged. The Contractor shall also Survey the exact location of any utilities encountered during construction.

1.11 CONTRACTOR QUALIFICATIONS

A. The Contractor, and all subcontractors, shall be licensed at the time of bidding, and throughout the period of the Contract, by the State of Utah to do the type of work required under terms of these Contract Documents. By submitting a bid, the Contractor certifies that he is skilled, competent, and knowledgeable on the nature, extent and inherent conditions of the Work to be performed and has been regularly engaged in the general class and type of work called for in these Contract Documents and meets the qualifications required in these Specifications.

B. The Construction Manager shall disqualify a bidder that either cannot provide references, or if the references cannot substantiate the Contractor's qualifications.

C. By submission of a bid for this Project, the Contractor acknowledges that he is thoroughly familiar with the Site conditions.

D. Contractor shall provide a full-time, on-site superintendent that is qualified in this type of work. Site superintendent shall have successfully completed three projects of similar scope (excavation of soil and rock, fill placement and compaction, finish work to close tolerances to lines and grades, and geosynthetic liner installation).

1.12 INTERPRETATION OF TECHNICAL SPECIFICATIONS, CQA PLAN, AND DRAWINGS

A. Should it appear that the Work to be done or any matters relative thereto are not sufficiently detailed or explained in the Technical Specifications, CQA Plan, and/or Drawings, the Design Engineer will further explain or clarify, as may be necessary. In the event of any questions arising respecting the true meaning of the Contract Documents, the matter shall be referred to the Design Engineer, whose decision thereon shall be final.

1.13 HEALTH AND SAFETY

A. The Contractor shall be responsible for health and safety of its own crew, subcontractors, suppliers, and visitors. The Contractor shall adhere to the Contractor Safety Rules for the Site and all applicable Mine Safety and Health Administration (MSHA) rules.

1.14 GENERAL REQUIREMENTS

A. SURVEYING – The Surveyor shall be responsible for all surveying required to layout and control the Work. Surveying shall be conducted such that all applicable standards required by the State of Utah are met.

B. PERMITS – The Contractor shall be required to obtain permits in accordance with construction of the facility.

C. SEDIMENTATION, EROSION CONTROL, AND DEWATERING – Contractor shall comply with all laws, ordinances, and permits for controlling erosion, water pollution, and dust emissions resulting from construction activities; the Contractor shall be responsible for any fines imposed due to noncompliance. The Contractor shall perform work in accordance with the Storm Water Pollution Prevention Plan (SWPPP) provided by the Owner. The Contractor shall pump all water generated from dewatering into Cell 4A and 4B, as directed by the Construction Manager.

D. PROTECTION OF EXISTING SERVICES AND WELLS – The Contractor shall exercise care to avoid disturbing or damaging the existing monitor wells, settlement monuments, electrical poles and lines, permanent below-ground utilities, permanent drainage structures, and temporary utilities and structures. When the Work requires the Contractor to be near or to cross locations of known utilities, the Contractor shall carefully uncover, support, and protect these utilities and shall not cut, damage, or otherwise disturb them without prior authorization from the Construction Manager. All utilities or wells damaged by the Contractor shall be immediately repaired by the Contractor to the satisfaction of the Construction Manager at no additional cost.

E. BURNING – The use of open fires for any reason is prohibited.

F. TEMPORARY ROADS – The Contractor shall be responsible for constructing and maintaining all temporary roads and lay down areas that the Contractor may require in the execution of the Work.

G. CONSTRUCTION WATER – The Contractor shall obtain water from the Owner for construction and dust control. The Contractor shall not add substances (such as soap) to construction water.

H. COOPERATION – The Contractor shall cooperate with all other parties engaged in project-related activities to the greatest extent possible. Disputes or problems should be referred to the Construction Manager for resolution.

I. FAMILIARIZATION – The Contractor is responsible for becoming familiar with all aspects of the Work prior to performing the Work.

J. SAFEGUARDS – The Contractor shall provide and use all personnel safety equipment, barricades, guardrails, signs, lights, flares, and flagmen as required by MSHA, Occupational Safety and Health Administration (OSHA), state, or local codes and ordinances. No excavations deeper than 4 feet with side slopes steeper than 2:1 (horizontal:vertical) shall be made without the prior approval of the Design Engineer and the Construction Manager. When shoring is required, the design and inspection of such shoring shall be the Contractor's responsibility and shall be subject to the review of the Design Engineer and Construction Manager prior to use. No personnel shall work within or next to an excavation requiring shoring until such shoring has been installed, inspected, and approved by an engineer registered in the State of Utah. The Contractor shall be responsible for any fines imposed due to violation of any laws and regulations relating to the safety of the Contractor's personnel.

K. CLEAN-UP – The Contractor shall be responsible for general housekeeping during construction. Upon completion of the Work, the Contractor shall remove all of his equipment, facilities, construction materials, and trash. All disturbed surface areas shall be re-paved, re-vegetated, or otherwise put into the pre-existing condition before performing the Work, or a condition satisfactory to the Construction Manager.

L. SECURITY – The Contractor is responsible for the safety and condition of all of his tools and equipment.

M. ACCEPTANCE OF WORK – The Contractor shall retain ownership and responsibility for all Work until accepted by Construction Manager. Construction Manager will accept ownership and responsibility for the Work: (i) when all Work is completed; and (ii) after the Contractor has submitted all required documentation, including manufacturing quality control documentation and manufacturing certifications.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

NOT USED.

[END OF SECTION]

SECTION 01025

MEASUREMENT AND PAYMENT

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. This section covers measurement and payment criteria applicable to the Work performed under lump sum and unit price payment methods, and non-payment for rejected work.

1.02 RELATED SECTIONS

A. This section relates to all other sections of the contract.

1.03 AUTHORITY

A. Measurement methods delineated in the individual specification sections are intended to complement the criteria of this section. In the event of conflict, the requirements of the individual specification section shall govern.

B. A surveyor, licensed in the State of Utah, hired by the Contractor will take all measurements and compute quantities accordingly. All measurements, cross-sections, and quantities shall be stamped and certified by the licensed surveyor and submitted to the Construction Manager. The Construction Manager maintains the right to provide additional measurements and calculation of quantities to verify measurements and quantities submitted by the Contractor.

1.04 UNIT QUANTITIES SPECIFIED

A. Quantities and measurements indicated in the Bid Schedule are for bidding and contract purposes only. Quantities and measurements supplied or placed in the Work and verified by the Construction Manager shall determine payment. If the actual work requires more or fewer quantities than those quantities indicated, the Contractor shall provide the required quantities at the lump sum and unit prices contracted unless modified elsewhere in these Contract Documents.

B. Utah sales tax shall be included in each bid item as appropriate.

1.05 MEASUREMENT OF QUANTITIES

A. Measurement by Volume: Measurement shall be by the cubic dimension using mean lengths, widths, and heights or thickness, or by average end area method as measured by the surveyor. All measurement shall be the difference between the original ground surface and the design ("neat-line") dimensions and grades.

B. Measurement by Area: Measurement shall be by the square dimension using mean lengths and widths and/or radius as measured by the surveyor. All measurement shall be the difference between the original ground surface and the design ("neat-line") dimensions and grades.

C. Linear Measurement: Measurement shall be by the linear dimension, at the item centerline or mean chord. All measurement shall be the difference between the original ground surface and the design ("neat-line") dimensions and grades.

D. Stipulated Lump Sum Measurement: Items shall be measured as a percentage by weight, volume, area, or linear means or combination, as appropriate, of a completed item or unit of Work.

1.06 PAYMENT

A. Payment includes full compensation for all required labor, products, tools, equipment, transportation, services, and incidentals; erection, application, or installation of an item of the Work; and all overhead and profit. Final payment for Work governed by unit prices will be made on the basis of the actual measurements and quantities accepted by the Construction Manager multiplied by the unit price for Work which is incorporated in or made necessary by the Work.

B. A monthly progress payment schedule will be used to compensate the Contractor for the Work. The monthly amount to be paid to the Contractor is calculated as the percent of completed work for each bid item multiplied by the total anticipated work for that bid item minus a 10 percent retainer.

C. When the Contractor has completed all Work associated with completion of the project, the remaining 10 percent retainer of the contract amount will be paid to the Contractor after filing the Notice of Completion.

1.07 NON-PAYMENT FOR REJECTED PRODUCTS

A. Payment shall not be made for any of the following:

1. Products wasted or disposed of in a manner that is not acceptable.
2. Products determined as unacceptable before or after placement.
3. Products not completely unloaded from the transporting vehicle.
4. Products placed beyond the design lines, dimensions, grades, and levels of the required Work.
5. Products remaining on hand after completion of the Work.
6. Loading, hauling, and disposing of rejected Products.
7. Products rejected because of contamination (i.e. soil residues, fuel spills, solvents, etc.).

B. Excavation of loose soil and/or rock, caused by actions of the Contractor (e.g. overblasting), necessary to meet specifications for engineered fill placement.

1.08 BID ITEMS

A. The following bid items shall be used by the Owner and by the Contractor to bid the Work described in these bid documents.

BID ITEM	SECTION	DESCRIPTION	UNITS
1	01500	Construction Facilities	LS
2	01505	Mobilization / Demobilization	LS
3	02070	Well Abandonment	LS
4	02200	Soil Excavation	LS
5	02200	Rock Excavation	LS
6	02200	Engineered Fill	LS
7	02220	Subgrade Preparation	LS
8	02220	Anchor Trench	LF
9	02616	4-inch PVC Pipe and Fittings	LF
10	02616	18-inch PVC Pipe and Fittings	LF
11	02616	Strip Drain Composite	LF
12	02770	60-mil Smooth HDPE Geomembrane	SF
13	02770	60-mil Textured HDPE Geomembrane	SF
14	02770	130-mil HDPE Drain Liner™ Geomembrane	SF
15	02772	Geosynthetic Clay Liner	SF
16	02773	300-mil Geonet	SF
17	03400	Cast-In-Place Concrete	LS
18	01505	Performance Bond	LS

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

NOT USED.

[END OF SECTION]

SECTION 01300

SUBMITTALS

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. This section contains requirements for administrative and work-related submittals such as construction progress schedules, Shop Drawings, test results, operation and maintenance data, and other submittals required by Contract Documents.

B. Submit required materials to the Construction Manager for proper distribution and review in accordance with requirements of the Contract Documents**.**

1.02 CONSTRUCTION PROGRESS SCHEDULES

A. The Contractor shall prepare and submit two (2) copies of the baseline construction progress Schedule to the Construction Manager for review within five (5) days after the effective date of Contract.

B. Schedules shall be prepared in Microsoft Project/Primavera. The schedule shall include the following items.

1. A separate horizontal bar for each operation.
2. A horizontal time scale, which identifies the first workday of each week.
3. A scale with spacing to allow space for notations and future revisions.
4. Listings arranged in order of start for each item of the Work.

C. The Construction Progress Schedule for construction of the Work shall include the following items where applicable.

1. Submittals: dates for beginning and completion of each major element of construction and installation dates for major items. Elements shall include, but not be limited to, the following items which are applicable:

   a. Mobilization schedule.
   b. Demobilization schedule.
   c. Final site clean-up.
   d. Show projected percentage of completion for each item as of first day of each week.
   e. Show each individual Bid Item.

D. Schedule Revisions:

1. Bi-weekly to reflect changes in progress of Work.
2. Indicate progress of each activity at submittal date.
3. Show changes occurring since the previous schedule submittal. Changes shall include the following.

    a. Major changes in scope.
    b. Activities modified since previous submittal.
    c. Revised projections of progress and completion.
    d. Other identifiable changes.

4. Provide narrative report as needed to define:

    a. Problem areas, anticipated delays, and impact on schedule.
    b. Recommended corrective action and its effect.

1.03 CONSTRUCTION WORK SCHEDULE

A. The Contractor shall submit an updated 14-day work schedule at the beginning of each week by Monday morning at 8:00 a.m. The schedule shall address applicable line items from the construction project schedule with a refined level of detail for special activities.

1.04 SHOP DRAWINGS AND SAMPLES

A. Shop Drawings, product data, and samples shall be submitted as required in individual Sections of the Specifications.

B. The Contractor's Responsibilities:

1. Review Shop Drawings, product data, and samples prior to submittal.
2. Determine and verify:
    a. Field measurements.
    b. Field construction criteria.
    c. Catalog numbers and similar data.
    d. Conformance with Specifications.

3. Coordinate each submittal with requirements of the Work and Contract Documents.
4. Notify the Construction Manager in writing, at the time of the submittal, of deviations from requirements of Contract Documents.
5. Begin no fabrication or Work pertaining to required submittals until return of the submittals with appropriate approval.
6. Designate dates for submittal and receipt of reviewed Shop Drawings and samples in the construction progress schedule.

C. Submittals shall contain:

1. Date of submittal and dates of previous submittals.
2. Project title and number.
3. Contract identification.
4. Names of:
    a. The Contractor.
    b. Supplier.
    c. Manufacturer.
5. Summary of items contained in the submittal.
6. Identification of the product with identification numbers and the Drawing and Specification section numbers.
7. Clearly identified field dimensions.
8. Details required on the Drawings and in the Specifications.
9. Manufacturer, model number, dimensions, and clearances, where applicable.
10. Relation to adjacent or critical features of the Work or materials.
11. Applicable standards, such as ASTM or Federal Specification numbers.
12. Identification of deviations from Contract Documents.
13. Identification of revisions on re-submittals.
14. 8-inch by 3-inch blank space for the Contractor's and proper approval stamp.
15. The Contractor's stamp, signed, certifying review of the submittal, verification of the products, field measurements, field construction criteria, and coordination of information within the submittal with requirements of Work and Contract Documents.

D. Re-submittal Requirements:

1. Re-submittal is required when corrections or changes in submittals are required by the Construction Manager, Design Engineer, or CQA Consultant. Re-submittals are required until all comments by the Construction Manager, Design Engineer, or CQA Consultant is addressed and the submittal is approved.
2. Shop Drawings and Product Data:
    a. Revise initial drawings or data and resubmit as specified for initial submittal.
    b. Indicate changes made other than those requested by the Construction Manager, Design Engineer, or CQA Consultant.

E. Distribute reproductions of Shop Drawings and copies of product data which have been accepted by the Construction Manager to:

1. Job site file.
2. Record documents file.

F. Construction Manager's Duties:

1. Verify that review comments are technically correct and are consistent with technical and contractual requirements of the work.
2. Return submittals to the Contractor for distribution or re-submittal.

G. Design Engineer's Duties:

1. Review submittals promptly for compliance with contract documents and in accordance with the schedule.
2. Affix stamp and signature, and indicate either the requirements for re-submittal or no comments.
3. Return submittals to the Construction Manager.

H. CQA Consultant's Duties:

1. Review submittals promptly for compliance with contract documents and in accordance with the schedule.
2. Affix stamp and signature, and indicate either the requirements for re-submittal or no comments.
3. Return submittals to the Construction Manager.

1.05 TEST RESULTS AND CERTIFICATION

A. Results of tests conducted by the Contractor on materials or products shall be submitted for review.

B. Certification of products shall be submitted for review.

1.06 SUBMITTAL REQUIREMENTS

A. Provide complete copies of required submittals as follows.

1. Construction Work Schedule:

   a. Two copies of initial schedule (baseline schedule).
   b. Two copies of each revision.

2. Construction Progress Schedule:

   a. Two copies of initial schedule.
   b. Two copies of each revision.

3. Shop Drawings: Two copies.
4. Certification Test Results: Two copies.
5. Other Required Submittals:

   a. Two copies, if required, for review.
   b. Two copies, if required, for record.

B. Deliver the required copies of the submittals to the Construction Manager.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

NOT USED.

[END OF SECTION]

SECTION 01400

QUALITY CONTROL

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. Monitor quality control over suppliers, Manufacturers, products, services, Site conditions, and workmanship, to produce Work of specified quality.

B. Comply with Manufacturers' instructions, including each step in sequence.

C. Should Manufacturers' instructions conflict with Technical Specifications, request clarification from Design Engineer before proceeding.

D. Comply with specified standards as minimum quality for the Work except where more stringent tolerances, codes, or specified requirements indicate higher standards or more precise workmanship.

E. Perform Work by persons qualified to produce workmanship of specified quality.

1.02 TOLERANCES

A. Monitor tolerance control of installed products to produce acceptable Work. Do not permit tolerances to accumulate.

B. Comply with Manufacturers' tolerances. Should Manufacturers' tolerances conflict with Technical Specifications, request clarification from Design Engineer before proceeding.

C. Adjust products to appropriate dimensions; position before securing products in place.

1.03 REFERENCES

A. For products or workmanship specified by association, trade, or other consensus standards, complies with requirements of the standard, except when more rigid requirements are specified or are required by applicable codes.

B. Conform to reference standard by date of current issue on date of Notice to Proceed with construction, except where a specific date is established by code.

C. Obtain copies of standards where required by product Specification sections.

1.04 INSPECTING AND TESTING SERVICES

A. The CQA Consultant will perform construction quality assurance (CQA) inspections, tests, and other services specified in individual Sections of the Specification.

B. The Contractor shall cooperate with CQA Consultant; furnish samples of materials, design mix, equipment, tools, storage, safe access, and assistance by incidental labor as requested.

C. CQA testing or inspecting does not relieve Contractor, subcontractors, and suppliers from their requirements to perform quality control Work as indicated in the Technical Specifications.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

NOT USED.

[END OF SECTION]

SECTION 01500

CONSTRUCTION FACILITIES

PART 1 – GENERAL

1.01 SECTION INCLUDES

A. Construction facilities include furnishing of all equipment, materials, tools, accessories, incidentals, labor, and performing all work for the installation of equipment and for construction of facilities, including their maintenance, operation, and removal, if required, at the completion of the Work under the Contract.

1.02 DESCRIPTION OF WORK

A. Construction facilities include, but are not limited to, the following equipment, materials, facilities, areas, and services:

1. Parking Areas.
2. Temporary Roads.
3. Storage of Materials and Equipment.
4. Construction Equipment.
5. Temporary Sanitary Facilities.
6. Temporary Water.
7. First Aid Facilities.
8. Health and Safety.
9. Security.

B. Construct/install, maintain, and operate construction facilities in accordance with the applicable federal, state, and local laws, rules, and regulations, and the Contract Documents.

1.03 GENERAL REQUIREMENTS

A. Contractor is responsible for furnishing, installing, constructing, operating, maintaining, removing, and disposing of the construction facilities, as specified in this Section, and as required for the completion of the Work under the Contract.

B. Contractor shall maintain construction facilities in a clean, safe, and sanitary condition at all times until completion of the Work.

C. Contractor shall minimize land disturbances related to the construction facilities to the greatest extent possible and restore land, to the extent reasonable and practical, to its original contours by grading to provide positive drainage and by seeding the area to match with existing vegetation or as specified elsewhere.

1.04 TEMPORARY ROADS AND PARKING AREAS

A. Temporary roads and parking areas are existing roads that are improved or new roads constructed by Contractor for convenience of Contractor in the performance of the Work under the Contract.

B. Contractor shall coordinate construction with Construction Manager.

C. Construct and operate roads in accordance with all MSHA and other applicable standards.

D. If applicable, coordinate all road construction activities with local utilities, fire, and police departments.

E. Keep erosion to a minimum and maintain suitable grade and radii of curves to facilitate ease of movement of vehicles and equipment.

F. Furnish and install longitudinal and cross drainage facilities, including, but not limited to, ditches, structures, pipes and the like.

G. Clean equipment so that mud or dirt is not carried onto public roads. Clean up any mud or dirt transported by equipment on paved roads both on-site and off-site.

1.05 STORAGE OF MATERIALS AND EQUIPMENT

A. Make arrangements for material and equipment storage areas. Locations and configurations of approved facilities are subject to the acceptance of the Construction Manager.

B. Confine all operations, including storage of materials, to approved areas. Store materials in accordance with these Technical Specifications and the Construction Drawings.

C. Store construction materials and equipment within boundaries of designated areas. Storage of gasoline or similar fuels must conform to state and local regulations and be limited to the areas approved for this purpose by the Construction Manager.

1.06 CONSTRUCTION EQUIPMENT

A. Erect, equip, and maintain all construction equipment in accordance with all applicable statutes, laws, ordinances, rules, and regulations or other authority having jurisdiction.

B. Provide and maintain scaffolding, staging, hoists, barricades, and similar equipment required for performance of the Work. Provide hoists or similar equipment with operators and signals, as required.

C. Provide, maintain, and remove upon completion of the Work, all temporary rigging, scaffolding, hoisting equipment, debris boxes, barricades around openings and excavations, fences, ladders, and all other temporary work, as required for all Work hereunder.

D. Construction equipment and temporary work must conform to all the requirements of state, county, and local authorities, MSHA, and underwriters that pertain to operation, safety, and fire hazard. Furnish and install all items necessary for conformity with such requirements, whether or not called for under separate Sections of these Technical Specifications.

1.07 TEMPORARY SANITARY FACILITIES

A. Provide temporary sanitary facilities for use by all employees and persons engaged in the Work, including subcontractors, their employees and authorized visitors, and the Construction Manager.

B. Sanitary facilities include enclosed chemical toilets and washing facilities. These facilities must meet the requirements of local public health standards.

C. Locate sanitary facilities as approved by Construction Manager, and maintain in a sanitary condition during the entire course of the Work.

1.08 TEMPORARY WATER

A. Make all arrangements for water needs from the Owner.

B. Provide drinking water for all personnel at the site.

1.09 FIRST AID FACILITIES

A. Provide first aid equipment and supplies to serve all Contractor personnel at the Site.

1.10 HEALTH AND SAFETY

A. The Contractor shall submit a Site Health and Safety Plan for review a minimum of 7 days prior to mobilization.

B. Provide necessary monitoring equipment and personal protective equipment in accordance with Contractor prepared Site Health and Safety Plan.

1.11 SECURITY

A. Make all necessary provisions and be responsible for the security of the Work and the Site until final inspection and acceptance of the Work, unless otherwise directed by the Construction Manager.

1.12 SHUT-DOWN TIME OF SERVICE

A. Do not disconnect or shut down any part of the existing utilities and services, except by express written permission of Construction Manager.

1.13 MAINTENANCE

A. Maintain all construction facilities, utilities, temporary roads, and the like in good working condition as required by the Construction Manager during the term of the Work.

1.14 STATUS AT COMPLETION

A. Upon completion of the Work, or prior thereto, when so required by Construction Manager:

1. Repair damage to roads caused by or resulting from the Contractor's work or operations.
2. Remove and dispose of all construction facilities. Similarly, all areas utilized for temporary facilities shall be returned to near original, natural state, or as otherwise indicated or directed by the Construction Manager.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for Construction Facilities shall be lump sum (LS) and payment will be based on the unit price provided on the Bid Schedule.

B. The following are considered incidental to the Work:

1. Mobilization.
2. Temporary roadways and parking areas.
3. Temporary sanitary facilities.
4. Decontamination of equipment.
5. Security.
6. Demobilization.

[END OF SECTION]

SECTION 01505

MOBILIZATION / DEMOBILIZATION

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. Mobilization consists of preparatory work and operations, including but not limited to those necessary for the movement of personnel and project safety; including: adequate personnel, equipment necessary for full planned production to meet baseline schedule, supplies, and incidentals to the project Site; establishment of facilities necessary for work on the project; premiums on bond and insurance for the project and for other work and operations the Contractor must perform or costs the Contractor must incur before beginning work on the project, which are not covered in other bid items.

B. Demobilization consists of work and operations including, but not limited to, movement of personnel, equipment, supplies, and incidentals off-site.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section shall be lump sum (LS) and payment will be based on the unit price provided on the Bid Schedule.

B. The Contract Price for Mobilization/Demobilization shall include the provision for movement of equipment onto the job site; removal of all facilities and equipment at the completion of the project; permits; preparation of a Health and Safety Plan; all necessary safety measures; and all other related mobilization and demobilization costs. Price bid for mobilization shall not exceed 10 percent of the total bid for the Project. Fifty percent of the mobilization bid price, less retention, will be paid on the initial billing provided all equipment and temporary facilities are in place and bond fees paid. The remaining 50 percent of the mobilization bid price will be paid on satisfactory removal of all facilities and equipment on completion of the project.

[END OF SECTION]

SECTION 01560

TEMPORARY CONTROLS

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. Temporary Controls required during the term of the Contract for the protection of the environment and the health and safety of workers and general public.

B. Furnishing all equipment, materials, tools, accessories, incidentals, and labor, and performing all work for the installation of equipment and construction of facilities, including their maintenance and operation during the term of the Contract.

C. Temporary Controls include:

1. Dust Control.
2. Pollution Control.
3. Traffic and Safety Controls.

D. Perform Work as specified in the Technical Specifications and as required by the Construction Manager. Maintain equipment and accessories in clean, safe, and sanitary condition at all times until completion of the Work.

1.02 DUST CONTROL

A. Provide dust control measures in-accordance with the Technical Specifications. Dust control measures must meet requirements of applicable laws, codes, ordinances, and permits.

B. Dust control consists of transporting water, furnishing required equipment, testing of equipment, additives, accessories and incidentals, and carrying out proper and efficient measures wherever and as often as necessary to reduce dust nuisance, and to prevent dust originating from construction operations throughout the duration of the Work.

C. Owner shall provide water. Contractor shall provide overhead tank and use water source to fill overhead tank on a continuous basis (i.e., water supply shall not be operated on and off quickly).

1.03 POLLUTION CONTROL

A. Pollution of Waterways:

1. Perform Work using methods that prevent entrance or accidental spillage of solid or liquid matter, contaminants, debris, and other objectionable pollutants and wastes into watercourses, flowing or dry, and underground water sources.
2. Such pollutants and wastes will include, but will not be limited to, refuse, earth and earth products, garbage, cement, concrete, sewage effluent, industrial waste, hazardous chemicals, oil and other petroleum products, aggregate processing tailings, and mineral salts.

B. Dispose of pollutants and wastes in accordance with applicable permit provisions or in a manner acceptable to and approved by the Construction Manager.

C. Storage and Disposal of Petroleum Product:

1. Petroleum products covered by this Section include gasoline, diesel fuel, lubricants, and refined and used oil. During project construction, store all petroleum products in such a way as to prevent contamination of all ground and surface waters and in accordance with local, state, and federal regulations.

2. Lubricating oil may be brought into the project area in steel drums or other means, as the Contractor elects. Store used lubricating oil in steel drums, or other approved means, and return them to the supplier for disposal. Do not burn or otherwise dispose of at the Site.

3. Secondary containment shall be provided for products stored on site, in accordance with the Owner provided Storm Water Pollution Prevention Plan.

1.04 TRAFFIC AND SAFETY CONTROLS

A. Perform in accordance with MSHA and other applicable requirements.

B. Post construction areas and roads with traffic control signs or devices used for protection of workmen, the public, and equipment. Signs and devices must conform to the American National Standards Institute (ANSI) Manual on Uniform Traffic Control Devices for Streets and Highways.

C. Remove signs or traffic control devices after they have finished serving their purpose. It is particularly important to remove any markings on road surfaces that under conditions of poor visibility could cause a driver to turn off the road or into traffic moving in the opposite direction.

D. Provide flag persons, properly equipped with International Orange protective clothing and flags, as necessary, to direct or divert pedestrian or vehicular traffic. A full-time flag person shall be required for the duration of importation of fill.

E. Barricades for protection of employees must conform to the portions of the ANSI Manual on Uniform Traffic Control Devices for Streets and Highways, relating to barricades.

F. Guard and protect all workers, pedestrians, and the public from excavations, construction equipment, all obstructions, and other dangerous items or areas by means of adequate railings, guard rails, temporary walks, barricades, warning signs, sirens, directional signs, overhead protection, planking, decking, danger lights, etc.

G. Construct and maintain fences, planking, barricades, lights, shoring, and warning signs as required by local authorities and federal and state safety ordinances, and as required to protect all property from injury or loss and as necessary for the protection of the public, and provide walks around any obstructions made in a public place for carrying out the Work covered in this Contract. Leave all such protection in place and maintained until removal is authorized by the Construction Manager.

1.05 MAINTENANCE

A. Maintain all temporary controls in good working conditions during the term of the Contract for the safe and efficient transport of equipment and supplies, and for construction of permanent works.

1.06 STATUS AT COMPLETION

A. Upon completion of the Work, or prior thereto as approved by the Construction Manager, remove all temporary controls and restore disturbed areas.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

4.01 TEMPORARY CONTROLS

A. Temporary Controls: the measurement and payment of temporary controls shall be in accordance with and as a part of Mobilization/Demobilization, as outlined in Section 01505.

[END OF SECTION]

SECTION 01700

CONTRACT CLOSEOUT

PART 1 – GENERAL

1.01 CLOSEOUT PROCEDURES

A. Contractor shall submit written certification that the Technical Specifications, CQA Plan, and Drawings have been reviewed, Work has been inspected, and that Work is complete and in-accordance with the Technical Specifications, CQA Plan, and Drawings and ready for Owner's inspection.

1.02 FINAL CLEANING

A. Contractor shall execute final cleaning prior to final inspection.

B. Contractor shall clean equipment and fixtures to a sanitary condition.

C. Contractor shall remove waste and surplus materials, rubbish, and construction facilities from the construction Site.

1.03 PROJECT RECORD DOCUMENTS

A. Maintain on Site, one set of the following record documents and record actual revisions to the Work.

1. Drawings.
2. Specifications.
3. Addenda.
4. Change Orders and other Modifications to the Contract.
5. Reviewed Shop Drawings, product data, and samples.

B. Store Record Documents separate from documents used for construction.

C. Record information concurrent with construction progress.

D. Specifications: Legibly mark and record at each product Section a description of actual products installed, including the following:

1. Manufacturer's name and product model and number.
2. Product substitutions or alternates utilized.
3. Changes made by Addenda and Modifications.

E. Record Documents and Shop Drawings: Legibly mark each item to record actual construction including:

1. Measured horizontal and vertical location of underground utilities and appurtenances referenced to permanent surface features.
2. Measured locations of internal utilities and appurtenances concealed in construction, referenced to visible, accessible, and permanent features of the Work.
3. Field changes of dimension and detail.
4. Details not shown on original Construction Drawings.

F. Submit record documents to the Construction Manager.

PART 2 – PRODUCTS

NOT USED.

PART 3 – EXECUTION

NOT USED.

PART 4 – MEASUREMENT AND PAYMENT

4.01 CONTRACT CLOSEOUT

A. Contract Closeout: the measurement and payment of contract close out shall be in accordance with and as part of Mobilization/Demobilization, as outlined in Section 01505.

[END OF SECTION]

SECTION 02070

WELL ABANDONMENT

PART 1 — GENERAL

1.01 DESCRIPTION OF WORK

A. Supply all equipment, materials, and labor needed to abandon two (2) 3-inch diameter polyvinyl chloride (PVC) casing groundwater monitoring wells as specified herein and as indicated on the Drawings.

B. Well abandonment shall be accomplished under the direct supervision of a currently licensed water well driller who shall be responsible for verification of the procedures and materials used.

1.02 RELATED SECTIONS

Section 01025 – Measurement and Payment

Section 01300 – Submittals

Section 01400 – Quality Control

1.03 REFERENCES

A. Drawings.

B. Construction Quality Assurance (CQA) Plan

C. Latest version of the ASTM International (ASTM) standards:

ASTM C-150 Standard Specification for Portland Cement.

D. Latest version of the American Petroleum Institute (API) standards:

API - 13A Specification for Drilling-Fluid Materials

1.04 SUBMITTALS

A. The Contractor shall keep detailed drilling logs for all wells abandoned, including drilling procedures, total depth of abandonment, depth to groundwater (if applicable), final depth of boring, and well destruction details, including the depths of placement of all well abandonment materials. The Contractor shall provide a minimum of 7 days advance notice prior to beginning drilling and shall submit a list of the type and quantity of materials used for well abandonment.

B. The Contractor shall acquire all necessary permits and prepare and file a well abandonment report as required by the State of Utah, Division of Water Rights.

PART 2 — PRODUCTS

2.01 BENTONITE

A. Bentonite shall be Volclay (powdered sodium bentonite API-13A) or as otherwise approved by the Design Engineer.

2.02 WATER

A. Water used in the grout mixture shall be potable water or disinfected in accordance with R655-4-9.6.5 Utah Administrative Code (UAC).

2.03 CEMENT

A. Cement shall be Portland Type I (ASTM C-150).

PART 3 — EXECUTION

3.01 GENERAL

A. The Contractor is responsible for obtaining all permits for the abandonment of wells and shall be responsible for following all regulatory requirements as outlined in the Administrative Rules for Water Well Drillers R655-4 UAC.

B. The Contractor shall be responsible for reviewing the well construction boring log for the groundwater well to be abandoned. The original construction boring logs for the well to be abandoned are attached to the end of this Section, as Exhibit I.

3.02 DRILLING

A. The Contractor shall sound and record the total depth of the well casing, depth to groundwater (if encountered), and depth of the over boring.

B. Each well shall be over bored to a diameter 3 inches greater than the well casing diameter to a depth of 3 feet below the well bottom of casing. The exact depth of the wells shall be in accordance with the Contract Documents and as determined by the Design Engineer.

3.03 CEMENT-BENTONITE GROUT

A. A cement-bentonite grout shall be mixed for each well. The cement-bentonite grout shall have approximately 2% by weight bentonite (i.e. one 94-lbs sack of cement and two lbs. of bentonite) and be mixed with approximately 6.5 gallons of water. The cement-bentonite grout shall be mixed using a recirculating pump to form a homogeneous mixture free of lumps.

B. Immediately after removing all well materials and recording the over bored depth, the slurry shall be pressure grouted into the well borehole to 10 feet below final ground surface (bgs) (i.e. subgrade elevations for Cells 5A and 5B).

C. The uppermost 10 feet of the abandoned well shall consist of neat cement grout or sand cement grout.

D. The Contractor shall monitor the mass, volume, and level of cement-bentonite grout placed in each well borehole. These quantities shall be reported to the Construction Manager during the abandonment process.

E. The cement grout or sand cement grout shall be allowed to settle. Cement grout or sand cement grout shall be added, as necessary, until the elevation of the cured and settled cement grout or sand cement grout conforms to the surface topography at the time of abandonment.

PART 4 — MEASUREMENT AND PAYMENT

4.01 GENERAL

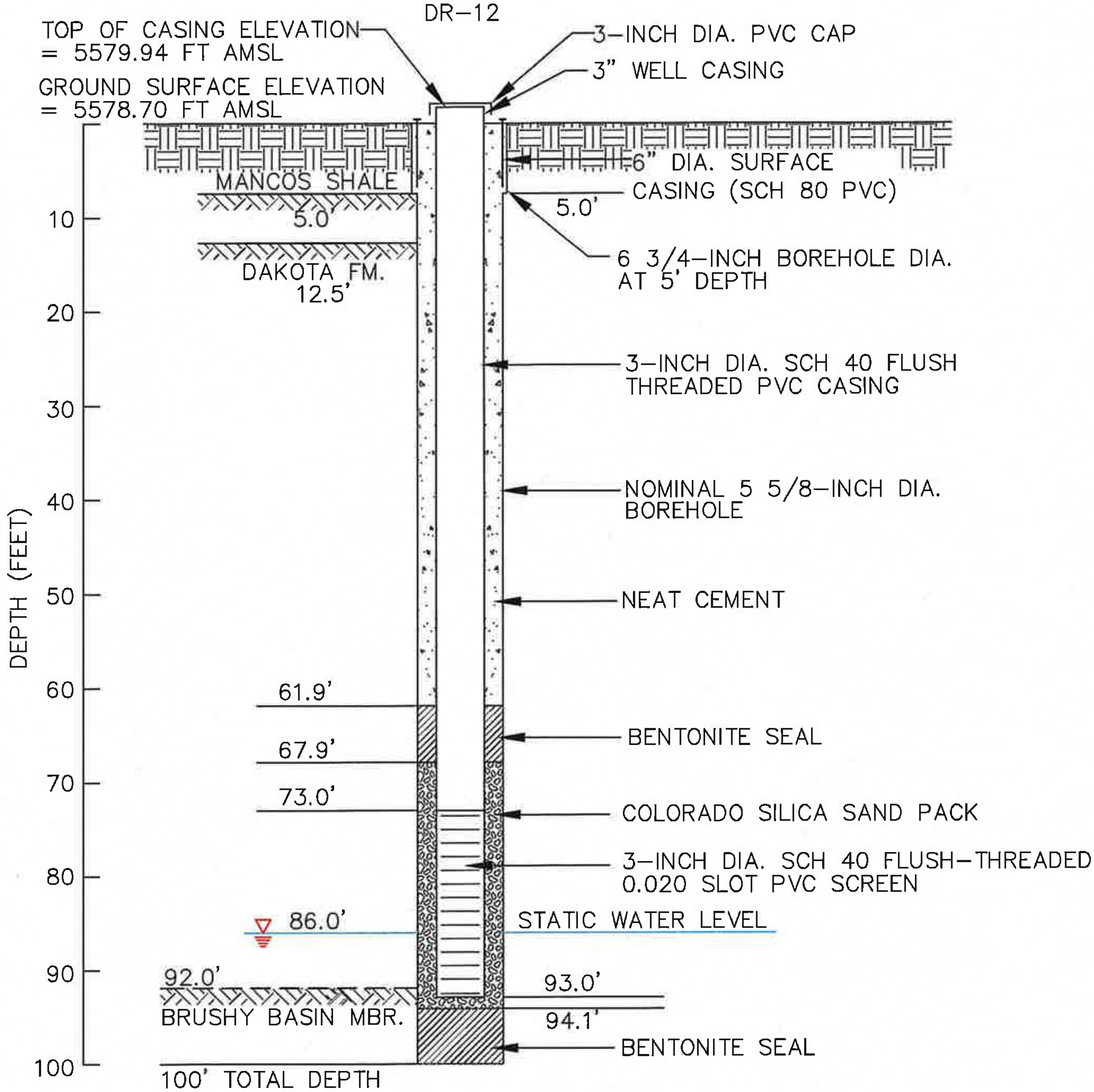
A. Providing for and complying with the requirements for well abandonment set forth in this Section will be measured as lump sum (LS); and payment will be based on the unit price provided on the Bid Schedule.

B. The following are considered incidental to the Work:

1. Submittals.
2. Bentonite.
3. Water.
4. Cement.
5. Well permits.
6. Mobilization.
7. Drilling.
8. Grading.
9. Decontamination of well abandonment equipment.
10. Disposal of decontamination materials.
11. Disposal of drill cuttings.

[END OF SECTION]

Well Completion Logs
DR-12 and DR-13



NOT TO SCALE

HYDRO GEO CHEM, INC.

DR-12
AS-BUILT WELL CONSTRUCTION SCHEMATIC

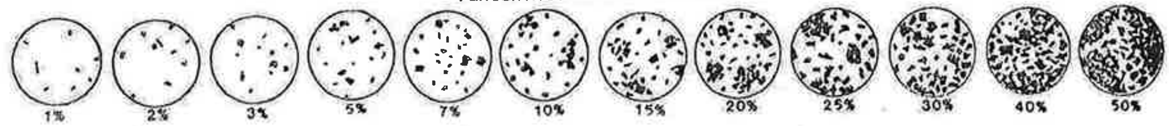
Approved	Date	Reference	Figure
SJS	1/9/12	K:\7180257A Well Construction Diagram	

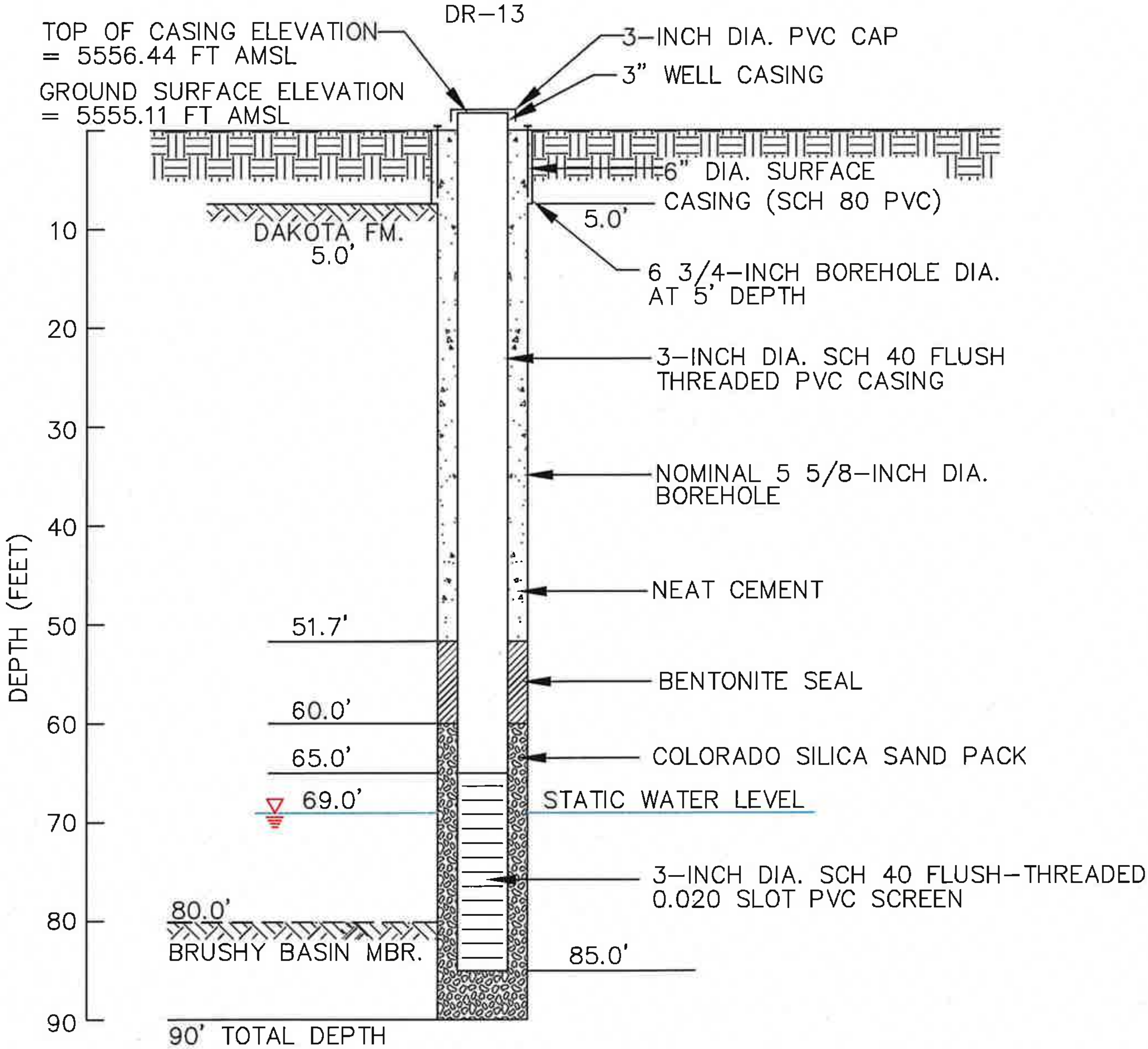
Date 28 APR 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. DR12
Property White Mesa Mill Project Cell 4B Unit No. ______ Sec. ______ Twp. ______ Rge. ______
County San Juan State Utah Location ______ Elev. ≈5584

PAGE 1 OF 1
T.D. PROBE ______
T.D. DRILL 100.0
FLUID LEVEL ______

Depth	Sample Taken	Graphic Log	Alteration	Gamma Anomaly	Breccia Pipe	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Cement Matrix	Iron Oxide	Pyrite Amount	Pyrite Habit	Pyrite Alter.	Metallic	Non-Metallic	React.-10% HCL	Carbon Amount	Carbon Type	Remarks
0																					
2.5						mdst	rd bn											W			Surface Soil unconsolidated fat clay w/sand CH
5.0						mdst	rd bn											VW			Surface Soil " " " " CH
7.5						sh	lt pk tn											VS			Manco: Shale Fm. consolidated. Lean clay w/ sand CL
10.0						sh	lt pk tn											VS			" "
12.5						sh	lt pk tn											S			" "
15.0						qtz ss, sh	lt bn	m	w	r		L						N			Upper Dakota Ct @ 12.5'
17.5						qtz ss	tn	m	w	r		L						N			
20.0						qtz ss	lt or-tn	m	w	r		L						N			
22.5						qtz ss	tn	m	w	a								N			
25.0						qtz ss	tn	m	w	a								N			
27.5						qtz ss	lt gy tn	m	w	r								N			some chert grains
30.0						qtz ss	tn	m-c	m	r								N			" " "
32.5						qtz ss	tn	m-c	m	r								N			
35.0						qtz ss	tn	m-c	m	r								N			
37.5						qtz ss	lt or tn	m	w	R		L						N			
40.0						qtz ss	tn	m	w	R								N			
42.5						qtz ss	tn	m-peb	f	a								N			some chert grains
45.0						qtz ss	lt bn	f-peb	p	a								N			" " "
47.5						qtz ss, sh, cgl	tn-gn	f-peb	p	a								N			" " "
50.0						qtz ss, sh, cgl	gn-tn	m-peb	p	A								N			" " "
52.5						qtz ss, sh	gn-tn	m-peb	p	a								N			abund. chert frags, grains
55.0						qtz ss	tn	m-peb	p	a		L						N			" " " "
57.5						qtz ss	tn	f-c	p	a		L						N			
60.0						qtz ss	tn	f-c	p	a								N			
62.5						qtz ss	lt gy tn	m	w	r								N			
65.0						qtz ss	lt gy tn	m	w	r								N			
67.5						qtz ss	lt gy tn	m	w	r								N			
70.0						qtz ss	tn	m	w	r								N			
72.5						qtz ss	lt gy tn	m	w	r								N			
75.0						qtz ss	lt bn	m	w	a								N			
77.5						qtz ss	lt gy tn	m	w	a								N			
80.0						qtz ss	tn	f-m	m	r								N			
82.5						qtz ss	tn	m	w	a								N			
85.0						qtz ss	tn	m-c	m	a			tr	C				N			
87.5						qtz ss, sh	gn-tn	f-c	m	a			tr	C				N			
90.0						qtz ss, sh	wh-lt gn	f-m	m	r			tr	C				N			
92.5						qtz ss, sh	wh-lt gn	f-m	m	r								N			Brushy Basin Ct @ 92.0 ft.
95.0						sh	gn, rd bn											N			
97.5						qtz ss, sh	wh-gn	f-m	m	R								N			
100.0						sh	gn-rd bn											N			T.D. Mottled Frags.
102.5																					
105.0																					
107.5																					
110.0																					
112.5																					
115.0																					
117.5																					
120.0																					
122.5																					
125.0																					

PERCENTAGE COMPOSITION IMAGE





NOT TO SCALE

HYDRO GEO CHEM, INC.	DR-13 AS-BUILT WELL CONSTRUCTION SCHEMATIC		
Approved SJS	Date 1/9/12	Reference K:\7180258A Well Construction Diagram	Figure

Changed P&A Ct from 82

Date 27 APR 2011 Geologist L. Casebolt Drilling Co. Bayles Exploration Co. Hole No. DR13

Property White Mesa Mill Project Cell 4B Unit No. ____ Sec. ____ Twp. ____ Rge. ____

County San Juan State Utah Location ____ Elev. 5575

PAGE 1 OF 1

T.D. PROBE ____

T.D. DRILL 90.0

FLUID LEVEL ____

Depth	Lithology	Color of Wet Sample	Grain Size	Sorting	Angularity	Iron Oxide	React.-10% HCl	Remarks
0–2.5	mdst	rdbn					W	Surface Soil. unconsolidated - lean clay w/sand CL
2.5–5.0	mdst	rdbn					S	surface Soil - unconsolidated - lean clay w/sand CL
5.0–7.5	qtz ss	ortn	m-peb	p	A		N	upper Dakota Ct @ 5.0' abund. chert frags, pebbles,
7.5–10.0	qtz ss, cgl	gyortn	m-peb	p	A		N	abundant chert frags + pebbles.
10.0–12.5	qtz ss	ortn	m-peb	p	r	L	N	" " " "
12.5–15.0	qtz ss, sh	ltgytn	m-peb	p	a		N	Some chert frag. + pebbles sandy fat clay CH
15.0–17.5	qtz ss, sh	ltgygntn	m-peb	p	a		N	" " " "
17.5–20.0	qtz ss, cgl	ltgytn-rd	m-peb	p	a		N	" " " "
20.0–22.5	qtz ss	lt tn	m-c	m	a		N	
22.5–25.0	qtz ss, sh	lt tn-ltgn	m-vc	f	a		N	
25.0–27.5	qtz ss, sh	lttn-ltgygn	m-peb	p	a		N	
27.5–30.0	qtz ss	tn	m	w	r		N	
30.0–32.5	qtz ss	tn	m	w	a		N	
32.5–35.0	qtz ss	lt bn	m-peb	p	a		N	
35.0–37.5	qtz ss, cgl	dk bn	m-peb	p	a		W	
37.5–40.0	qtz ss	tn	m	w	R		N	
40.0–42.5	qtz ss	tn	m-peb	p	r		N	
42.5–45.0	qtz ss	tn	f-peb	p	a		N	
45.0–47.5	qtz ss	tn	m	w	r		N	
47.5–50.0	qtz ss	tn	m	w	r		N	
50.0–52.5	qtz ss	vlttn	m	w	r		N	
52.5–55.0	qtz ss	vlttn	m	w	r		N	
55.0–57.5	qtz ss	lt tn	m	w	r		N	
57.5–60.0	qtz ss, cgl	gytn	m-peb	p	a	L	N	abund multi colored chert frags + grains
60.0–62.5	qtz ss, cgl	ltgytn	m-peb	p	a	L	N	" " " " " "
62.5–65.0	qtz ss	lt tn	m	w	r		VS	
65.0–67.5	sh, qtz ss	lt blgy	m-peb	p	a		VW	
67.5–70.0	qtz ss, sh	wh-blgy	vf-m	f	r		N	
70.0–72.5	qtz ss	wh-ltgy	f	w	r		N	
72.5–75.0	qtz ss	wh-ltgy	f	w	r		N	
75.0–77.5	qtz ss	wh-ltblgn	f	w	r		N	
77.5–80.0	qtz ss	wh-ltblgn	f	w	r		N	sparse chert pebble frags.
80.0–82.5	sh	gy-rdbn					N	Brushy Basin Fm Ct @ 80.0'
82.5–85.0	sh	blgy-rdbn					N	
85.0–87.5	sh	blgy-rdbn					N	
87.5–90.0	sh	pprdbn-gn					N	TD

PERCENTAGE COMPOSITION IMAGE

1% 2% 3% 5% 7% 10% 15% 20% 25% 30% 40% 50%

SECTION 02200

EARTHWORK

PART 1 — GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary to perform all Earthwork. The Work shall be carried out as specified herein and in accordance with the Drawings.

B. The Work shall include, but not be limited to excavating, blasting, ripping, trenching, hauling, placing, moisture conditioning, backfilling, compacting and grading. Earthwork shall conform to the dimensions, lines, grades, and sections shown on the Drawings or as directed by the Construction Manager.

1.02 RELATED SECTIONS

Section 02220 – Subgrade Preparation

1.03 REFERENCES

A. Drawings

B. Latest version of ASTM International (ASTM) standards:

ASTM D 422	Standard Method for Particle-Size Analysis of Soils
ASTM D 1557	Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lb-ft/ft^3 (2,700 kN-m/m^3))
ASTM D 6938	Standard Test Method for In-Place Density and Water Content of Soil-Aggregate by Nuclear Methods (Shallow Depth)

C. Results of seismic refraction survey for Cells 5A and 5B (Attached Herein).

1.04 QUALIFICATIONS

A. The Contractor's Site superintendent for the earthworks operations shall have supervised the construction of at least three earthwork construction projects, in accordance with Section 01010, Part 1.11.

1.05 SUBMITTALS

A. The Contractor shall submit to the Construction Manager a baseline survey to the limits of the work. The baseline survey shall be prepared by a Utah licensed professional land surveyor and shall form the basis for establishing pay quantities.

B. The Contractor shall submit to the Construction Manager a description of equipment and methods proposed for excavation, and fill placement and compaction construction at least 14 days prior to the start of activities covered by this Section.

C. If rock blasting is the chosen rock removal technique, the Contractor shall submit to the Construction Manager a blast plan describing blast methods to remove rock to proposed grade. The blast plan shall include a pre-blast survey, blast schedule, seismic monitoring records, blast design and diagrams, and blast safety. The Contractor shall submit the plan to the Construction Manager at least 21 days prior to blast.

D. If the Work of this Section is interrupted for reasons other than inclement weather, the Contractor shall notify the Construction Manager a minimum of 48 hours prior to the resumption of Work.

E. If foreign borrow materials are proposed to be used for any earthwork material on this project, the Contractor shall provide the Construction Manager information regarding the source of the material. In addition, the Contractor shall provide the Construction Manager an opportunity to obtain samples for conformance testing 14 days prior to delivery of foreign borrow materials to the Site. If conformance testing fails to meet these Specifications, the Contractor shall be responsible for reimbursing the Owner for additional conformance testing costs.

F. The Contractor shall submit as-built Record Drawing electronic files and data, to the Construction Manager, within 7 days of project substantial completion, in accordance with this Section.

1.06 QUALITY ASSURANCE

A. The Contractor shall ensure that the materials and methods used for Earthwork meet the requirements of the Drawings and this Section. Any material or method that does not conform to these documents, or to alternatives approved in writing by the Construction Manager will be rejected and shall be repaired, or removed and replaced, by the Contractor at no additional expense to the Owner.

B. The Contractor shall be aware of and accommodate all monitoring and field/laboratory conformance testing required by the Contract Documents. This monitoring and testing, including random conformance testing of construction materials and completed Work, will be performed by the CQA Consultant. If nonconformances or other deficiencies are found in the materials or completed Work, the Contractor will be required to repair the deficiency or replace the deficient materials at no additional cost to the Owner.

PART 2 — PRODUCTS

2.01 MATERIAL

A. Top soil material shall consist of the top 6 to 12 inches of existing grade.

B. All materials excavated not considered as rock, boulders, or detached pieces of solid rock less than 1 cubic yard in volume are classified as common excavation.

C. Engineered fill material shall consist of on-site soil obtained from excavation or owner provided stockpile and shall be free from rock larger than 6 inches, organic or other deleterious material.

D. Rock shall consist of all hard, compacted, or cemented materials that require blasting or the use of ripping and excavating equipment larger than defined for common excavation. The excavation and removal of isolated boulders or rock fragments larger than 1 cubic yard encountered in materials otherwise conforming to the definition of common excavation shall be classified as rock excavation. The presence of isolated boulders or rock fragments larger than 1 cubic yard is not in itself sufficient to cause to change the classification of the surrounding material.

E. Rippable Soil and Rock, common excavation: Material that can be ripped at more than 250 cubic yards per hour for each Caterpillar D9N dozer (or equivalent) with a single shank ripper attachment.

F. Loose material: Soil and rock material below finished grade elevations that was blasted or loosened by ripping or is naturally loose.

2.02 EQUIPMENT

A. The Contractor shall furnish, operate, and maintain compaction equipment as is necessary to produce the required in-place soil density and moisture content.

B. The Contractor shall furnish, operate and maintain tank trucks, pressure distributors, or other equipment designed to apply water uniformly and in controlled quantities.

C. The Contractor shall furnish, operate, and maintain miscellaneous equipment such as earth excavating equipment, earth hauling equipment, and other equipment, as necessary for Earthwork construction.

D. The Contractor shall be responsible for cleaning up all fuel, oil, or other spills, at the expense of the Contractor, and to the satisfaction of the Construction Manager.

PART 3 — EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the Work in this Section, the Contractor shall become thoroughly familiar with the Site, the Site conditions, and all portions of the Work falling within this and other related Sections.

B. Inspection:

1. The Contractor shall carefully inspect the installed Work of all other Sections and verify that all Work is complete to the point where the installation of the Work specified in this Section may properly commence without adverse impact.

2. If the Contractor has any concerns regarding the installed Work of other Sections, the Construction Manager shall be notified in writing prior to commencing Work. Failure to notify the Construction Manager, or commencement of the Work of this Section, will be construed as Contractor's acceptance of the related Work of all other Sections.

C. Existing soil and top of rock information is provided in the attached trench logs (Exhibit I). In addition, rock rippability data obtained during site seismic refraction surveys is attached.

3.02 SOIL EXCAVATION

A. The Contractor shall excavate materials to the limits and grades shown on the Drawings.

B. The Contractor shall excavate top soil (top 6 to 12 inches of existing ground) to the limits of the work and stockpile as directed by Construction Manager. During top soil removal, archeologist personnel employed by the Owner will monitor excavation for archeological artifacts and may stop excavation in a defined area to remove these artifacts.

C. The Contractor shall rip, blast, and/or mechanically remove rock 6-inches below final grades shown on the Drawings.

D. The Contractor shall excavate loose soil/rock below final grades shown on the Drawings until competent soil/rock surface is achieved to allow construction of engineered fill.

E. All excavated material not used as fill shall be stockpiled as shown on the Drawings and in accordance with Subpart 3.05 of this Section.

3.03 ROCK EXCAVATION

A. The Contractor shall remove rock by ripping, drilling, or blasting, or as approved by Construction Manager.

B. Requirements for Blasting:

1. The Contractor shall arrange for a pre-blast survey of nearby buildings, berms, or other structures that may potentially be at risk from blasting damage. The survey method used shall be acceptable to the Contractor's insurance company. The Contractor shall be responsible for any damage resulting from blasting. The preblast survey shall be made available for review three weeks before any blasting begins. Pre-blast surveys shall be completed by a practicing civil engineer registered in the State of Utah, who has experience in rock excavation and geotechnical design.

2. The Contractor shall submit for review the proposed methods and sequence of blasting for rock excavations. The Contractor shall identify the number, depth, and spacing of holes; stemming and number and type of delays; methods of controlling overbreak/overblasting at excavation limits, procedures for monitoring the shots and recording information for each shot; proposed depth of cover soil and overblasting; and other data that may be required to control the blasting.

3. Blasting shall be done in accordance with the federal, state, or local regulatory requirements for explosives and firing of blasts. Such regulations shall not relieve the Contractor of any responsibility for damages caused by them or their employees due to the work of blasting. All blasting work must be performed or supervised by a licensed blaster who shall at all times have a license on their person and shall permit examination thereof by the Construction Manager or other officials having jurisdiction.

4. The Contractor shall develop a trial blasting technique that identifies and limits the vibrations and damage at varying distances from each shot. This trial blasting information shall be collected and recorded by beginning the work at points farthest from areas to remain without damage. The Contractor can vary the hole spacing, depths and orientations, explosive types and quantities, blasting sequence, and delay patterns to obtain useful information to safeguard against damage at critical areas.

5. Establish appropriate maximum limit for peak particle velocity for each structure or facility that is adjacent to, or near blast sites. Base maximum limits on expected sensitivity of each structure or facility to blast induced vibrations and federal, state, or local regulatory requirements. In areas of blasting within 100 feet from the top of the existing berms, the blasting peak particle velocities (PPV) shall not exceed 2 inches per second.

6. The Contractor shall discontinue any method of blasting which leads to overshooting/overblasting or is dangerous to the berms surrounding the existing pond structures.

7. The Contractor shall have sufficient cover soil to provide safety and minimize fly rock while minimizing the quantity of fill material impacted with oversized rock and boulders.

8. The Contractor shall minimize overshooting/overblasting. All loose material shall be removed prior to placing engineered fill.

9. The Contractor shall install a blast warning sign to display warning signals. Sign shall indicate the following:

   a. Five (5) minutes before blast: Three (3) long sounds of airhorn or siren
   b. Immediately before blast: Three (3) short sounds of airhorn or siren
   c. All clear signal after blast: one (1) long sound of airhorn or siren

3.04 FILL

A. Prior to fill placement, areas to receive fill shall be cleared and grubbed and top soil shall be removed.

B. The fill material shall be placed to the lines and grades shown on the Drawings.

C. Soil used for fill shall meet the requirements of Subpart 2.01 of this Section.

D. Soil used for fill shall be placed in a loose lift that results in a compacted lift thickness of no greater 8 inches and compacted to 90% of the maximum density at a moisture content of between -3% and +3% of optimum moisture content, as determined by ASTM D 1557.

E. The Contractor shall utilize compaction equipment suitable and sufficient for achieving the soil compaction requirements.

F. During soil wetting or drying, the material shall be regularly disced or otherwise mixed so that uniform moisture conditions in the appropriate range are obtained.

3.05 STOCKPILING

A. Soil suitable for fill and excavated rock shall be stockpiled, separately, in areas as shown on the Drawings or as designated by the Construction Manager, and shall be free of incompatible soil, clearing debris, or other objectionable materials.

B. Separate soil stockpiles shall be constructed to contain topsoil, rock, sandy soil, and clayey soil.

C. Stockpiles shall be no steeper than 2H:1V (Horizontal:Vertical) or other slope approved by the Design Engineer, graded to drain, sealed by tracking parallel to the slope with a dozer or other means approved by the Construction Manager, and dressed daily during periods when fill is taken from the stockpile. The Contractor shall employ temporary erosion and sediment control measures (i.e. silt fence) as directed by the Construction Manager around stockpile areas.

D. There are no compaction requirements for stockpiled materials.

3.06 FIELD TESTING

A. The minimum frequency and details of quality control testing for Earthwork are provided below. This testing will be performed by the CQA Consultant. The Contractor shall take this testing frequency into account in planning the construction schedule.

1. The CQA Consultant will perform conformance tests on placed and compacted fill to evaluate compliance with these Specifications. The dry density and moisture content of the soil will be measured in-situ with a nuclear moisture-density gauge in accordance with ASTM D 6938. The frequency of testing will be one test per 500 cubic yards of soil placed.

2. A special testing frequency will be used by the CQA Consultant when visual observations of construction performance indicate a potential problem. Additional testing will be considered when:

   a. The rollers slip during rolling operation;
   b. The lift thickness is greater than specified;
   c. The fill is at improper and/or variable moisture content;
   d. Fewer than the specified number of roller passes are made;
   e. Dirt-clogged rollers are used to compact the material;
   f. The rollers do not have optimum ballast; or

g. The degree of compaction is doubtful.

3. During construction, the frequency of testing will be increased by the Construction Manager in the following situations:

   a. Adverse weather conditions;
   b. Breakdown of equipment;
   c. At the start and finish of grading;
   d. If the material fails to meet Specifications; or
   e. The work area is reduced.

B. Defective Areas:

1. If a defective area is discovered in the Earthwork, the CQA Consultant will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Consultant will determine the extent of the defective area by additional tests, observations, a review of records, or other means that the Construction Manager deems appropriate. If the defect is related to adverse Site conditions, such as overly wet soils or surface desiccation, the CQA Site Manager shall define the limits and nature of the defect.

2. Once the extent and nature of a defect is determined, the Contractor shall correct the deficiency to the satisfaction of the CQA Consultant. The Contractor shall not perform additional Work in the area until the Construction Manager approves the correction of the defect.

3. Additional testing may be performed by the CQA Consultant to verify that the defect has been corrected. This additional testing will be performed before any additional Work is allowed in the area of deficiency. The cost of the additional Work and the testing shall be borne by the Contractor.

3.07 SURVEY CONTROL

A. The Contractor shall perform all surveys necessary for construction layout and control.

3.08 CONSTRUCTION TOLERANCE

A. The Contractor shall perform the Earthwork construction to within ±0.1 vertical feet of elevations on the Drawings.

3.09 AS-BUILT SURVEY

A. For purposes of payment on Earthwork quantities, the Contractor shall conduct a comprehensive as-built survey that complies with this Section.

B. The Contractor shall produce complete electronic as-built Record Drawings in conformance with the requirements set forth in this Section. This electronic file shall be provided to the Construction Manager for verification. Surveys shall be submitted for existing topography, top of rock, base of excavation, and top of fill.

C. The Contractor shall produce an electronic boundary file that accurately conforms to the project site boundary depicted on the plans or as modified during construction by approved change order. The electronic file shall be provided to the Construction Manager for verification prior to use in any earthwork computations or map generation.

D. As-built survey data shall be collected throughout the project as indicated in these Specifications. This data shall be submitted in hard-copy and American Standard Code for Information Interchange (ASCII) format. ASCII format shall include: point number, northing and easting, elevations, and descriptions of point. The ASCII format shall be as follows:

1. PPPP,NNNNNN.NNN,EEEEEE.EEE,ELEV.XXX,Description

a. Where:

- P – point number
- N- Northing
- E – Easting
- ELEV.XXX – Elevation
- Description – description of the point

3.10 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect completed Work of this Section.

B. At the end of each day, the Contractor shall verify that the entire work area is left in a state that promotes drainage of surface water away from the area and from finished Work. If threatening weather conditions are forecast, soil surfaces shall be seal-rolled at a minimum to protect finished Work.

C. In the event of damage to Work, the Contractor shall make repairs and replacements to the satisfaction of the Construction Manager, at the expense of the Contractor.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. All earthwork quantities shall be independently verified by the Construction Manager prior to approval. The independent verification by the Construction Manager shall utilize the same basic procedures as those used by the Contractor.

B. Any interim or soon-to-be buried (or otherwise obstructed) earthwork shall be surveyed and quantified as the project progresses to enable timely verification by the Construction Manager.

C. Providing for and complying with the requirements set forth in this Section for Soil Excavation will be measured as lump sum (LS) and payment will be based on the unit price provided on the Bid Schedule.

D. Providing for and complying with the requirements set forth in this Section for Rock Excavation will be measured as lump sum (LS) and payment will be based on the unit price provided on the Bid Schedule.

E. Providing for and complying with the requirements set forth in this Section for Fill will be measured as lump sum (LS) and payment will be based on the unit price provided on the Bid Schedule.

F. The following are considered incidental to the work:

- Submittals.
- Quality Control.
- Material samples, sampling, and testing.
- Excavation.
- Blasting, ripping, and hammering.
- Loading, and hauling.
- Scarification.

- Screening.
- Layout survey.
- Rejected material removal, retesting, handling, and repair.
- Temporary haul roads.
- Erosion control.
- Dust control.
- Spill cleanup.
- Placement, compaction, and moisture conditioning.
- Stockpiling.
- Record survey.

[END OF SECTION]

TABLE 02200-1

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TABLE 02200-1
SUMMARY OF SEISMIC REFRACTION SURVEYS -
Cells 5A and 5B
Energy Fuels, White Mesa Mill
Blanding, Utah

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
SL-12-01-01F	N37.52603	W109.51611	Fwd S32E	5A	0 to 4 4 to 36 > 36	1287 to 1392 4944 to 5053 6195 to 7403	Rippable Rippable Rippable	
SL-12-01-01R	N37.52554	W109.51566	Rev N32W	5A	0 to 6 > 6	1312 to 2563 5358 to 6372	Rippable Rippable	
SL-12-02-01F	N37.52603	W109.51611	Fwd N32W	5A	0 to 4 4 to 14 > 14	1341 to 1408 3457 to 5578 6512 to 6802	Rippable Rippable Rippable	
SL-12-02-01R	N37.52647	W109.51649	Rev S32E	5A	0 to 8 8 to 12 >12	1571 to 2191 4245 to 5672 6538 to 7012	Rippable Rippable Rippable	
TP12-02	N37.52600	W109.51614	Fwd N30W	5A	-	-		0-5.25 FT Residual Soil 5.25-6.75 FT Weathered Sandstone 6.75 to 7.0 FT Dakota Sandstone
SL-12-03-01F	N37.52499	W109.51506	Fwd S30W	5A	0 to 5 5 to 21 >21	1482 to 1658 3866 to 4754 6087 to 6492	Rippable Rippable Rippable	
SL-12-03-01R	N37.52447	W109.51466	Rev N30E	5A	0 to 6 >6	1804 to 2078 4854 to 5966	Rippable Rippable	
TP12-04	N37.52507	W109.51506	Fwd N32W	5A	-	-		0-1.5 FT Residual Soil 1.5-7.5 FT Weathered Sandstone 7.5-8.0 FT Shale Layer 8.0 FT Dakota Sandstone
SL-12-04-01F	N37.52546	W109.51749	Fwd S75E	5A	0 to 4 4 to 25 >25	1059 to 1317 3264 to 4564 5918 to 6499	Rippable Rippable Rippable	
SL-12-04-01R	N37.52532	W109.51675	Rev N75W	5A	0 to 5 5 to 14 >14	1052 to 1681 2998 to 5299 5663 to 7907	Rippable Rippable Marginal	
TP12-01	N37.52546	W109.51749	Fwd S65E	5A	-	-		0-5 FT Residual Soil 5.0-6.75 FT Weathered Sandstone 6.75 to 7.0 FT Dakota Sandstone
SL-12-05-01F	N37.52384	W109.51791	Fwd N62E	5A	0 to 9 >9	1137 to 1691 6235 to 7003	Rippable Rippable	
SL-12-05-01R	N37.52416	W109.51729	Rev S62W	5A	0 to 7 >7	1684 to 1939 6281 to 8285	Rippable Marginal	
TP12-07	N37.52388	W109.51793	Fwd N20E	5A	-	-		0-7.0 FT Residual Soil 7.0-8.5 FT Weathered Sandstone 8.5-9.5 FT Dakota Sandstone
SL-12-06-01F	N37.52438	W109.51460	Fwd S30E	5A	0 to 3 3 to 46	2083 to 2347 4826 to 4905	Rippable Rippable	
SL-12-06-01R	N37.52388	W109.51418	Rev N30W	5A	0 to 4 >4	1489 to 2965 4955 to 6415	Rippable Rippable	
TP12-06	N37.52408	W109.51434	Fwd N30W	5A	-	-		0-2.0 FT Residual Soil 2.0-3.5 FT Weathered Sandstone 3.5 FT Dakota Sandstone
SL-12-07-01F	N37.52438	W109.51460	Fwd S30E	5A	0 to 4 4 to 19 > 19	1488 to 2035 4757 to 5046 6696	Rippable Rippable Rippable	
SL-12-07-01R	N37.52338	W109.51372	Rev N30W	5A	0 to 4 4 to 34 > 34	1308 to 2080 4899 to 5169 8444 to 8736	Rippable Rippable Marginal	

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TABLE 02200-1
SUMMARY OF SEISMIC REFRACTION SURVEYS - Cells 5A and 5B
Energy Fuels, White Mesa Mill
Blanding, Utah

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
TP12-09	N37.52294	W109.51320	Fwd N20E	5A/5B	-	-		0-5.5 FT Residual Soil 5.5-6.5 FT Weathered Sandstone 6.5-7.5 FT Dakota Sandstone
SL-12-08-01F	N37.52443	W109.51648	Fwd N62E	5A	0 to 5	1061 to 1283	Rippable	
					5 to 17	3354 to 4800	Rippable	
					> 17	6025	Rippable	
SL-12-08-01R	N37.52477	W109.51582	Rev S62W	5A	0 to 7	1521 to 1732	Rippable	
					> 7	4927 to 5849	Rippable	
TP12-05	N37.52443	W109.51621	Fwd N40E	5A	-	-		0-4.5 FT Residual Soil 4.5-6.5 FT Weathered Sandstone 6.5-7.5 FT Dakota Sandstone
TP12-08	N37.52326	W109.51534	Fwd N10W	5A	-	-		0-6.0 FT Residual Soil 6.0-7.5 FT Weathered Sandstone 7.5 FT Dakota Sandstone
SL-12-09-01F	N37.52544	W109.51392	Fwd N65E	5A	0 to 5	1211 to 2207	Rippable	
					>5	5570 to 6148	Rippable	
SL-12-09-01R	N37.52570	W109.51324	Rev S65W	5A	0 to 6	1269 to 1639	Rippable	
					6 to 17	4661 to 6630	Rippable	
					>17	7230 to 7274	Rippable	
TP12-03	N37.52559	W109.51355	Fwd S65W	5A	-	-		0-5.5 FT Residual Soil 5.5-7.0 FT Weathered Sandstone 7.0 FT Dakota Sandstone
TP12-10	N37.52464	W109.51260	Fwd N88W	5A/5B	-	-		0-4.5 FT Residual Soil 4.5-9.0 FT Weathered Sandstone 9.0-9.5 FT Dakota Sandstone
SL-12-10-01F	N37.524778	W109.50861	Fwd S68W	5B	0 to 6	1442 to 1904	Rippable	
					>6	5620 to 7611	Marginal	
SL-12-10-01R	N37.52452	W109.50928	Rev N68E	5B	0 to 4	1835 to 2395	Rippable	
					>4	6387 to 7509	Marginal	
TP12-12	N37.52479	W109.50859	Fwd S65W	5B	-	-		0-6.5 FT Residual Soil 6.5-7.5 FT Weathered Sandstone 7.5-8.0 FT Dakota Sandstone
SL-12-11-01F	N37.525045	W109.507928	Fwd N68E	5B	0 to 6	1157 to 1227	Rippable	
					>6	7036 to 7052	Rippable	
SL-12-11-01R	N37.524778	W109.50861	Rev S68W	5B	0 to 10	1411 to 1480	Rippable	
					>10	7343 to 8088	Marginal	
SL-12-12-01F	N37.52419	W109.51025	Fwd N70E	5B	0 to 4	1061 to 1488	Rippable	
					4 to 17	3331 to 4947	Rippable	
					> 17	8999 to 9761	Non-Rippable	
SL-12-12-01R	N37.52441	W109.50956	Rev S70W	5B	0 to 3	1672 to 1955	Rippable	
					3 to 18	4721 to 5496	Rippable	
					>18	6643 to 7372	Rippable	
TP12-13	N37.52419	W109.51025	Fwd S70W	5B	-	-	-	0-0.5 FT Residual Soil 0.5-1.0 FT Weathered Sandstone 1.0-2.0 FT Dakota Sandstone
SL-12-13-01F	N37.5249	W109.51025	Fwd S70W	5B	0 to 6	1349 to 3557	Rippable	
					>6	7286 to 9352	Non-Rippable	
SL-12-13-01R	N37.52389	W109.51102	Rev N70E	5B	0 to 5	1138 to 1248	Rippable	
					>5	6186 to 8977	Marginal	

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TABLE 02200-1
SUMMARY OF SEISMIC REFRACTION SURVEYS -
Cells 5A and 5B
Energy Fuels, White Mesa Mill
Blanding, Utah

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
SL-12-14-01F	N37.52330	W109.51234	Fwd N62E	5B	0 to 6	1098 to 1775	Rippable	
					6 to 28	6361 to 6041	Rippable	
					>28	8046 to 8964	Marginal	
SL-12-14-01R	N37.52361	W109.51167	Rev S62W	5B	0 to 6	1369 to 1419	Rippable	
					>6	7171 to 7762	Marginal	
TP12-15	N37.52361	W109.51167	Fwd S60W	5B	-	-		0-5.5 FT Residual Soil 5.5-6.0 FT Weathered Sandstone 6.5 FT Dakota Sandstone
TP12-17	N37.52253	W109.51065	Fwd N8E	5B	-	-	-	0-0.5 FT Residual Soil 0.5-2.0 FT Weathered Sandstone 2.0-3.5 FT Dakota Sandstone
SL-12-15-01F	N37.52542	W109.51112	Fwd S20E	5B	0 to 8	1478 to 3030	Rippable	
					>8	6346 to 7738	Marginal	
SL-12-15-01R	N37.52493	W109.51077	Rev S30E	5B	0 to 9	1305 to 1554	Rippable	
					9 to 16	3197 to 4279	Rippable	
					>16	7886 to 8107	Marginal	
TP12-11	N37.52512	W109.51098	Fwd N25W	5B	-	-		0-3.5 FT Residual Soil 3.5-11.0 FT Weathered Sandstone 11.0-12.0 FT Dakota Sandstone
TP12-19	N37.52550	W109.50965	Fwd N15W	5B	-	-		0-1.5 FT Residual Soil 1.5 FT Dakota Sandstone
SL-12-16-01F	N37.52330	W109.50919	Fwd N32W	5B	0 to 6	1388	Rippable	
					6 to 22	2951 to 5517	Rippable	
					>22	9648	Non-Rippable	
SL-12-16-01R	N37.52380	W109.50957	Rev S32E	5B	0 to 6	1215 to 1816	Rippable	
					>6	6435 to 6930	Rippable	
TP12-16	N37.52329	W109.50913	Fwd S40E	5B	-	-	-	0-0.5 FT Residual Soil 0.5-6.0 FT Weathered Sandstone 6.0-6.5 FT Dakota Sandstone
SL-12-17-01F	N37.52330	W109.50919	Fwd S32E	5B	0 to 4	1391 to 2336	Rippable	
					4 to 37	4801 to 4874	Rippable	
					>37	7554	Marginal	
SL-12-17-01R	N37.52280	W109.50872	Rev N32W	5B	0 to 5	1694 to 1730	Rippable	
					5 to 22	4762 to 5491	Rippable	
					>22	6479 to 6483	Rippable	
TP12-18	N37.52223	W109.50835	Fwd N30W	5B	-	-		0-4.5 FT Residual Soil 4.5-6.0 FT Weathered Sandstone 6.0-6.5 FT Dakota Sandstone
SL-12-18-01F	N37.52431	W109.50755	Fwd E-W	5B	0 to 5	1090 to 1379	Rippable	
					5 to 26	5202 to 6893	Rippable	
					>26	7491 to 10938	Non-Rippable	
SL-12-18-01R	N37.52430	W109.50829	Rev E-W	5B	0 to 4	1361 to 1420	Rippable	
					4 to 20	5110 to 5363	Rippable	
					>20	7861 to 11264	Non-Rippable	
TP12-14	N37.52431	W109.50749	Fwd S88W	5B	-	-	-	0-4.5 FT Residual Soil 4.5-7.5 FT Weathered Sandstone 7.5 FT Dakota Sandstone

Notes:
1 - Surveyed end point of refraction survey lines coordinates in Latitude/Longitude decimal degree World Geodetic System (WGS) 84. Data collected in field.
2 - Calculated depth of seismic refractor based on P-wave first arrival times using Snells Law.
3 - Excavatability assessment based on correlations between seismic wave velocities and rippability using a Single Shank No. 9 ripper on a D9N dozer (Caterpillar, 2006)
RS - Residual Soil
wxs - weathered sandstone
Kds - Cretaceous Dakota Sandstone

SECTION 02220

SUBGRADE PREPARATION

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary to perform all Subgrade Preparation. The Work shall be carried out as specified herein and in accordance with the Drawings and the Construction Quality Assurance (CQA) Plan.

B. The Work shall include, but not be limited to placement, moisture conditioning, compaction, and grading of subgrade soil and construction of geosynthetics anchor trench. Earthwork shall conform to the dimensions, lines, grades, and sections shown on the Drawings or as directed by the Design Engineer.

1.02 RELATED SECTIONS

Section 02200 – Earthwork

Section 02270 – Geomembrane

1.03 REFERENCES

A. Drawings

B. Site CQA Plan

C. Latest version of ASTM International (ASTM) standards:

ASTM D 422	Standard Method for Particle-Size Analysis of Soils
ASTM D 1557	Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lb_f/ft^3 (2,700 kN-m/m^3))
ASTM D 6938	Standard Test Method for In-Place Density and Water Content of Soil and Rock In-Place by Nuclear Methods (Shallow Depth)

1.04 QUALITY ASSURANCE

A. The Contractor shall ensure that the materials and methods used for subgrade preparation meet the requirements of the Drawings and this Section. Any material or method that does not conform to these documents, or to alternatives approved in writing by the Design Engineer will be rejected and shall be repaired, or removed and replaced, by the Contractor at no additional expense to the Owner.

PART 2 – PRODUCTS

2.01 SUBGRADE SOIL

A. Subgrade surface shall be free of protrusions larger than 0.7 inches. Any such observed particles shall be removed prior to placement of geosynthetics.

B. Subgrade surface shall be free of large desiccation cracks (ie, larger than ¼ inch) at the time of geosynthetics placement.

C. Subgrade soil shall consist of on-site soils that are free of particles greater than 3 inches in longest dimension, deleterious, organic, and/or other soil impacts that can damage the overlying liner system.

D. The subgrade surface shall be firm and unyielding, with no abrupt elevation changes, ice, or standing water.

E. The subgrade surface shall be smooth and free of vegetation, sharp-edged rock, stones, sticks, construction debris, and other foreign matter that could contact the geosynthetics.

F. At a minimum, the subgrade surface shall be rolled with a smooth-drum compactor of sufficient weight to remove any excessive wheel ruts greater than 1-inch or other abrupt grade changes.

2.02 ANCHOR TRENCH BACKFILL

A. Anchor trench backfill is the soil material that is placed in the anchor trench, as shown on the Drawings.

B. Where rocks are included in the anchor trench backfill, they shall be mixed with suitable excavated materials to eliminate voids.

C. Material removed during trench excavation may be utilized for anchor trench backfill, provided that all organic material, rubbish, debris, and other objectionable materials are first removed.

2.03 EQUIPMENT

A. The Contractor shall furnish, operate, and maintain grading and compaction equipment as is necessary to produce smooth surfaces for the placement of geosynthetics and acceptable in-place soil density in the anchor trenches.

B. The Contractor shall furnish, operate, and maintain tank trucks, pressure distributors, or other equipment designed to apply water uniformly and in controlled quantities for dust control and for moisture conditioning soils to be placed as trench backfill.

C. The Contractor shall be responsible for cleaning up all fuel, oil, or other spills, at the expense of the Contractor, and to the satisfaction of the Construction Manager.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work in this Section, the Contractor shall become thoroughly familiar with the Site, the Site conditions, and all portions of the work falling within this and other related Sections.

B. The Contractor shall provide for the protection of work installed in accordance with other Sections. In the event of damage to other work, the Contractor shall make repairs and replacements to the satisfaction of the Construction Manager, at the expense of the Contractor.

3.02 SUBGRADE SOIL SURFACE

A. The Contractor shall remove vegetation and roots to a minimum depth of 4-inches below ground surface in all areas where geosynthetic materials are to be installed.

B. Contractor shall grade subgrade soil to be uniform in slope, free from ruts, mounds, or depressions.

C. Prior to tertiary geomembrane (Option A) or GCL (Option B) installation, the subgrade surface shall be proof-rolled with appropriate compaction equipment to confirm subgrade stability.

3.03 TRENCH EXCAVATION

A. The Contractor shall excavate the anchor trench to the limits and grades shown on the Drawings.

B. Excavated anchor trench materials shall be returned as backfill for the anchor trench and compacted.

C. Material not suitable for anchor trench backfill shall be relocated as directed by the Construction Manager.

3.04 TRENCH BACKFILL

A. The anchor trench backfill shall be placed to the lines and grades shown on the Drawings.

B. Soil used for anchor trench backfill shall meet the requirements of Subpart 2.02 of this Section.

C. Soil used for anchor trench backfill shall be placed in loose lifts of no more than 12 inches and compacted to 90% of maximum dry density per ASTM D 1557. Backfill shall be within -3% to +3% of optimum moisture content. The maximum permissible pre-compaction soil clod size is 6 inches.

D. The Contractor shall compact each lift of anchor trench backfill to the satisfaction of the Construction Manager.

E. The Contractor shall utilize compaction equipment suitable and sufficient for achieving the soil compaction requirements.

F. During soil wetting or drying, the material shall be regularly disked or otherwise mixed so that uniform moisture conditions are obtained in the appropriate range.

3.05 SURVEY CONTROL

A. The Contractor shall perform all surveys necessary for construction layout and control.

B. The Contractor shall perform as-built surveys for all completed surfaces for purposes of Record Drawing preparation. At a minimum, survey points shall be obtained at grade breaks, top of slope, toe of slope, and limits of material type.

3.06 PROTECTION OF WORK

A. The Contractor shall protect completed work of this Section.

B. At the end of each day, the Contractor shall verify that the entire work area is left in a state that promotes drainage of surface water away from the area and from finished work.

C. In the event of damage to Work, the Contractor shall make repairs and replacements to the satisfaction of the Construction Manager, at the expense of the Contractor.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements for subgrade preparation will be measured as lump sum (LS) and payment will be based on the unit price as provided on the Bid Schedule.

B. Providing for and complying with the requirements for anchor trench excavation and backfill shall be measured on a lineal foot (LF) basis and payment will be based on the unit price as provided on the Bid Schedule.

C. The following are considered incidental to the work:

- Submittals.
- Quality Control.
- Material samples.
- Screening.
- Excavation, loading, and hauling.
- Temporary haul roads.
- Layout survey.
- Rejected material removal, testing, hauling, and repair.
- Erosion Control
- Dust control.
- Spill Clean-up
- Placement, compaction, and moisture conditioning.
- Stockpiling.
- Record survey.

[END OF SECTION]

SECTION 02225

DRAINAGE AGGREGATE

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary for the installation of Drainage Aggregate. The work shall be carried out as specified herein and in accordance with the Drawings and the site Construction Quality Assurance (CQA) Plan.

B. The work shall include, but not be limited to, delivery, offloading, storage, and placement of Drainage Aggregate (aggregate).

1.02 RELATED SECTIONS

Section 02616 – PVC Pipe

Section 02770 – Geomembrane

Section 02771 – Geotextile

Section 02773 – Geonet

1.03 REFERENCES

A. Drawings

B. Site Construction Quality Assurance (CQA) Plan

C. Latest Version of ASTM International (ASTM) Standards:

ASTM C 33	Standard Specification for Concrete Aggregates
ASTM C 136	Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM D 2434	Test Method for Permeability of Granular Soils (Constant Head)
ASTM D 3042	Standard Test Method for Insoluble Residue in Carbonate Aggregates

1.04 SUBMITTALS

A. The Contractor shall submit to the Construction Manager for approval, at least 7 days prior to the start of construction, Certificates of Compliance for proposed aggregate materials. Certificates of Compliance shall include, at a minimum, typical gradation, insoluable residue content, representative sample, and source of aggregate materials.

B. The Contractor shall submit to the Construction Manager a list of equipment and technical information for equipment proposed for use in placing the aggregate material in accordance with this Section.

1.05 CONSTRUCTION QUALITY ASSURANCE (CQA) MONITORING

A. The Contractor shall be aware of and accommodate all monitoring and field/laboratory conformance testing required by the CQA Plan. This monitoring and testing, including random conformance testing of construction materials and completed work, will be performed by the CQA Consultant. If nonconformances or other deficiencies are found in the materials or completed work, the Contractor will be required to repair the deficiency or replace the deficient materials.

PART 2 – PRODUCTS

2.01 MATERIALS

A. Aggregate shall meet the requirements specified in ASTM C 33 and shall not contain limestone. Aggregate shall have a minimum permeability of 1×10^{-1} cm/sec when tested in accordance with ASTM D 2434. The requirements of the Aggregate are presented below:

Maximum Particle Size	Percent Finer
1 - inch	100
¼ - inch	0 to 5
No. 200 Sieve	0 to 2

B. Carbonate loss shall be no greater than 10 percent by dry weight basis when tested in accordance with ASTM D 3042.

2.02 EQUIPMENT

A. The Contractor shall furnish, operate, and maintain hauling, placing, and grading equipment as necessary for aggregate placement.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work in this Section, the Contractor shall become thoroughly familiar with the site, the site conditions, and all portions of the work falling within this and other related Sections.

B. Inspection:

1. The Contractor shall carefully inspect the installed work of all other Sections and verify that all work is complete to the point where the installation of the work specified in this Section may properly commence without adverse impact.

2. If the Contractor has any concerns regarding the installed work of other Sections, the Construction Manager shall be notified in writing prior to commencing work. Failure to notify the Construction Manager or commencement of the work of this Section will be construed as Contractor's acceptance of the related work of all other Sections.

3.02 PLACEMENT

A. Place after underlying geosynthetic installation is complete, including construction quality control (CQC) and CQA work.

B. Place to the lines, grades, and dimensions shown on the Drawings.

C. The subgrade of the aggregate consists of a geotextile overlying a geomembrane. The Contractor shall avoid creating large wrinkles (greater than 6-inches high), tearing, puncturing, folding, or damaging in any way the geosynthetic materials during placement of the aggregate material.

D. Damage to the geosynthetic liner system caused by the Contractor or his representatives shall be repaired by the Geosynthetic Installer, at the expense of the Contractor.

E. No density or moisture requirements are specified for placement of the aggregate material.

3.03 FIELD TESTING

A. The minimum frequency and details of conformance testing are provided below. This testing will be performed by the CQA Consultant. The Contractor shall take this testing frequency into account in planning the construction schedule.

1. Aggregates conformance testing:

a. particle-size analyses conducted in accordance with ASTM C 136 at a frequency of one per source; and

b. permeability tests conducted in accordance with ASTM D 2434 at a frequency of one per source.

3.04 SURVEY CONTROL

A. The Contractor shall perform all surveys necessary for construction layout, control, and Record Drawings.

3.05 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all work of this Section.

B. In the event of damage, the Contractor shall make repairs and replacements to the satisfaction of the Construction Manager at no additional cost to the Owner.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for Drainage Aggregate will be incidental to the PVC pipe, and payment will be based on the unit price for PVC pipe provided on the Bid Schedule.

B. The following are considered incidental to the work:

- Submittals.
- Quality Control.
- Material samples, sampling, and testing.
- Excavation, loading, stockpiling, and hauling.
- Placing and grading.
- Layout survey.
- Rejected material.
- Rejected material removal, re-testing, handling, and repair.
- Mobilization.

[END OF SECTION]

SECTION 02616

POLYVINYL CHLORIDE (PVC) PIPE

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, and equipment necessary to install perforated and solid wall polyvinyl chloride (PVC) Schedule 40 pipe and fittings, as shown on the Drawings and in accordance with the Construction Quality Assurance (CQA) Plan.

1.02 RELATED SECTIONS

Section 02225 – Drainage Aggregate

Section 02270 – Geomembrane

Section 02771 – Geotextile

Section 02773 – Geonet

1.03 REFERENCES

A. Drawings.

B. Site CQA Plan.

C. Latest version of the ASTM International (ASTM) standards:

ASTM D 1784	Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and chlorinated Poly (Vinyl Chloride) (CPVC) Compounds.
ASTM D 1785	Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120.
ASTM D 2466	Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40.
ASTM D 2564	Standard Specification for Solvent Cements for Poly (Vinyl Chloride) (PVC) Plastic Pipe and Fittings.
ASTM D 2774	Practice for Underground Installation of Thermoplastic Pressure Piping.
ASTM D 2855	Standard Practice for Making Solvent-Cemented Joints with Poly (Vinyl Chloride) (PVC) Pipe and Fittings.
ASTM F 656	Standard Specification for Primers for Use in Solvent Cement Joints of Poly (Vinyl Chloride) (PVC) Plastic Pipe and Fittings.

1.04 SUBMITTALS

A. The Contractor shall submit to the Construction Manager for approval, at least 7 days prior to installation of this material, Certificates of Compliance for the pipe and fittings to be furnished. Certificates of Compliance shall consist of a properties sheet, including specified properties measured using test methods indicated herein.

B. The Contractor shall submit to the Construction Manager, Record Drawings of the installed piping at a frequency of not less than once per every 100 feet of installed pipe and strip composite. Record Drawings shall be submitted within 7 days of completion of the record survey.

1.05 CQA MONITORING

A. The Contractor shall ensure that the materials and methods used for PVC pipe and fittings installation meet the requirements of the Drawings and this Section. Any material or method that does not conform to these documents, or to alternatives approved in writing by the Construction Manager, will be rejected and shall be repaired or replaced by the Contractor at no additional cost to the Owner.

PART 2 – MATERIALS

2.01 PVC PIPE & FITTINGS

A. PVC pipe and fittings shall be manufactured from a PVC compound which meets the requirements of Cell Classification 12454 polyvinyl chloride as outlined in ASTM D 1784.

B. PVC pipe shall meet the requirements of ASTM D 1784 and ASTM D 1785 for Schedule 40 PVC pipe.

C. PVC fittings shall meet the requirements of ASTM D 2466.

D. Clean rework or recycle material generated by the Manufacturer's own production may be used so long as the pipe or fittings produced meet all the requirements of this Section.

E. Pipe and fittings shall be homogenous throughout and free of visible cracks, holes, foreign inclusions, or other injurious defects, being uniform in color, capacity, density, and other physical properties.

F. PVC pipe and fitting primer shall meet the requirements of ASTM F 656 and solvent cements shall meet the requirements of ASTM D 2564.

2.02 PVC PERFORATED PIPE

A. Perforated pipe shall meet the requirements listed above for solid wall pipe, unless otherwise approved by the Design Engineer. PVC pipe perforations shall be as shown on the Drawings.

2.03 STRIP COMPOSITE

A. Strip composite shall be comprised of high density polyethylene core Multi-Flow Drainage Systems 12-inch product, or Design Engineer approved equal. Consideration for equality will involve chemical resistance, compressive strength, and flow capacity. Strip composite shall be installed as shown on the Drawings.

B. Sand bags used to continuously cover the strip composite shall be comprised of woven geotextile capable of allowing liquids to pass and shall have a minimum length of 18-inches.

C. Sand bags shall contain Utah Department of Transportation (UDOT) concrete sand having a carbonate loss of no greater than 10 percent by dry weight basis when tested in accordance with ASTM D 3042 and meeting the following gradation.

Sieve Size	Percent Passing
3/8 inch	100%
No. 4	95% to 100%
No. 16	45% to 80%
No. 50	10% to 30%
No. 100	2% to 10%

D. Contractor shall monitor that sand bags shall not be overfilled to the extent that the underlying strip composite is visible.

E. In lieu of sand bag replacement if underlying strip composite is visible, additional sand bags may be placed parallel and adjacent to strip composite and overlying sandbags such that visible portions of the strip composite are covered.

F. In lieu of sandbags, Contractor may elect to install woven geotextile strips, partially covered with UDOT concrete sand, overlying the strip of composite. Woven geotextile shall be folded over the top of the sand and sewn to complete a geotextile wrap of the sand as shown on the Drawings.

PART 3 – PART 3 EXECUTION

3.01 PVC PIPE HANDLING

A. When shipping, delivering, and installing pipe, fittings, and accessories, do so to ensure a sound, undamaged installation. Provide adequate storage for all materials and equipment delivered to the site. PVC pipe and pipe fittings shall be handled carefully in loading and unloading so as not to damage the pipe, fittings, or underlying materials.

3.02 PVC PIPE INSTALLATION

A. PVC pipe installation shall conform to these Specifications, the Manufacturer's recommendations, and as outlined in ASTM D 2774.

B. PVC perforated and solid wall pipe shall be installed as shown on the Drawings.

C. PVC pipe shall be inspected for cuts, scratches, or other damages prior to installation. Any pipe showing damage, which in the opinion of the CQA Consultant will affect performance of the pipe, must be removed from the site. Contractor shall replace any material found to be defective at no additional cost to the Owner.

3.03 JOINING OF PVC PIPES

A. PVC pipe and fittings shall be joined by primer and solvent-cements per ASTM D 2855.

B. All loose dirt and moisture shall be wiped from the interior and exterior of the pipe end and the interior of fittings.

C. All pipe cuts shall be square and perpendicular to the centerline of the pipe. All burrs, chips, etc., from pipe cutting shall be removed from pipe interior and exterior.

D. Pipe and fittings shall be selected so that there will be as small a deviation as possible at the joints, and so inverts present a smooth surface. Pipe and fittings that do not fit together to form a tight fit will be rejected.

3.04 PROTECTION OF WORK

A. The Contractor shall use all means necessary to protect all work of this Section.

B. In the event of damage, the Contractor shall make all repairs and replacements necessary, to the satisfaction of the Construction Manager.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for 4-inch PVC Pipe will be measured as in-place linear foot (LF) to the limits shown on the Drawings, and payment will be based on the unit price provided on the Bid Schedule.

B. Providing for and complying with the requirements set forth in this Section for 18-inch PVC Pipe will be measured as in-place LF to the limits shown on the Drawings, and payment will be based on the unit price provided on the Bid Schedule.

C. Providing for and complying with the requirements set forth in this Section for Strip Drain, including connectors and sand bags or geotextile alternative, will be measured as in-place LF to the limits shown on the Drawings, and payment will be based on the unit price provided on the Bid Schedule.

D. The following are considered incidental to the Work:

- Submittals.
- Quality Control.
- Shipping, handling and storage.
- Fittings.
- Drainage aggregate.
- Joining.
- Mobilization.
- Placement.
- Rejected material.
- Rejected material removal, handling, re-testing, and repair.
- Gravel and sand bags and/or woven geotextile.
- UDOT sand.

[END OF SECTION]

SECTION 02770

GEOMEMBRANE

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary for the installation of smooth and textured high-density polyethylene (HDPE) geomembrane and HDPE Drain Liner™ geomembrane, as shown on the Drawings. The work shall be performed as specified herein and in accordance with the Drawings and the site Construction Quality Assurance (CQA) Plan.

B. The work shall include, but not be limited to, delivery, offloading, storage, placement, anchorage, and seaming of the geomembrane.

1.02 RELATED SECTIONS

Section 02225 – Drainage Aggregate

Section 02771 – Geotextile

Section 02772 – Geosynthetic Clay Liner

Section 02773 – Geonet

1.03 REFERENCES

A. Drawings

B. Site CQA Plan

C. Latest version of Geosynthetic Research Institute (GRI) GM-9 – Cold Weather Seaming of Geomembranes

D. Latest version of the ASTM International (ASTM) standards:

ASTM D 638	Standard Test Method for Tensile Properties of Plastics
ASTM D 792	Standard Test Methods for Specific Gravity (Relative Density) and Density of Plastics by Displacement
ASTM D 1505	Standard Test Methods for Density of Plastics by Density-Gradient Technique
ASTM D 1603	Standard Test Method for Carbon Black in Olefin Plastics
ASTM D 4439	Terminology for Geosynthetics
ASTM D 4833	Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
ASTM D 5199	Standard Test Method for Measuring the Nominal Thickness of Geosynthetics
ASTM D 5397	Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test
ASTM D 5596	Recommended Practice for Microscopical Examination of Pigment Dispersion in Plastic Compounds

ASTM D 5641 Practice for Geomembrane Seam Evaluation by Vacuum Chamber

ASTM D 5820 Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes

ASTM D 6365 Standard Test Method for the Non-destructive Testing of Geomembrane Seams using the Spark Test.

ASTM D 6392 Standard Test Method for Determining the Integrity of Non-reinforced Geomembrane Seams Produced using Thermo-Fusion Methods.

1.04 QUALIFICATIONS

A. Geomembrane Manufacturer:

1. The Geomembrane Manufacturer shall be responsible for the production of geomembrane rolls from resin and shall have sufficient production capacity and qualified personnel to provide material meeting the requirements of this Section and the construction schedule for this project.

2. The Geomembrane Manufacturer shall have successfully manufactured a minimum of 20,000,000 square feet of polyethylene geomembrane.

B. Geosynthetics Installer:

1. The Geosynthetics Installer shall be responsible and shall provide sufficient resources for field handling, deploying, seaming, temporarily restraining (against wind), and other aspects of the deployment and installation of the geomembrane and other geosynthetic components of the project.

2. The Geosynthetics Installer shall have successfully installed a minimum of 20,000,000 square feet of polyethylene geomembrane on previous projects with similar side slopes, bench widths, and configurations.

3. The installation crew shall have the following experience.

a. The Superintendent shall have supervised the installation of a minimum of 10,000,000 square feet of polyethylene geomembrane on at least ten (10) different projects.

b. At least one seamer shall have experience seaming a minimum of 2,000,000 square feet of polyethylene geomembrane using the same type of seaming apparatus to be used at this Site. Seamers with such experience will be designated "master seamers" and shall provide direct supervision over less experienced seamers.

c. All other seaming personnel shall have seamed at least 100,000 square feet of polyethylene geomembrane using the same type of seaming apparatus to be used at this site. Personnel who have seamed less than 100,000 square feet shall be allowed to seam only under the direct supervision of the master seamer or Superintendent.

1.05 WARRANTY

A. The Geosynthetic Manufacturer shall furnish the Owner a 20-year written warranty against defects in materials. Warranty conditions concerning limits of liability will be evaluated by, and must be acceptable to, the Owner.

B. The Geosynthetic Installer shall furnish the Owner with a 1-year written warranty against defects in workmanship. Warranty conditions concerning limits of liability will be evaluated by, and must be acceptable to, the Owner.

1.06 SUBMITTALS

A. The Geosynthetic Installer shall submit the following documentation on the resin used to manufacture the geomembrane to the Construction Manager for approval 14 days prior to transporting any geomembrane to the Site.

1. Copies of quality control certificates issued by the resin supplier including the production dates, brand name, and origin of the resin used to manufacture the geomembrane for the project.

2. Results of tests conducted by the Geomembrane Manufacturer to verify the quality of the resin used to manufacture the geomembrane rolls assigned to the project.

3. Certification that no reclaimed polymer is added to the resin during the manufacturing of the geomembrane to be used for this project, or, if recycled polymer is used, the Manufacturer shall submit a certificate signed by the production manager documenting the quantity of recycled material, including a description of the procedure used to measure the quantity of recycled polymer.

B. The Geosynthetic Installer shall submit the following documentation on geomembrane roll production to the Construction Manager for approval 14 days prior to transporting any geomembrane to the site.

1. Quality control certificates, which shall include:

   a. roll numbers and identification; and

   b. results of quality control tests, including descriptions of the test methods used, outlined in Subpart 2.02 of this Section.

2. The manufacturer warranty specified in Subpart 1.05 of this Section.

C. The Geosynthetic Installer shall submit the following information to the Construction Manager for approval 14 days prior to mobilization.

1. A Panel Layout Drawing showing the installation layout and identifying geomembrane panel configurations, dimensions, details, locations of seams, as well as any variance or additional details that deviate from the Drawings. The Panel Layout Drawing shall be adequate for use as a construction plan and shall include dimensions, details, etc. The Panel Layout Drawing, as modified and/or approved by the Construction Manager, shall become Subpart of these Technical Specifications.

2. Installation schedule.

3. Copy of Geosynthetic Installer's letter of approval or license by the Geomembrane Manufacturer.

4. Installation capabilities, including:

   a. information on equipment proposed for this project;

   b. average daily production anticipated for this project; and

   c. quality control procedures.

5. A list of completed facilities for which the Geosynthetic Installer has installed a minimum of 20,000,000 square feet of polyethylene geomembrane, in accordance with Subpart 1.04 of this Section. The following information shall be submitted to the Construction Manager for each facility:

   a. the name and purpose of the facility, its location, and dates of installation;

   b. the names of the owner, Engineer, and geomembrane manufacturer;

   c. name of the supervisor of the installation crew; and

   d. thickness and surface area of installed geomembrane.

6. In accordance with Subpart 1.04 of this Section, a resume of the Superintendent to be assigned to this project, including dates and duration of employment, shall be submitted at least 7 days prior to beginning geomembrane installation.

7. In accordance with Subpart 1.04 of this Section, resumes of all personnel who will perform seaming operations on this project, including dates and duration of employment, shall be submitted at least 7 days prior to beginning geomembrane installation.

D. A Certificate of Calibration less than 12 months old shall be submitted for each field tensiometer prior to installation of any geomembrane.

E. During installation, the Geosynthetic Installer shall be responsible for the timely submission to the Construction Manager of:

1. Quality control documentation; and

2. If geomembrane is placed directly on the subgrade (Option A), Subgrade Acceptance Certificates, signed by the Geosynthetic Installer, for each area of subgrade to be covered by geosynthetic materials.

F. Upon completion of the installation, the Geosynthetic Installer shall be responsible for the submission to the Construction Manager of a warranty from the Geosynthetic Installer as specified in Subpart 1.05.B of this Section.

G. Upon completion of the installation of each layer, the Geosynthetic Installer shall be responsible for the submission to the Construction Manager of a Record Drawing showing the location and number of each panel and locations and numbers of destructive tests and repairs.

H. The Geosynthetic Installer shall submit samples and material property cut-sheets on the proposed geomembrane to the Construction Manager at least 7 days prior to delivery of this material to the site.

I. The Geosynthetic Installer shall submit the following documentation on welding rod to the Construction Manager for approval 14 days prior to transporting welding rod to the Site:

1. Quality control documentation, including lot number, welding rod spool number, and results of quality control tests on the welding rod.

2. Certification that the welding rod is compatible with the geomembrane and this Section.

1.07 CONSTRUCTION QUALITY ASSURANCE (CQA) MONITORING

A. The Geosynthetic Installer shall be aware of and accommodate all monitoring and conformance testing required by the CQA Plan. This monitoring and testing, including random conformance testing of construction materials and completed work, will be performed by the CQA Consultant. If nonconformances or other deficiencies are found in the Geosynthetic Installer's materials or completed work, the Geosynthetic Installer will be required to repair the deficiency or replace the deficient materials.

PART 2 – PRODUCTS

2.01 GEOMEMBRANE PROPERTIES

A. The Primary Geomembrane Manufacturer shall furnish white-or off-white-surfaced (upper side only), smooth and textured geomembrane having properties that comply with the required property values shown in Table 02770-1.

B. The Secondary Floor Geomembrane Manufacturer shall furnish black, smooth and textured geomembrane having properties that comply with the required property values shown in Table 02770-1

C. The Secondary Side Slope Geomembrane Manufacturer shall furnish black Drain Liner™ geomembrane having properties that comply with the required property values shown in Table 02770-2.

D. The Tertiary Geomembrane Manufacturer shall furnish black Drain Liner™ geomembrane having properties that comply with the required property values shown in Table 02770-2, if applicable.

E. In addition to the property values listed in Tables 02770-1 and 02770-2, the geomembrane shall:

1. Contain a maximum of 1 percent by weight of additives, fillers, or extenders (not including carbon black and titanium dioxide).

2. Not have striations, pinholes (holes), bubbles, blisters, nodules, undispersed raw materials, or any sign of contamination by foreign matter on the surface or in the interior.

2.02 MANUFACTURING QUALITY CONTROL (MQC)

A. Rolls:

1. The Geomembrane Manufacturer shall continuously monitor geomembrane during the manufacturing process for defects.

2. No geomembrane shall be accepted that exhibits any defects.

3. The Geomembrane Manufacturer shall measure and report the geomembrane thickness at regular intervals along the roll length.

4. No geomembrane shall be accepted that fails to meet the specified thickness.

5. The Geomembrane Manufacturer shall sample and test the geomembrane at a minimum of once every 50,000 square feet, to demonstrate that its properties conform to the values specified in Tables 02770-1 and 02770-2. At a minimum, the following tests shall be performed:

Test	Procedure
Thickness	ASTM D 5199 or ASTM D 5994
Specific Gravity	ASTM D 792
Tensile Properties	ASTM D 6933
Puncture Resistance	ASTM D 4833
Carbon Black	ASTM D 4218
Carbon Black Dispersion	ASTM D 5596

6. Tests not listed above but listed in Table 02770-1 or Table 02770-2 need not be run at the one per 50,000 square feet frequency. However, the Geomembrane Manufacturer shall certify that these tests are in compliance with this Section and have been performed on a sample that is identical to the geomembrane to be used on this project. The Geosynthetic Installer shall provide the test result documentation to the Construction Manager.

7. Any geomembrane sample that does not comply with the requirements of this Section will result in rejection of the roll from which the sample was obtained and will not be used for this project.

8. If a geomembrane sample fails to meet the quality control requirements of this Section, the Geomembrane Manufacturer shall sample and test, at the expense of the Manufacturer, rolls manufactured in the same resin batch, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established to bound the failed roll(s).

9. Additional testing may be performed at the Geomembrane Manufacturer's discretion and expense, to isolate and more closely identify the non-complying rolls and/or to qualify individual rolls.

B. The Geomembrane Manufacturer shall permit the CQA Consultant to visit the manufacturing plant for project specific visits. If possible, such visits will be prior to or during the manufacturing of the geomembrane rolls for the specific project. The CQA Consultant may elect to collect conformance samples at the manufacturing facility to expedite the acceptance of the materials.

2.03 INTERFACE SHEAR TESTING

A. Interface shear test(s) shall be performed by the CQA Consultant on the proposed geosynthetic components in accordance with ASTM D 5321. Tests shall be performed on geosynthetic interfaces as outlined below.

1. Geotextile and Textured HDPE Geomembrane – the nonwoven cushion geotextile shall be overlain by a 60-mil textured HDPE geomembrane.

   a. Concrete sand shall be placed overlying and underlying the materials being tested. The test shall be performed at normal stresses of 100, 200, and 400 psf at a shear rate of no more than 0.20 in./min (5 mm/min.).

b. The results of this test shall have peak shear strength values in excess of 53 psf, 106 psf, and 213 psf for normal stresses of 100 psf, 200 psf, and 400 psf, respectively.

2. Drain Liner™ and Smooth HDPE Geomembrane – the Drain Liner™ shall be overlain by a 60-mil smooth geomembrane.

a. Concrete sand shall be placed overlying and underlying the materials being tested. The test shall be performed at normal stresses of 10, 20, and 40 psi at a shear rate of no more than 0.20 in./min. (5 mm/min.).

b. The results of this test shall have a peak apparent friction angle in excess of 11 degrees.

3. Geonet and smooth HDPE Geomembrane – the geonet shall be overlain by a 60-mil smooth HDPE geomembrane.

a. Concrete sand shall be placed overlying the geomembrane being tested. The test shall be performed at normal stresses of 10, 20, and 40 psi at a shear rate of no more than 0.20 in./min. (5 mm/min.).

b. The results of this test shall have a peak apparent friction angle in excess of 11 degrees.

4. Hydrated GCL interface – the GCL shall be overlain by a textured 60-mil HDPE Concrete sand shall be placed overlying and underlying the materials being tested.

a. Before shearing, the GCL shall be hydrated under normal stresses for each individual test (e.g. 100, 200, and 400 psf) for 48 hours. The test shall be performed at normal stresses of 100, 200, and 400 psf at a shear rate of no more than 0.04 in./min. (1 mm/min.).

b. The results of this test shall have peak shear strength values in excess of 53 psf, 106 psf, and 213 psf for normal stresses of 100 psf, 200 psf, and 400 psf, respectively.

5. Hydrated GCL interface – the GCL shall be overlain by a smooth 60-mil HDPE geomembrane. Concrete sand shall be placed overlying and underlying the materials being tested.

a. Before shearing, the GCL shall be hydrated under a loading of 250 psf for 48 hours. The test shall be performed at normal stresses of 10, 20, and 40 psi at a shear rate of no more than 0.04 in./min. (1 mm/min.).

b. The results of this test shall have a peak apparent friction angle in excess of 11 degrees.

2.04 LABELING

A. Geomembrane rolls shall be labeled with the following information.

1. thickness of the material;

2. length and width of the roll;

3. name of Geomembrane Manufacturer;

4. product identification;

5. lot number; and

6. roll number.

2.05 TRANSPORTATION, HANDLING, AND STORAGE

A. The Geosynthetic Manufacturer shall be liable for any damage to the geomembrane incurred prior to and during transportation to the site.

B. Handling and care of the geomembrane at the site prior to and following installation shall be the responsibility of the Geosynthetic Installer. The Geosynthetic Installer shall be liable for all damage to the materials incurred prior to final acceptance of the liner system by the Owner.

C. Geosynthetic Installer shall be responsible for storage of the geomembrane at the site. The geomembrane shall be protected from excessive heat or cold, dirt, puncture, cutting, or other damaging or deleterious conditions. Any additional storage procedures required by the Geomembrane Manufacturer shall be the Geosynthetic Installer's responsibility. Geomembrane rolls shall not be stored or placed in a stack of more than two rolls high.

D. The geomembrane shall be delivered at least 14 days prior to the planned deployment date to allow the CQA Consultant adequate time to perform conformance testing on the geomembrane samples as described in Subpart 3.05 of this Section. If the CQA Consultant performed a visit to the manufacturing plant and performed the required conformance sampling, geomembrane can be delivered to the site within the 14 days prior to the planned deployment date as long as there is sufficient time for the CQA Consultant to complete the conformance testing and confirm that the rolls shipped to the site are in compliance with this Section.

PART 3 – GEOMEMBRANE INSTALLATION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work described in this Section, the Geosynthetic Installer shall become thoroughly familiar with all portions of the work falling within this Section.

B. Inspection:

1. The Geosynthetic Installer shall carefully inspect the installed work of all other Sections and verify that all work is complete to the point where the work of this Section may properly commence without adverse effect.

2. If the Geosynthetic Installer has any concerns regarding the installed work of other Sections, he shall notify the Construction Manager in writing prior to the start of the work of this Section. Failure to inform the Construction Manager in writing or commencing installation of the geomembrane will be construed as the Geosynthetic Installer's acceptance of the related work of all other Sections.

C. A pre-installation meeting shall be held to coordinate the installation of the geomembrane with the installation of other components of the liner system.

3.02 GEOMEMBRANE DEPLOYMENT

A. Layout Drawings:

1. The Geosynthetic Installer shall deploy the geomembrane panels in general accordance with the Panel Layout Drawing specified. The Panel Layout Drawing must be approved by the CQA Consultant prior to installation of any geomembrane.

B. Field Panel Identification:

1. A geomembrane field panel is a roll or a portion of roll cut in the field.

2. Each field panel shall be given a unique identification code (number or letter-number). This identification code shall be agreed upon by the Construction Manager and Geosynthetic Installer.

C. Field Panel Placement:

1. Field panels shall be installed, as approved or modified, at the location and positions indicated on the Panel Layout Drawing.

2. Primary geomembrane field panels shall be installed with the white side of the geomembrane upward with the exception of the splash pads which will have the black side of the geomembrane upward.

3. Drain Liner™ shall be placed with the studded side upward.

4. Panels shall be laid out in a manner which minimizes seams.

5. Field panels shall be placed one at a time.

6. Geomembrane shall not be placed when the ambient temperature is below 32°F or above 122°F, as measured in Subpart 3.03.C.3 in this Section, unless otherwise authorized in writing by the Design Engineer. Geomembrane panels shall be allowed to equilibrate to temperature of adjacent panels prior to seaming.

7. Geomembrane shall not be placed during any precipitation, in the presence of excessive moisture (e.g., fog, dew), in an area of ponded water, or in the presence of wind speeds greater than 20 mph.

8. The Geosynthetic Installer shall ensure that:

   a. No vehicular traffic is allowed on the geomembrane with the exception of all terrain vehicles with contact pressures at or lower than that exhibited by foot traffic.

   b. Equipment used does not damage the geomembrane by handling, trafficking, or leakage of hydrocarbons (i.e., fuels).

   c. Personnel working on the geomembrane do not smoke, wear damaging shoes, bring glass onto the geomembrane, or engage in other activities that could damage the geomembrane.

   d. The method used to unroll the panels does not scratch or crimp the geomembrane and does not damage the supporting soil or geosynthetics.

   e. The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels). The method used to place the panels results in intimate contact between the geomembrane and adjacent components.

   f. Temporary ballast and/or anchors (e.g., sand bags) are placed on the geomembrane to prevent wind uplift. Ballast methods must not damage the geomembrane.

   g. The geomembrane is especially protected from damage in heavily trafficked areas.

h. Any rub sheets to facilitate seaming are removed prior to installation of subsequent panels.

9. Any field panel or portion thereof that becomes seriously damaged (torn, twisted, or crimped) shall be replaced with new material. Less serious damage to the geomembrane may be repaired, as approved by the Construction Manager. Damaged panels or portions of damaged panels that have been rejected shall be removed from the work area and not reused.

10. Care shall be taken during placement of tertiary, Drain Liner™ geomembrane to prevent dirt or excessive dust in the liner studs that could cause clogging and/or damage to the adjacent materials.

D. If the Geosynthetic Installer intends to install geomembrane between one hour before sunset and one hour after sunrise, he shall notify the Construction Manager in writing prior to the start of the work. The Geosynthetic Installer shall indicate additional precautions that shall be taken during these installation hours. The Geosynthetic Installer shall provide proper illumination for work during this time period.

3.03 FIELD SEAMING

A. Seam Layout:

1. In corners and at odd-shaped geometric locations, the number of field seams shall be minimized. On slopes steeper than 10:1 (horizontal:vertical), geomembrane panels shall be continuous down the slope, i.e., no horizontal seams shall be allowed on the slope. Horizontal seams shall be considered as any seam having an alignment exceeding 45 degrees from being perpendicular to the slope contour lines, unless otherwise approved by the Design Engineer. No seams shall be located in an area of potential stress concentration.

2. Seams shall not be allowed within 5 feet of the top or toe of any slope.

B. Personnel:

1. All personnel performing seaming operations shall be qualified as indicated in Subpart 1.04 of this Section. No seaming shall be performed unless a "master seamer" is present on-site.

C. Weather Conditions for Seaming:

1. Unless authorized in writing by the Design Engineer, seaming shall not be attempted at ambient temperatures below 32°F or above 122°F. If the Geosynthetic Installer wishes to use methods that may allow seaming at ambient temperatures below 32°F or above 122°F, the procedure must be in accordance with GRI GM-9 for cold weather seaming and be approved by the Construction Manager.

2. A meeting will be held between the Geosynthetic Installer and Design Engineer to establish acceptable installation procedures. In all cases, the geomembrane shall be dry and protected from wind damage during installation.

3. Ambient temperatures, measured by the CQA Site Manager, shall be measured between 0 and 6 inches above the geomembrane surface.

D. Overlapping:

1. The geomembrane shall be cut and/or trimmed such that all corners are rounded.

2. Geomembrane panels shall be shingled with the upslope panel placed over the down slope panel.

3. Geomembrane panels shall be sufficiently overlapped for welding and to allow peel tests to be performed on the seam. Any seams that cannot be destructively tested because of insufficient overlap shall be treated as failing seams.

E. Seam Preparation:

1. Prior to seaming, the seam area shall be clean and free of moisture, dust, dirt, debris of any kind, and foreign material.

2. If seam overlap grinding is required, including to remove Drain Liner™ studs, the process shall be completed according to the Geomembrane Manufacturer's instructions within 20 minutes of the seaming operation and in a manner that does not damage the geomembrane. The grind depth shall not exceed ten percent of the core geomembrane thickness.

3. Seams shall be aligned with the fewest possible number of wrinkles and "fishmouths." Proper temperature and sunlight acclimation shall be allowed prior to seaming a newly placed panel to a previously placed panel (panels must be allowed to expand and contract to be in equilibrium with adjacent panels prior to seaming).

F. General Seaming Requirements:

1. Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle to achieve a flat overlap, ending the cut with circular cut-out. The cut fishmouths or wrinkles shall be seamed and any portion where the overlap is insufficient shall be patched with an oval or round patch of geomembrane that extends a minimum of 6 inches beyond the cut in all directions.

2. Any electric generator shall be placed outside the area to be lined or mounted in a manner that protects the geomembrane from damage due to the weight and frame of the generator or due to fuel leakage. The electric generator shall be properly grounded.

G. Seaming Process:

1. Approved processes for field seaming are extrusion welding and double-track hot-wedge fusion welding. Only equipment identified as part of the approved submittal specified in Subpart 1.06 of this Section shall be used.

2. Extrusion Equipment and Procedures:

a. The Geosynthetics Installer shall maintain at least one spare operable seaming apparatus on site.

b. Extrusion welding apparatuses shall be equipped with gauges giving the temperatures in the apparatuses.

c. Prior to beginning an extrusion seam, the extruder shall be purged until all heat-degraded extrudate has been removed from the barrel.

d. A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after use.

3. Fusion Equipment and Procedures:

a. The Geosynthetic Installer shall maintain at least one spare operable seaming apparatus on site.

b. Fusion-welding apparatus shall be automated vehicular-mounted devices equipped with gauges giving the applicable temperatures and speed.

c. A smooth insulating plate or fabric shall be placed beneath the hot welding apparatus after use.

H. Drain Liner™ butt-seams

1. At the Drain Liner™ butt-seams (end of panel), a 2-foot length of 200-mil geonet will be installed over the seams to extend a minimum of 6-inches onto the adjacent panel studs and shall extend across the width of the panel. Butt-seam requirement applies to Drain Liner™ to Drain Liner™, not to Drain Liner™ to smooth or textured HDPE geomembrane.

2. Distance between studs on the panel and studs on extrusion-welded patches shall not exceed 3-inches.

I. Trial Seams:

1. Trial seams shall be made on fragment pieces of geomembrane to verify that seaming conditions are adequate. Trial seams shall be conducted on the same material to be installed and under similar field conditions as production seams. Such trial seams shall be made at the beginning of each seaming period, typically at the beginning of the day and after lunch, for each seaming apparatus used each day, but no less frequently than once every 5 hours. The trial seam sample shall be a minimum of 5 feet long by 1 foot wide (after seaming) with the seam centered lengthwise for fusion equipment and at least 3 feet long by 1 foot wide for extrusion equipment. Seam overlap shall be as indicated in Subpart 3.03.D of this Section.

2. Four coupon specimens, each 1-inch wide, shall be cut from the trial seam sample by the Geosynthetics Installer using a die cutter to ensure precise 1-inch wide coupons. The coupons shall be tested, by the Geosynthetic Installer, with the CQA Site Manager present, in peel (both the outside and inside track) and in shear using an electronic readout field tensiometer in accordance with ASTM D 6392, at a strain rate of 2 inches/minute. The samples shall not exhibit failure in the seam, i.e., they shall exhibit a Film Tear Bond (FTB), which is a failure (yield) in the parent material. The required peel and shear seam strength values are listed in Table 02770-3. At no time shall specimens be soaked in water.

3. If any coupon specimen fails, the trial seam shall be considered failing and the entire operation shall be repeated. If any of the additional coupon specimens fail, the seaming apparatus and seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved.

J. Nondestructive Seam Continuity Testing:

1. The Geosynthetic Installer shall nondestructively test for continuity on all field seams over their full length. Continuity testing shall be carried out as the seaming work progresses, not at the completion of all field seaming. The Geosynthetic Installer shall complete any required repairs in accordance with Subpart 3.03.K of this Section. The following procedures shall apply:

a. Vacuum testing in accordance with ASTM D 5641.

b. Air channel pressure testing for double-track fusion seams in accordance with ASTM D 5820 and the following:

i. Insert needle, or other approved pressure feed device, from pressure gauge and inflation device into the air channel at one end of a double track seam.

ii. Energize the air pump and inflate air channel to a pressure between 25 and 30 pounds per square inch (psi). Close valve and sustain the pressure for not less than 5 minutes.

iii. If loss of pressure exceeds 3 psi over 5 minutes, or if the pressure does not stabilize, locate the faulty area(s) and repair seam in accordance with Subpart 3.03.K of this Section.

iv. After 5 minutes, cut the end of air channel opposite from the end with the pressure gauge and observe release of pressure to ensure air channel is not blocked. If the channel does not depressurize, find and repair the portion of the seam containing the blockage per Subpart 3.03.K of this Section. Repeat the air pressure test on the resulting segments of the original seam created by the repair and the ends of the seam. Repeat the process until the entire length of seam has successfully passed pressure testing or contains a repair. Repairs shall also be non-destructively tested per Subpart 3.03.K.5 of this Section.

v. Remove needle, or other approved pressure feed device, and seal repair in accordance with Subpart 3.03.K of this Section.

c. Spark test seam integrity verification shall be performed in accordance with ASTM D 6365 if the seam cannot be tested using other nondestructive methods.

K. Destructive Testing:

1. Destructive seam tests shall be performed on samples collected from selected locations to evaluate seam strength and integrity. Destructive tests shall be carried out as the seaming work progresses, not at the completion of all field seaming.

2. Sampling:

a. Destructive test samples shall be collected at a minimum average frequency of one test location per 500 feet of total seam length. If after a total of 50 samples have been tested and no more than 1 sample has failed, the frequency can be increased to one per 1,000 feet. Test locations shall be determined during seaming, and may be prompted by suspicion of excess crystallinity, contamination, offset seams, or any other potential cause of imperfect seaming. The CQA Site Manager will be responsible for choosing the locations. The Geosynthetic Installer shall not be informed in advance of the locations where the seam samples will be taken. The CQA Site Manager reserves the right to increase the sampling frequency if observations suggest an increased frequency is warranted.

b. The CQA Site Manager shall mark the destructive sample locations. Samples shall be cut by the Geosynthetic Installer at the locations designated by the CQA Site Manager as the seaming progresses in order to obtain laboratory test results before the geomembrane is covered by another material. Each sample shall be numbered and the sample number and location identified on the Panel Layout Drawing. All holes in the geomembrane resulting from the destructive seam sampling shall be immediately repaired in accordance with the repair procedures described in Subpart 3.03.K of this Section. The continuity of the new seams associated with the repaired areas shall be tested according to Subpart 3.03.I of this Section.

c. Two coupon strips of dimensions 1-inch wide and 12-inches long with the seam centered parallel to the width shall be taken from any side of the sample location. These samples shall be tested in the field in accordance with Subpart 3.03.J.3 of this Section. If these samples pass the field test, a laboratory sample shall be taken. The laboratory sample shall be at least 1-foot wide by 3.5-feet long with the seam centered along the length. The sample shall be cut into three parts and distributed as follows:

i. One portion 12-inches long to the Geosynthetic Installer.

ii. One portion 18-inches long to the Geosynthetic CQA Laboratory for testing.

iii. One portion 12-inches long to the Owner for archival storage.

3. Field Testing:

a. The two 1-inch wide strips shall be tested in the field tensiometer in the peel mode on both sides of the double track fusion welded sample. The CQA Site Manager has the option to request an additional test in the shear mode. If any field test sample fails to meet the requirements in Table 02770-3, then the procedures outlined in Subpart 3.03.J.5 of this Section for a failing destructive sample shall be followed.

4. Laboratory Testing:

a. Testing by the Geosynthetics CQA Laboratory will include "Seam Strength" and "Peel Adhesion" (ASTM D 6392) with 1-inch wide strips tested at a rate of 2 inches/minute. At least 5 specimens will be tested for each test method (peel and shear). Four of the five specimens per sample must pass both the shear strength test and peel adhesion test when tested in accordance with ASTM D 6392. The minimum acceptable values to be obtained in these tests are indicated in Table 02770-3. Both the inside and outside tracks of the dual track fusion welds shall be tested in peel.

5. Destructive Test Failure:

a. The following procedures shall apply whenever a sample fails a destructive test, whether the test is conducted by the Geosynthetic CQA's laboratory, the Geosynthetic Installer laboratory, or by a field tensiometer. The Geosynthetic Installer shall have two options:

i. The Geosynthetic Installer can reconstruct the seam (e.g., remove the old seam and reseam) between any two laboratory-passed destructive test locations created by that seaming apparatus. Trial welds do not count as a passed destructive test.

ii. The Geosynthetic Installer can trace the welding path in each direction to an intermediate location, a minimum of 10 feet from the location of the failed test, and take a small sample for an additional field test at each location. If these additional samples pass the field tests, then full laboratory samples shall be taken. These full laboratory samples shall be tested in accordance with Subpart 3.03.J.4 of this Section. If these laboratory samples pass the tests, then the seam path between these locations shall be reconstructed and nondestructively (at a minimum) tested. If a sample fails, then the process shall be repeated, i.e. another destructive sample shall be obtained and tested at a distance of at least 10 more feet in the seaming path from the failed sample. The seam path between the ultimate passing sample locations shall be reconstructed and nondestructively (at a minimum) tested. In cases where repaired seam lengths exceed 150 feet, a destructive sample shall be taken from the repaired seam and the above procedures for destructive seam testing shall be followed.

b. Whenever a sample fails destructive or non-destructive testing, the CQA Consultant may require additional destructive tests be obtained from seams that were created by the same seamer and/or seaming apparatus during the same time shift.

L. Defects and Repairs:

1. The geomembrane will be inspected before and after seaming for evidence of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. The surface of the geomembrane shall be clean at the time of inspection. The geomembrane surface shall be swept or washed by the Installer if surface contamination inhibits inspection.

2. At observed suspected flawed location, both in seamed and non-seamed areas, shall be nondestructively tested using the methods described Subpart 3.03.I of this Section, as appropriate. Each location that fails nondestructive testing shall be marked by the CQA Site Manager and repaired by the Geosynthetic Installer.

3. When seaming of a geomembrane is completed (or when seaming of a large area of a geomembrane is completed) and prior to placing overlying materials, the CQA Site Manager shall identify all excessive geomembrane wrinkles. The Geosynthetic Installer shall cut and reseam all wrinkles so identified. The seams thus produced shall be tested as per all other seams.

4. Repair Procedures:

a. Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, shall be repaired by the Geosynthetic Installer. Several repair procedures are acceptable. The final decision as to the appropriate repair procedure shall be agreed upon between the Design Engineer and the Geosynthetic Installer. The procedures available include:

i. Patching – extrusion welding a patch to repair holes larger than 1/16 inch, tears, undispersed raw materials, and contamination by foreign matter;

ii. Abrading and reseaming – applying an extrusion seam to repair very small sections of faulty extruded seams;

iii. Spot seaming – applying an extrusion bead to repair minor, localized flaws such as scratches and scuffs;

iv. Capping – extrusion welding a geomembrane cap over long lengths of failed seams; and

v. Strip repairing – cutting out bad seams and replacing with a strip of new material seamed into place on both sides with fusion welding.

b. In addition, the following criteria shall be satisfied:

i. surfaces of the geomembrane that are to be repaired shall be abraded no more than 20 minutes prior to the repair;

ii. the grind depth around the repair shall not exceed ten percent of the core geomembrane thickness;

iii. all surfaces must be clean and dry at the time of repair;

iv. all seaming equipment used in repair procedures must be approved by trial seaming;

v. any other potential repair procedures shall be approved in advance, for the specific repair, by the Design Engineer;

vi. patches or caps shall extend at least 6 inches beyond the edge of the defect, and all corners of patches and holes shall be rounded with a radius of at least 3 inches;

vii. extrudate shall extend a minimum of 3 inches beyond the edge of the patch at fusion welded seam overlaps.

5. Repair Verification:

a. Repairs shall be nondestructively tested using the methods described in Subpart 3.03.I of this Section, as appropriate. Repairs that pass nondestructive testing shall be considered acceptable repairs. Repairs that failed nondestructive or destructive testing will require the repair to be reconstructed and retested until passing test results are observed. At the discretion of the CQA Consultant, destructive testing may be required on any caps.

3.04 MATERIALS IN CONTACT WITH THE GEOMEMBRANE

A. The Geosynthetic Installer shall take all necessary precautions to ensure that the geomembrane is not damaged during its installation. During the installation of other components of the liner system by the Contractor, the Contractor shall ensure that the geomembrane is not damaged. Any damage to the geomembrane caused by the Contractor shall be repaired by the Geosynthetic Installer at the expense of the Contractor.

B. Soil and aggregate materials shall not be placed over the geomembranes at ambient temperatures below 32°F or above 122°F, unless otherwise specified.

C. All attempts shall be made to minimize wrinkles in the geomembrane.

D. Construction loads permitted on the geomembrane are limited to foot traffic and all terrain vehicles with a contact pressures at or lower than 7 pounds per square inch.

3.05 CONFORMANCE TESTING

A. Samples of the geomembrane will be removed by the CQA Site Manager and sent to a Geosynthetic CQA Laboratory for testing to ensure conformance with the requirements of this Section. The CQA Consultant may collect samples at the manufacturing plant or from the rolls delivered to the site. The Geosynthetic Installer shall assist the CQA Site Manager in obtaining conformance samples from any geomembrane rolls sampled at the site. The Geosynthetic Installer and Contractor shall account for this sampling and testing requirement in the installation schedule, including the turnaround time for laboratory results. Only materials that meet the requirements of Subpart 2.02 of this Section shall be installed.

B. Samples will be selected by the CQA Consultant in accordance with this Section and with the procedures outlined in the CQA Plan.

C. Samples will be taken at a minimum frequency of one sample per 100,000 square feet excluding the splash pads. If the Geomembrane Manufacturer provides material that requires sampling at a frequency (due to lot size, shipment size, etc.) resulting in one sample per less than 90 percent of 100,000 square feet (90,000 square feet), then the Geosynthetic Installer shall pay the cost for all additional testing.

D. The CQA Consultant may increase the frequency of sampling in the event that test results do not comply with the requirements of Subpart 2.02 of this Section.

E. The following tests will be performed by the CQA Consultant:

Test	Procedure
Thickness	ASTM D 5199 or ASTM D 5944
Specific Gravity	ASTM D 792
Tensile Properties	ASTM D 6693
Carbon Black	ASTM D 4218
Carbon Black Dispersion	ASTM D 5596

F. Any geomembrane that is not certified in accordance with Subpart 1.06.C of this Section, or that conformance testing indicates does not comply with Subpart 2.02 of this Section, shall be rejected. The Geosynthetic Installer shall replace the rejected material with new material.

3.06 GEOMEMBRANE ACCEPTANCE

A. The Geosynthetic Installer shall retain all ownership and responsibility for the geomembrane until accepted by the Owner.

B. The geomembrane will not be accepted by the Owner before:

1. the installation is completed;
2. all documentation is submitted;
3. verification of the adequacy of all field seams and repairs, including associated testing, is complete; and
4. all warranties are submitted.

3.07 PROTECTION OF WORK

A. The Geosynthetic Installer and Contractor shall use all means necessary to protect all work of this Section.

B. In the event of damage, the Geosynthetic Installer shall make all repairs and replacements necessary, to the satisfaction of the Construction Manager.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for 60-mil, smooth, textured, and Drain Liner™ HDPE geomembrane will be measured as in-place square feet (SF), as measured by the surveyor, including geomembrane in the anchor trench to the limits shown on the Drawings, and payment will be based on the unit price provided on the Bid Schedule.

B. The following are considered incidental to the Work:

- Submittals.
- Quality Control.
- Shipping, handling, and storage.
- Deployment.
- Layout survey.
- Mobilization.
- Rejected material.
- Rejected material removal, handling, re-testing, and repair.
- Overlaps and seaming.
- Temporary anchorage.
- Pipe boots.
- Cleaning seam area.

TABLE 02770-1
REQUIRED HDPE GEOMEMBRANE PROPERTIES

PROPERTIES	QUALIFIERS	UNITS	SMOOTH HDPE SPECIFIED VALUES	TEXTURED HDPE SPECIFIED VALUES	TEST METHOD
Physical Properties					
Thickness	Average Minimum	mils mils	60 54	60 54	ASTM D 5199 or ASTM D 5944
Specific Gravity	Minimum	N/A	0.94	0.94	ASTM D 792 Method A or ASTM D 1505
Mechanical Properties Tensile Properties (each direction) 1. Tensile (Break) Strength 2. Elongation at Break 3. Tensile (Yield) Strength 4. Elongation at Yield	Minimum	lb/in % lb/in %	228 700 126 12	90 100 126 12	ASTM D 6693
Puncture	Minimum	lb	108	90	ASTM D 4833
Environmental Properties					
Carbon Black Content	Range	%	2-3	2	ASTM D 4218
Carbon Black Dispersion	N/A	none	Note 1	Note 1	ASTM D 5596
Environmental Stress Crack	Minimum	hr	300	300	ASTM D 5397
Liner System Properties					
Interface Shear Strength – Textured Geomembrane and Geotextile	Minimum	psf	N/A	53, 106, 213	ASTM D5321[2]
Interface Shear Strength – Smooth Geomembrane to Geonet	Minimum	degrees	N/A	11	ASTM D 5321[2]
Interface Shear Strength – Smooth Geomembrane to Drain Liner™ HDPE geomembrane	Minimum	degrees	N/A	11	ASTM D 5321[2]

Notes: (1) Minimum 9 of 10 in Categories 1 or 2; 10 in Categories 1, 2, or 3.
(2) Interface shear strength testing shall be performed, by the CQA Consultant, in accordance with part 2.03.1 of this Section.

TABLE 02770-2
REQUIRED HDPE DRAIN LINER™ GEOMEMBRANE PROPERTIES

PROPERTIES	QUALIFIERS	UNITS	SPECIFIED VALUES	TEST METHOD
Physical Properties				
Thickness	Average Minimum	mils mils	60 54	ASTM D 5994
Specific Gravity	Minimum	N/A	0.94	ASTM D 792
Drainage Stud Height	Average Minimum	mils	130	ASTM D 7466
Mechanical Properties Tensile Properties (each direction) 1. Tensile (Break) Strength 2. Elongation at Break 3. Tensile (Yield) Strength 4. Elongation at Yield	Minimum	lb/in % lb/in %	132 13 132 300	ASTM D 6693
Puncture	Minimum	lb lb	95 72	ASTM D 4833
Environmental Properties				
Carbon Black Content	Range	%	2	ASTM D 4218
Carbon Black Dispersion	N/A	none	Note 1	ASTM D 5596
Environmental Stress Crack	Minimum	hr	300	ASTM D 5397
Liner System Properties				
Interface Shear Strength	Minimum	degrees	11	ASTM D5321[2]

Notes: (1) Minimum 9 of 10 in Categories 1 or 2; 10 in Categories 1, 2, or 3.
(2) Interface shear strength testing shall be performed, by the CQA Consultant, in accordance with part 2.03.3 of this Section.

TABLE 02770-3
REQUIRED GEOMEMBRANE SEAM PROPERTIES

PROPERTIES	QUALIFIERS	UNITS	SPECIFIED VALUES(3)	TEST METHOD
Shear Strength(1)				
Fusion	minimum	lb/in	120	ASTM D 6392
Extrusion	minimum	lb/in	120	ASTM D 6392
Peel Adhesion				
FTB(2)				Visual Observation
Fusion	minimum	lb/in	91	ASTM D 6392
Extrusion	minimum	lb/in	78	ASTM D 6392

Notes: (1) Also called “Bonded Seam Strength”.
(2) FTB = Film Tear Bond means that failure is in the parent material, not the seam. The maximum seam separation is 25 percent of the seam area.
(3) Four of five specimens per destructive sample must pass both the shear and peel strength tests.

[END OF SECTION]

SECTION 02771

GEOTEXTILE

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary for the installation of the geotextile. The work shall be carried out as specified herein and in accordance with the Drawings and the Construction Quality Assurance (CQA) Plan.

B. The work shall include, but not be limited to, delivery, offloading, storage, placement, and seaming of the various geotextile components of the project.

C. Nonwoven cushion geotextile shall be used between the Drainage Aggregate and Geomembrane as shown on the Drawings. Woven geotextile shall be used overlying the cushion geotextile/drainage aggregate and as a substitute for sand bags, as shown on the Drawings.

1.02 RELATED SECTIONS

Section 02200 – Earthwork

Section 02225 – Drainage Aggregate

Section 02616 – Polyvinyl Chloride (PVC) Pipe

Section 02770 – Geomembrane

Section 02773 – Geonet

1.03 REFERENCES

A. Drawings

B. Site CQA Plan

C. Latest version of ASTM International (ASTM) standards:

ASTM D 4355 Standard Test Method for Deterioration of Geotextile from Exposure to Ultraviolet Light and Water

ASTM D 4439 Terminology for Geosynthetics

ASTM D 4491 Standard Test Method for Water Permeability of Geotextile by Permittivity

ASTM D 4533 Standard Test Method for Trapezoid Tearing Strength of Geotextile

ASTM D 4632 Standard Test Method for Breaking Load and Elongation of Geotextile (Grab Method)

ASTM D 4751 Standard Test Method for Determining Apparent Opening Size of a Geotextile

ASTM D 6241 Standard Test Method for the Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe

ASTM D 5261 Standard Test Method for Measuring Mass Per Unit Area of Geotextile

1.04 SUBMITTALS

A. The Contractor shall submit the following information regarding the proposed geotextile to the Construction Manager for approval at least 7 days prior to geotextile delivery:

1. manufacturer and product name;

2. minimum property values of the proposed geotextile and the corresponding test procedures;

3. projected geotextile delivery dates; and

4. list of geotextile roll numbers for rolls to be delivered to the site.

B. At least 7 days prior to geotextile placement, the Contractor shall submit to the Construction Manager the Manufacturing Quality Control (MQC) certificates for each roll of geotextile. The certificates shall be signed by responsible parties employed by the geotextile manufacturer (such as the production manager). The MQC certificates shall include:

1. lot, batch, and/or roll numbers and identification;

2. MQC test results, including a description of the test methods used; and

3. Certification that the geotextile meets or exceeds the required properties of the Drawings and this Section.

1.05 CQA MONITORING

A. The Contractor shall be aware of and accommodate all monitoring and conformance testing required by the CQA Plan. This monitoring and testing, including random conformance testing of construction materials and completed work, will be performed by the CQA Consultant. If nonconformances or other deficiencies are found in the Contractor's materials or completed work, the Contractor will be required to repair the deficiency or replace the deficient materials at no additional expense to the Owner.

PART 2 – PRODUCTS

2.01 GEOTEXTILE PROPERTIES

A. The Geotextile Manufacturer shall furnish materials that meet or exceed the criteria specified in Table 02771-1 in accordance with the minimum average roll value (MARV), as defined by ASTM D 4439.

B. The cushion geotextile shall be nonwoven materials, suitable for use in filter/separation and cushion applications.

2.02 MANUFACTURING QUALITY CONTROL (MQC)

A. The geotextile shall be manufactured with MQC procedures that meet or exceed generally accepted industry standards.

B. The Geotextile Manufacturer shall sample and test the geotextile to demonstrate that the material conforms to the requirements of these Specifications.

C. Any geotextile sample that does not comply with this Section shall result in rejection of the roll from which the sample was obtained. The Contractor shall replace any rejected rolls.

D. If a geotextile sample fails to meet the MQC requirements of this Section the Geotextile Manufacturer shall additionally sample and test, at the expense of the Manufacturer, rolls manufactured in the same lot, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established to define the bounds of the failed roll(s). All the rolls pertaining to the failed rolls shall be rejected.

E. Additional sample testing may be performed, at the Geotextile Manufacturer's discretion and expense, to identify more closely the extent of non-complying rolls and/or to qualify individual rolls.

F. Sampling shall, in general, be performed on sacrificial portions of the geotextile material such that repair is not required. The Geotextile Manufacturer shall sample and test the geotextile to demonstrate that the geotextile properties conform to the values specified in Table 02771-1.

1. At a minimum, the following MQC tests shall be performed on the geotextile (results of which shall meet the requirements specified in Table 02271):

Test	Procedure	Frequency
Grab strength	ASTM D 4632	130,000 ft^2
Mass per Unit Area	ASTM D 5261	130,000 ft^2
Tear strength	ASTM D 4533	130,000 ft^2
Puncture strength	ASTM D 4833	130,000 ft^2
Permittivity	ASTM D 4491	540,000 ft^2
A.O.S.	ASTM D 4751	540,000 ft^2

G. The Geotextile Manufacturer shall comply with the certification and submittal requirements of this Section.

2.03 INTERFACE SHEAR TESTING

A. Interface shear test(s) shall be performed on the proposed geosynthetic components in accordance with Section 02270, Part 2.03.A

2.04 PACKING AND LABELING

A. Geotextile shall be supplied in rolls wrapped in relatively impervious and opaque protective covers.

B. Geotextile rolls shall be marked or tagged with the following information:

1. manufacturer's name;
2. product identification;
3. lot or batch number;
4. roll number; and
5. roll dimensions.

2.05 TRANSPORTATION, HANDLING, AND STORAGE

A. The Geosynthetic Manufacturer shall be liable for any damage to the geotextile incurred prior to and during transportation to the site.

B. The geotextile shall be delivered to the site at least 14 days prior to the planned deployment date to allow the CQA Consultant adequate time to perform conformance testing on the geotextile samples as described in Subpart 3.06 of this Section.

C. Handling, unloading, storage, and care of the geotextile at the site, prior to and following installation, are the responsibility of the Contractor. The Contractor shall be liable for any damage to the materials incurred prior to final acceptance by the Owner.

D. The Contractor shall be responsible for offloading and storage of the geotextile at the site.

E. The geotextile shall be protected from sunlight, puncture, or other damaging or deleterious conditions. The geotextile shall be protected from mud, dirt, and dust. Any additional storage procedures required by the geotextile Manufacturer shall be the responsibility of the Contractor.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work described in this Section, the Contractor shall become thoroughly familiar with the site, the site conditions, and all portions of the work falling within this Section.

B. If the Contractor has any concerns regarding the installed work of other Sections or the site, the Construction Manager shall be notified, in writing, prior to commencing the work. Failure to notify the Construction Manager or commencing installation of the geotextile will be construed as Contractor's acceptance of the related work of all other Sections.

3.02 PLACEMENT

A. Geotextile installation shall not commence over other materials until CQA conformance evaluations, by the CQA Consultant, of underlying materials are complete, including evaluations of the Contractor's survey results to confirm that the previous work was constructed to the required grades, elevations, and thicknesses. Should the Contractor begin the work of this Section prior to the completion of CQA evaluations for underlying materials or this material, this shall be at the risk of removal of these materials, at the Contractor’s expense, to remedy the non-conformances. The Contractor shall account for the CQA conformance evaluations in the construction schedule.

B. The Contractor shall handle all geotextile in such a manner as to ensure it is not damaged in any way.

C. The Contractor shall take any necessary precautions to prevent damage to underlying materials during placement of the geotextile.

D. After unwrapping the cushion geotextile from its opaque cover, the geotextile shall not be left exposed for a period in excess of 15 days unless a longer exposure period is approved in writing by the Geotextile Manufacturer.

E. The Contractor shall take care not to entrap stones, excessive dust, or moisture in the geotextile during placement.

F. The Contractor shall anchor or weight all geotextile with sandbags, or the equivalent, to prevent wind uplift.

G. The Contractor shall examine the entire geotextile surface after installation to ensure that no foreign objects are present that may damage the geotextile or adjacent layers. The Contractor shall remove any such foreign objects and shall replace any damaged geotextile.

3.03 SEAMS AND OVERLAPS

A. On slopes steeper than 10 horizontal to 1 vertical, geotextiles shall be continuous down the slope; that is, no horizontal seams are allowed. Horizontal seams shall be considered as any seam having an alignment exceeding 45 degrees from being perpendicular to the slope contour lines, unless otherwise approved by the Design Engineer. No horizontal seams shall be allowed within 5 feet of the top or toe of the slopes.

B. Nonwoven geotextile seams shall be overlapped and continuously sewn. Thread shall by polymeric with chemical and ultraviolet resistance properties equal or exceeding those of the geotextile.

C. Woven geotextile shall be overlapped and continuously sewn.

3.04 REPAIR

A. Any holes or tears in the geotextile shall be repaired using a patch made from the same geotextile. If a tear exceeds 50 percent of the width of a roll, that roll shall be removed and replaced.

3.05 PLACEMENT OF SOIL MATERIALS

A. The Contractor shall place soil materials on top of the geotextile in such a manner as to ensure that:

1. the geotextile and the underlying materials are not damaged;
2. minimum slippage occurs between the geotextile and the underlying layers during placement; and
3. excess stresses are not produced in the geotextile.

B. Equipment shall not be driven directly on the geotextile.

3.06 CONFORMANCE TESTING

A. Conformance samples of the geotextile materials will be removed by the CQA Site Manager after the material has been received at the site and sent to a Geosynthetic CQA Laboratory for testing to ensure conformance with the requirements of this Section and the CQA Plan. This testing will be carried out, in accordance with the CQA Plan, prior to the start of the work of this Section.

B. Samples of each geotextile will be taken, by the CQA Site Manager, at a minimum frequency of one sample per 260,000 square feet (minimum of one).

C. The CQA Consultant may increase the frequency of sampling in the event that test results do not comply with requirements of Subpart 2.01 of this Section until passing conformance test results are obtained for all material that is received at the site. This additional testing shall be performed at the expense of the Contractor.

D. The following conformance tests will be performed (results of which shall meet the requirements specified in Table 02771):

Test	Cushion Geotextile Procedure	Woven Geotextile Procedure
Grab strength	ASTM D 4632	ASTM D 4632
Mass per Unit Area	ASTM D 5261	N/A
Puncture strength	ASTM D 4833	ASTM D 4833

Test	Cushion Geotextile Procedure	Woven Geotextile Procedure
Permittivity	ASTM D 4491	ASTM D 4491
A.O.S.	ASTM D 4751	ASTM D 4751

E. Any geotextile that is not certified in accordance with Subpart 1.04 of this Section, or that conformance testing results do not comply with Subpart 2.01 of this Section, will be rejected. The Contractor shall replace the rejected material with new material. All other rolls that are represented by failing test results will also be rejected, unless additional testing is performed to further determine the bounds of the failed material.

3.07 PROTECTION OF WORK

A. The Contractor shall protect all work of this Section.

B. In the event of damage, the Contractor shall make repairs and replacements to the satisfaction of the Construction Manager at the expense of the Contractor.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for Geotextile will be incidental to PVC Pipe, and payment will be based on the unit price provided for PVC Pipe on the Bid Schedule.

B. The following are considered incidental to the work:

- Submittals.
- Quality Control.
- Shipping, handling, and storage.
- Layout survey.
- Mobilization.
- Rejected material.
- Overlaps and seaming.
- Rejected material removal, handling, re-testing, and repair.
- Temporary anchorage.

TABLE 02771-1
REQUIRED PROPERTY VALUES FOR GEOTEXTILE

PROPERTIES	QUALIFIERS	UNITS	NONWOVEN CUSHION GEOTEXTILE SPECIFIED VALUES	WOVEN GEOTEXTILE SPECIFIED VALUES	TEST METHOD
Physical Properties					
Mass per unit area	Minimum	oz/yd^2	16	N/A	ASTM D 5261
Apparent opening size (O_{95})	Maximum	mm	0.21	0.43	ASTM D 4751
Permittivity	Minimum	s^{-1}	0.5	0.05	ASTM D 4491
Grab strength	Minimum	lb	390	200	ASTM D 4632
Tear strength	Minimum	lb	150	N/A	ASTM D 4533
Puncture strength	Minimum	lb	1,120	700	ASTM D 6241
Ultraviolet Resistance @ 500 hours	Minimum	%	70	70	ASTM D 4355

[END OF SECTION]

SECTION 02772
GEOSYNTHETIC CLAY LINER (OPTION B ONLY)

PART 1 – GENERAL

1.01 SCOPE

A. The Geosynthetic Installer shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary for installation of the geosynthetic clay liner (GCL). The work shall be carried out as specified herein and in accordance with the Drawings and Construction Quality Assurance (CQA) Plan.

B. The work shall include, but not be limited to, delivery, offloading, storage, placement, anchorage, and seaming of the GCL.

1.02 RELATED SECTIONS

Section 02220 – Subgrade Preparation

Section 02770 – Geomembrane

1.03 REFERENCES

A. Drawings

B. Site CQA Plan

C. Latest Version American Society of Testing and Materials (ASTM) Standards:

ASTM D 5887	Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens using a Flexible Wall Permeameter
ASTM D 5888	Guide for Storage and Handling of Geosynthetic Clay Liners
ASTM D 5890	Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners
ASTM D 5891	Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners
ASTM D 5993	Test Method for Measuring Mass per Unit Area of Geosynthetic Clay Liners

1.04 QUALIFICATIONS

A. GCL Manufacturer:

1. The Manufacturer shall be a well-established firm with more than five (5) years of experience in the manufacturing of GCL.

2. The GCL Manufacturer shall be responsible for the production of GCL rolls and shall have sufficient production capacity and qualified personnel to provide material meeting the requirements of this Section and the construction schedule for this project.

B. GCL Installer:

1. The Geosynthetic Installer shall install the GCL and shall meet the requirements of Section 02770 Subpart 1.04. B and this Section.

2. The Geosynthetics Installer shall be responsible and shall provide sufficient resources for field handling, deploying, temporarily restraining (against wind), and other aspects of the deployment and installation of the GCL and other geosynthetic components of the project.

1.05 SUBMITTALS

A. At least 7 days before transporting any GCL to the site, the Manufacturer shall provide the following documentation to the Construction Manager for approval.

1. list of material properties, including test methods utilized to analyze/confirm properties.

2. projected delivery dates for this project.

3. Manufacturing quality control certificates for each shift's production for which GCL for the project was produced, signed by responsible parties employed by the Manufacturer (such as the production manager).

4. Manufacturer Quality Control (MQC) certificates, including:

a. roll numbers and identification; and

b. MQC results, including description of test methods used, outlined in Subpart 2.02 of this Section.

5. Certification that the GCL meets all the properties outlined in Subpart 2.01 of this Section.

B. During installation, the Geosynthetic Installer shall be responsible for the timely submission to the Construction Manager of:

1. Quality control documentation; and

2. Subgrade Acceptance Certificates, signed by the Geosynthetic Installer, for each area of subgrade to be covered by geosynthetic clay liner.

1.06 CONSTRUCTION QUALITY ASSURANCE (CQA) MONITORING

A. The Geosynthetic Installer shall be aware of all monitoring and conformance testing required by the CQA Plan. This monitoring and testing, including random conformance testing of construction materials and completed work, will be performed by the CQA Consultant. If nonconformances or other deficiencies are found in the materials or completed work, the Geosynthetic Installer will be required to repair the deficiency or replace the deficient materials at no additional cost to the Owner.

PART 2 – PRODUCTS

2.01 MATERIAL PROPERTIES

A. The flux of the bentonite portion of the GCL shall be no greater than 1×10^{-8} m^3/m^2-sec, when measured in a flexible wall permeameter in accordance with ASTM D 5887 under an effective confining stress of 5 pounds per square inch (psi).

B. The GCL shall have the following minimum dimensions:

1. the minimum roll width shall be 15 feet; and

2. the linear length shall be long enough to conform with the requirements specified in this Section.

C. The bentonite component of the GCL shall be applied at a minimum concentration of 0.75 pound per square foot (psf), when measured at a water content of 0 percent.

D. The GCL shall meet or exceed all required property values listed in Table 02772-1.

E. The bentonite will be adhered to the backing material(s) in a manner that prevents it from being dislodged when transported, handled, and installed in a manner prescribed by the Manufacturer. The method used to hold the bentonite in place shall not be detrimental to other components of the lining system.

F. The geotextile components of the GCL shall be woven and nonwoven and have a combined mass per unit area of 9 ounces per square yard (oz./SY).

G. The GCL shall be needle punched.

2.02 INTERFACE SHEAR TESTING

A. Interface shear testing requirements and results shall be in accordance with Section 02770 2.03A.

2.03 MANUFACTURING QUALITY CONTROL (MQC)

A. The GCL shall be manufactured with quality control procedures that meet or exceed generally accepted industry standards.

B. The Manufacturer shall sample and test the GCL to demonstrate that the material complies with the requirements of this Section.

C. Any GCL sample that does not comply with this Section will result in rejection of the roll from which the sample was obtained. The Manufacturer shall replace any rejected rolls.

D. If a GCL sample fails to meet the quality control requirements of this Section, the Construction Manager will require that the Manufacturer sample and test, at the expense of the Manufacturer, rolls manufactured in the same lot, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established to determine the bounds of the failed roll(s). All rolls pertaining to failed tests shall be rejected.

E. Additional sample testing may be performed, at the Manufacturer's discretion and expense, to more closely identify the extent of any non-complying rolls and/or to qualify individual rolls.

F. Sampling shall, in general, be performed on sacrificial portions of the GCL material such that repair is not required. The Manufacturer shall sample and test the GCL to demonstrate that its properties conform to the requirements stated herein. At a minimum, the following (MQC) tests shall be performed by the Manufacturer: dry mass per unit area (ASTM D5993) and index flux at frequencies of at least one per 50,000 square feet and one per 200,000 square feet, respectively.

G. The Manufacturer shall comply with the certification and submittal requirements of this Section.

2.04 PACKING AND LABELING

A. GCL shall be supplied in rolls wrapped in impervious and opaque protective covers.

B. GCL shall be marked or tagged with the following information:

1. Manufacturer's name;
2. product identification;
3. lot number;
4. roll number; and
5. roll dimensions.

2.05 TRANSPORTATION, HANDLING AND STORAGE

A. The Geosynthetic Manufacturer shall be liable for any damage to the GCL incurred prior to and during transportation to the site.

B. Handling, storage, and care of the GCL at the site prior to and following installation, are the responsibility of the Geosynthetic Installer, until final acceptance by the Owner.

C. The GCL shall be stored and handled in accordance with ASTM D 5888.

D. The Geosynthetic Installer shall be liable for all damage to the materials incurred prior to and during transportation to the site including hydration of the GCL prior to placement.

E. The GCL shall be on-site at least 14 days prior to the scheduled installation date to allow for completion of conformance testing described in Subpart 3.07 of this Section.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work described in this Section, the Geosynthetic Installer shall carefully inspect the installed work of all other Sections and verify that all work is complete to the point where the installation of this Section may properly commence without adverse impact.

B. If the Geosynthetic Installer has any concerns regarding the installed work of other Sections, he should notify the Construction Manager in writing prior to commencing the work. Failure to notify the Construction Manager or commencing installation of the GCL will be construed as Geosynthetic Installer's acceptance of the related work of all other Sections.

C. A pre-installation meeting shall be held to coordinate the installation of the GCL with the installation of other components of the lining system.

3.02 SURFACE PREPARATION

A. The Geosynthetics Installer shall provide certification in writing that the surface on which the GCL will be installed is acceptable. This certification of acceptance shall be given to the Construction Manager prior to commencement of geosynthetics installation in the area under consideration. Special care shall be taken to maintain the prepared soil surface.

B. Special care shall be taken to maintain the prepared soil surface. The subgrade shall be moisture conditioned prior to installation of the GCL. GCL subgrade shall be moisture conditioned the day before installation such that the surface is workable but not dry to a depth of more than 1 inch from subgrade surface.

C. No GCL shall be placed onto an area that has been softened by precipitation or that has cracked due to desiccation. The soil surface shall be observed daily to evaluate the effects of desiccation cracking and/or softening on the integrity of the prepared subgrade.

D. Subgrade protrusions shall not exceed 0.7 inch.

3.03 HANDLING AND PLACEMENT

A. The Geosynthetic Installer shall handle all GCL in such a manner that it is not damaged in any way.

B. In the presence of wind, all GCL shall be sufficiently weighted with sandbags to prevent their movement.

C. Any GCL damaged by stones or other foreign objects, or by installation activities, shall be repaired in accordance with Subpart 3.06 by the Geosynthetic Installer, at the expense of the Geosynthetic Installer.

D. All GCL shall be hydrated by the Geosynthetic Installer once in place by direct spraying with water. Hydrated GCL shall be defined as greater than 50% moisture content when tested in accordance with ASTM D 2216. To monitor the hydration process, small, shallow, flat bottom containers shall be deployed on the GCL surface by the CQA Site Manager during water spraying to measure the amount (depth) of water applied. Minimum depth of water will be 1/8-inch. During hot, dry periods, additional water may be required. Upon completion of the direct spraying with water, the GCL shall be covered with the overlying secondary geomembrane within 2 hours. Samples of the hydrated GCL will be obtained by the CQA Site Manager from locations of destructive tests in the secondary geomembrane. GCL sample holes shall be repaired in accordance with Part 3.06 of this Section.

E. The GCL shall be installed with the woven geotextile facing up (against the overlying geomembrane).

3.04 OVERLAPS

A. On slopes steeper than 10:1 (horizontal:vertical), all GCL shall be continuous down the slope, i.e., no horizontal seams shall be allowed on the slope. Horizontal seams shall be considered as any seam having an alignment exceeding 30 degrees from being perpendicular to the slope contour lines, unless otherwise approved by the Construction Manager.

B. All GCL shall be overlapped in accordance with the Manufacturer's recommended procedures. At a minimum, along the length (i.e., the sides) of the GCL placed on slopes steeper than 10:1 (horizontal:vertical), the overlap shall be 12 inches, and along the width (i.e., the ends) the overlap shall be 24 inches.

C. At a minimum, along the length (i.e., the sides) of the GCL placed on non-sloped areas (i.e. slopes no steeper than 10:1), the overlap shall be 6-inches, and along the width (i.e., the ends) the overlap shall be 12-inches.

3.05 MATERIALS IN CONTACT WITH THE GCL

A. Installation of other components of the liner system shall be carefully performed to avoid damage to the GCL.

B. Construction Manager approved low ground pressure equipment may be driven directly on the GCL.

C. Installation of the GCL in appurtenant areas, and connection of the GCL to appurtenances shall be made according to the Drawings. The Geosynthetic Installer shall ensure that the GCL is not damaged while working around the appurtenances.

3.06 REPAIR

A. Any holes or tears in the GCL shall be repaired by placing a GCL patch over the defect. On slopes steeper than 10 percent, the patch shall overlap the edges of the hole or tear by a minimum of 2 feet in all directions. On slopes 10 percent or flatter, the patch shall overlap the edges of the hole or tear by a minimum of 1 foot in all directions. The patch shall be secured with a Manufacturer recommended water-based adhesive.

B. Care shall be taken to remove any soil, rock, or other materials, which may have penetrated the torn GCL.

C. The patch shall not be nailed or stapled.

3.07 CONFORMANCE TESTING

A. Samples of the GCL will be removed by the CQA Site Manager and sent to a Geosynthetic CQA Laboratory for testing to ensure conformance with the requirements of this Section and the CQA Plan. The Geosynthetic Installer shall assist the CQA Site Manager in obtaining conformance samples. The Geosynthetic Installer shall account for this testing in the installation schedule.

B. At a minimum, the following conformance tests will be performed at a minimum frequency rate of one sample per 100,000 square feet: mass per unit area (ASTM D 5993) and bentonite moisture content (ASTM D 5993). At a minimum, the following conformance tests will be performed at a frequency of one sample per 400,000 square feet: index flux (ASTM D 5887). If the GCL Manufacturer provides material that requires sampling at a frequency (due to lot size, shipment size, etc.) resulting in one sample per less than 90 percent of 100,000 square feet (90,000 square feet), then the Geosynthetic Installer shall pay the cost for all additional testing.

C. The CQA Consultant may increase the frequency of sampling in the event that test results do not comply with the requirements of Subpart 2.01 of this Section until passing conformance test results are obtained for all material that is received at the site. This additional testing shall be performed at the expense of the Geosynthetic Installer.

D. Any GCL that is not certified by the Manufacturer in accordance with Subpart 1.05 of this Section or that does not meet the requirements specified in Subpart 2.01 shall be rejected and replaced by the Geosynthetic Installer, at the expense of the Geosynthetic Installer.

3.08 PROTECTION OF WORK

A. The Geosynthetic Installer shall protect all work of this Section.

B. In the event of damage, the Geosynthetic Installer shall immediately make all repairs and replacements necessary to the approval of the Construction Manager, at the expense of the Geosynthetic Installer.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for GCL will be measured as in-place square feet (SF), as measured by the surveyor, to the limits shown on the Drawings, and payment will be based on the unit price provided on the Bid Schedule.

B. The following are considered incidental to the Work:

- Submittals.
- Quality Control.
- Shipping, handling and storage.
- Overlaps and seaming.
- Hydration.
- Layout survey.
- Mobilization.
- Rejected material.
- Rejected material removal, handling, re-testing, and repair.
- Overlaps and seaming.
- Temporary anchorage.
- Visqueen.

TABLE 02772-1
REQUIRED GCL PROPERTY VALUES

PROPERTIES	QUALIFIERS	UNITS	SPECIFIEDVALUES	TEST METHOD
GCL Properties				
Bentonite Content[2]	minimum	lb/ft^3	0.75	ASTM D 5993
Bentonite Swell Index	minimum	mL/2g	24	ASTM D 5890
Bentonite Fluid Loss	maximum	mL	18	ASTM D 5891
Hydraulic Index Flux	maximum	m^3/m^2-s	1 x 10^{-8}	ASTM D 5887[1]

Notes: (1) Hydraulic flux testing shall be performed under an effective confining stress of 5 pounds per square inch.
(2) Measured at a moisture content of 0 percent; also known as mass per unit area

[END OF SECTION]

SECTION 02773

GEONET

PART 1 – GENERAL

1.01 SCOPE

A. The Geosynthetic Installer shall furnish all labor, materials, tools, supervision, transportation, equipment, and incidentals necessary for installation of the geonet. The work shall be carried out as specified herein and in accordance with the Drawings and Construction Quality Assurance (CQA) Plan.

B. The work shall include, but not be limited to, delivery, offloading, storage, placement, anchorage, and seaming of the geonet.

C. 300-mil geonet shall be installed above the secondary geomembrane to form the primary leak detection system. 200-mil geonet shall be installed overlying the butt seams of the tertiary Drain Liner™ geomembrane, if applicable.

1.02 RELATED SECTIONS

Section 02220 – Subgrade Preparation

Section 02225 – Drainage Aggregate

Section 02616 – Polyvinyl Chloride (PVC) Pipe

Section 02770 – Geomembrane

Section 02771 – Geotextile

1.03 REFERENCES

A. Drawings

B. Site CQA Plan

C. Latest Version ASTM International (ASTM) Standards:

ASTM D792	Standard Test Methods for Specific Gravity and Density of Plastics by Displacement
ASTM D1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique
ASTM D1603	Standard Test Method for Carbon Black in Olefin Plastics
ASTM D4218	Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by Muffle-Furnace Technique
ASTM D4716	Standard Test Method for Constant Head Hydraulic Transmissivity (In-Place Flow) of Geotextiles and Geotextile Related Products
ASTM D5199	Standard Test Method for Measuring Nominal Thickness of Geosynthetics

1.04 QUALIFICATIONS

A. Geonet Manufacturer:

1. The Manufacturer shall be a well-established firm with more than five (5) years of experience in the manufacturing of geonet.

2. The Manufacturer shall be responsible for the production of geonet rolls and shall have sufficient production capacity and qualified personnel to provide material meeting the requirements of this Section and the construction schedule for this project.

B. Geonet Installer:

1. The Geosynthetic Installer shall meet the requirements of Subpart 1.04. B of Section 02770, and this Section.

2. The Geosynthetics Installer shall be responsible and shall provide sufficient resources for field handling, deploying, temporarily restraining (against wind and re-curling), and other aspects of the deployment and installation of the geonet and other geosynthetic components of the project.

1.05 SUBMITTALS

A. At least 7 days before transporting any geonet to the site, the Manufacturer shall provide the following documentation to the Construction Manager for approval.

1. list of material properties, including test methods utilized to analyze/confirm properties.

2. projected delivery dates for this project.

3. Manufacturing Quality Control (MQC) certificates for each shift's production for which geonet for the project was produced, signed by responsible parties employed by the Manufacturer (such as the production manager). MQC certificates shall include:

a. roll numbers and identification; and

b. MQC results, including description of test methods used, outlined in Subpart 2.01 of this Section.

c. Certification that the geonet meets all the properties outlined in Subpart 2.01 of this Section.

1.06 CONSTRUCTION QUALITY ASSURANCE (CQA)

A. The Geosynthetic Installer shall ensure that the materials and methods used for producing and handling the geonet meet the requirements of the Drawings and this Section. Any material or method that does not conform to these documents, or to alternatives approved in writing by the Design Engineer, will be rejected and shall be repaired or replaced, at the Geosynthetic Installer's expense.

B. The Geosynthetic Installer shall be aware of all monitoring and conformance testing required by the CQA Plan. This monitoring and testing, including random conformance testing of construction materials and completed work, will be performed by the CQA Consultant. If nonconformances or other deficiencies are found in the materials or completed work, the Geosynthetic Installer will be required to repair the deficiency or replace the deficient materials at no additional cost to the Owner.

PART 2 – PRODUCTS

2.01 GEONET PROPERTIES

A. The Manufacturer shall furnish geonet having properties that comply with the required property values shown on Table 02773-1.

B. In addition to documentation of the property values listed in Table 02773-1, the geonet shall contain a maximum of one percent by weight of additives, fillers, or extenders (not including carbon black) and shall not contain foaming agents or voids within the ribs of the geonet.

2.02 MANUFACTURING QUALITY CONTROL (MQC)

A. The geonet shall be manufactured with MQC procedures that meet or exceed generally accepted industry standards.

B. Any geonet sample that does not comply with the Specifications will result in rejection of the roll from which the sample was obtained. The Geonet Manufacturer shall replace any rejected rolls at no additional cost to Owner.

C. If a geonet sample fails to meet the MQC requirements of this Section, then the Geonet Manufacturer shall sample and test each roll manufactured, in the same lot, or at the same time, as the failing roll. Sampling and testing of rolls shall continue until a pattern of acceptable test results is established.

D. Additional sample testing may be performed, at the Geonet Manufacturer's discretion and expense, to more closely identify any non-complying rolls and/or to qualify individual rolls.

E. Sampling shall, in general, be performed on sacrificial portions of the geonet material such that repair is not required. The Manufacturer shall sample and test the geonet, at a minimum, once every 100,000 square feet to demonstrate that its properties conform to the values specified in Table 02773-1.

F. At a minimum, the following MQC tests shall be performed:

Test	Procedure
Density	ASTM D 792 or D 1505
Thickness	ASTM D 5199
Carbon Black Content	ASTM D 1603

G. The hydraulic transmissivity test (ASTM D 4716) in Table 02773-1 need not be performed at a frequency of one per 100,000 square feet. However, the Geonet Manufacturer will certify that this test has been performed on a sample of geonet identical to the product that will be delivered to the Site. The Geonet Manufacturer shall provide test results as part of MQC documentation.

H. The Geonet Manufacturer shall comply with the certification and submittal requirements of this Section.

2.03 LABELING

A. Geonet shall be supplied in rolls labeled with the following information:

1. manufacturer's name;
2. product identification;
3. lot number;
4. roll number; and
5. roll dimensions.

2.04 TRANSPORTATION

A. Transportation of the geonet shall be the responsibility of the Geonet Manufacturer. The Geonet Manufacturer shall be liable for all damages to the materials incurred prior to and during transportation to the site.

B. Geonet shall be delivered to the site at least 7 days before the scheduled date of deployment to allow the CQA Site Manager adequate time to inventory the geonet rolls and obtain additional conformance samples, if needed. The Geosynthetic Installer shall notify the Construction Manager a minimum of 48 hours prior to any delivery.

2.05 HANDLING AND STORAGE

A. The Geosynthetic Manufacturer shall be responsible for handling, off-loading, storage, and care of the geonet prior to and following installation at the Site. The Geosynthetic Installer shall be liable for all damages to the materials incurred prior to final acceptance of the geonet drainage layer by the Owner.

B. The geonet shall be stored off the ground and out of direct sunlight, and shall be protected from mud and dirt. The Geosynthetic Installer shall be responsible for implementing any additional storage procedures required by the Geonet Manufacturer.

2.06 CONFORMANCE TESTING

A. Conformance testing, if required, shall be performed in accordance with the CQA Plan. The Geosynthetics installer shall assist the CQA Site Manager in obtaining conformance samples, if requested. The CQA Consultant has the option of collecting samples at the manufacturing facility.

B. Passing conformance testing results, if applicable, are required before any geonet is deployed.

C. Samples shall be taken at a minimum frequency of one sample per 200,000 square feet with a minimum of one sample per lot. If the Geonet Manufacturer provides material that requires sampling at a frequency (due to lot size, shipment size, etc.) resulting in one sample per less than 90 percent of 200,000 square feet (180,000 square feet), then the Geosynthetic Installer shall pay the cost for all additional testing.

D. The CQA Consultant may increase the frequency of sampling in the event that test results do not comply with the requirements of Subpart 2.01 of this Section until passing conformance test results are obtained for all material that is received at the Site. This additional testing shall be performed at the expense of the Geosynthetic Installer.

E. Any geonet that are not certified in accordance with Subpart 1.05 of this Section, or that conformance testing indicates do not comply with Subpart 2.01 of this Section, will be rejected by the CQA Consultant. The Geonet Manufacturer shall replace the rejected material with new material at no additional cost to the Owner.

PART 3 – EXECUTION

3.01 HANDLING AND PLACEMENT

A. The geonet shall be handled in such a manner as to ensure it is not damaged in any way.

B. Precautions shall be taken to prevent damage to underlying layers during placement of the geonet.

C. The geonet shall be installed in a manner that minimizes wrinkles.

D. Care shall be taken during placement of geonet to prevent dirt or excessive dust in the geonet that could cause clogging and/or damage to the adjacent materials.

3.02 JOINING AND TYING

A. Adjacent panels of geonet shall be overlapped by at least 4 inches. These overlaps shall be secured by tying with nylon ties.

B. Tying shall be achieved by plastic fasteners or polymer braid. Tying devices shall be white or yellow for easy inspection. Metallic devices shall not be used.

C. Tying shall be performed at a minimum interval of every 5 feet along the geonet roll edges and 2 feet along the geonet roll ends.

3.03 REPAIR

A. Any holes or tears in the geonet shall be repaired by placing a patch extending 1 foot beyond the edges of the hole or tear. The patch shall be secured to the original geonet by tying every 6 inches with approved tying devices. If the hole or tear width across the roll is more than 50 percent of the width of the roll, then the damaged area shall be cut out and the two portions of the geonet shall be joined in accordance with the requirements of Subpart 3.02 of this Section.

3.04 PRODUCT PROTECTION

A. The Geosynthetics Installer shall use all means necessary to protect all prior work, and all materials and completed work of other Sections.

B. In the event of damage to the geonet, the Geosynthetic Installer shall immediately make all repairs per the requirements of this Section.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for geonet will be measured as in-place square feet (SF), as measured by the surveyor, to the limits shown on the Drawings, and payment will be based on the unit price provided on the Bid Schedule.

B. The following are considered incidental to the Work:

- Submittals.
- Quality Control.
- Shipping, handling, and storage.
- Overlaps and seaming.
- Layout survey.
- Offloading.
- Mobilization.
- Rejected material.

- Rejected material removal, handling, re-testing, and repair.
- Temporary anchorage.

TABLE 02773-1
REQUIRED GEONET PROPERTY VALUES

PROPERTIES	QUALIFIERS	UNITS	300-MIL GEONET SPECIFIED(1) VALUES	200-MIL GEONET SPECIFIED(1) VALUES	TEST METHOD
Resin Density	Minimum	g/cc	0.94	0.94	ASTM D792 or D1505
Carbon Black Content	Range	%	2.0 – 3.0	2.0 – 3.0	ASTM D1603 or D4218
Thickness	Minimum	mils	300	200	ASTM D5199
Transmissivity(2)	Minimum	m^2 / sec	8×10^{-3}	1×10^{-3}	ASTM D4716

Notes: (1) All values (except transmissivity) represent average roll values.
(2) Transmissivity shall be measured using water at 68°F with a gradient of 0.1 under a confining pressure of 7,000 lb/ft^2. The geonet shall be placed in the testing device between 60-mil HDPE smooth geomembrane. Measurements are taken one hour after application of confining pressure.
(3) Interface shear strength testing shall be performed, by the CQA Consultant, in accordance with Part 2.03 of this Section.

[END OF SECTION]

SECTION 03400

CAST-IN-PLACE CONCRETE

PART 1 – GENERAL

1.01 DESCRIPTION OF WORK

A. The Contractor shall furnish all labor, materials, tools, transportation and equipment necessary to construct a cast-in-place spillway crossing as shown on the Drawings and as specified herein.

B. The Work shall include, but not be limited to, procurement, delivery, subgrade preparation, formwork, concrete placement, control joints, surface treatment, and curing.

1.02 RELATED SECTIONS

None.

1.03 REFERENCES

A. Drawings

B. Construction Quality Assurance (CQA) Plan

C. Latest version of American Concrete Institute (ACI) standards:

ACI 117	Tolerances for Concrete Construction and Materials
ACI 211.1	Selecting Proportions for Normal, Heavyweight, and Mass Concrete
ACI 301	Structural Concrete for Buildings
ACI 304R	Measuring, Mixing, Transporting, and Placing Concrete
ACI 308	Standard Practice for Curing Concrete
ACI 318	Building Code Requirements for Reinforced Concrete
ACI 347R	Formwork for Concrete

D. Latest version of the ASTM International (ASTM) standards:

ASTM A 615	Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
ASTM C 33	Concrete Aggregates
ASTM C 39	Compressive Strength of Cylindrical Concrete Specimens
ASTM C 94	Ready- Mixed Concrete
ASTM C 127	Specific Gravity and Adsorption of Coarse Aggregate
ASTM C 128	Specific Gravity and Adsorption of Fine Aggregate
ASTM C 143	Slump of Hydraulic Cement Concrete
ASTM C 150	Portland Cement

ASTM C 171	Sheet Materials for Curing Concrete
ASTM C 192	Making and Curing Concrete Test Specimens in the Laboratory
ASTM C 309	Liquid Membrane - Forming Compounds for Curing Concrete
ASTM C 403	Time of Setting of Concrete Mixtures by Penetration Resistance
ASTM C 494	Chemical Admixtures for Concrete
ASTM C 618	Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete

1.04 SUBMITTALS

A. At least 7 days prior to construction of the concrete, Contractor shall submit a mix design for the type of concrete. Submit a complete list of materials including types, brands, sources, amount of cement, fly ash, pozzolans, retardants, and admixtures, and applicable reference specifications for the following:

1. Slump design based on total gallons of water per cubic yard.

2. Type and quantity of cement.

3. Brand, type, ASTM designation, active chemical ingredients, and quantity of each admixture.

4. Compressive strength based on 28-day compression tests.

B. Delivery Tickets:

1. Provide duplicate delivery tickets with each load of concrete delivered, one for Contractor's records and one for the Construction Manager, with the following information:

a. Date and serial number of ticket.
b. Name of ready-mixed concrete plant, operator, and job location.
c. Type of cement, admixtures, if any, and brand name.
d. Cement content, in bags per cubic yard (CY) of concrete, and mix design.
e. Truck number, time loaded, and name of dispatcher.
f. Amount of concrete (CY) in load delivered.
g. Gallons of water added at job, if any, and slump of concrete after water was added.

C. Delivery

1. The Concrete Manufacturer shall be liable for all damage to the materials incurred prior to and during transportation to the Site.

1.05 MANUFACTURER QUALITY CONTROL (MQC)

A. Aggregates shall be sampled and tested in accordance with ASTM C 33.

B. Concrete test specimens shall be made, cured, and stored in conformity with ASTM C 192 and tested in conformity with ASTM C 39.

C. Slump shall be determined in accordance with ASTM C 143.

1.06 LIMITING REQUIREMENTS

A. Unless otherwise specified, each concrete mix shall be designed and concrete shall be controlled within the following limits:

1. Concrete slump shall be kept as low as possible, consistent with proper handling and thorough compaction. Unless otherwise authorized by the Construction Manager, slump shall not exceed 5 inches.

2. The admixture content, batching method, and time of introduction to the mix shall be in accordance with the manufacturer's recommendations for minimum shrinkage and for compliance with this Section. A water-reducing admixture may be included in concrete.

PART 2 – PRODUCTS

2.01 PROPORTIONING AND DESIGN MIXES

A. Concrete shall have the following properties.

1. 3,000 pounds per square inch (psi), 28-day compressive strength.

2. Slump range of 1 to 5 inches.

3. Coarse Aggregate Gradation, ASTM C 33, Number 57 or 67.

B. Retarding admixture in proportions recommended by the manufacturer to attain additional working and setting time from 1 to 5 hours.

2.02 CONCRETE MATERIALS

A. Cement shall conform to ASTM C 150 Type II.

B. Water shall be fresh and clean, free from oils, acids, alkalis, salts, organic materials, and other substances deleterious to concrete.

C. Aggregates shall conform to ASTM C 33. Aggregates shall not contain any substance which may be deleteriously reactive with the alkalis in the cement, and shall not possess properties or constituents that are known to have specific unfavorable effects in concrete.

D. The Contractor may use a water reducing chemical admixture. The water reducing admixture shall conform to ASTM C 494, Type A. The chemical admixture shall be approved by the Construction Manager.

2.03 REINFORCING STEEL

A. The reinforcing steel shall be Grade 60 in accordance with ASTM A 615.

B. Unless otherwise noted on the Drawings, all reinforcement bars shall be No. 3 (3/8-inch diameter) in accordance with ASTM A 615 and welded wire fabric shall be sized as 6 x 6, W1.4 x W1.4.

PART 3 – EXECUTION

3.01 BATCHING, MIXING, AND TRANSPORTING CONCRETE

A. Batching shall be performed according to ASTM C 94, ACI 301, and ACI 304R, except as modified herein. Batching equipment shall be such that the concrete ingredients are consistently measured within the following tolerances: 1 percent for cement and water, 2 percent for aggregate, and 3 percent for admixtures. Concrete Manufacturer shall furnish mandatory batch ticket information for each load of ready mix concrete.

B. Machine mixing shall be performed according to ASTM C 94 and ACI 301. Mixing shall begin within 30 minutes after the cement has been added to the aggregates. Concrete shall be placed within 90 minutes of either addition of mixing water to cement and aggregates or addition of cement to aggregates. Additional water may be added, provided that both the specified maximum slump and water-cement ratio are not exceeded. When additional water is added, an additional 30 revolutions of the mixer at mixing speed is required. Dissolve admixtures in the mixing water and mix in the drum to uniformly distribute the admixture throughout the batch.

C. Transport concrete from the mixer to the forms as rapidly as practicable. Prevent segregation or loss of ingredients. Clean transporting equipment thoroughly before each batch. Do not use aluminum pipe or chutes. Remove concrete which has segregated in transporting and dispose of as directed.

3.02 SUBGRADE PREPARATION

A. Subgrade shall be graded to the lines and elevations as shown on the Drawings.

B. Standing water, mud, debris, and foreign matter shall be removed before concrete is placed.

3.03 PLACING CONCRETE

A. Place concrete in accordance with ACI 301, ACI 318, and ACI 304R. Place concrete as soon as practicable after the forms and the reinforcement have been approved by the CQA Site Manager. Do not place concrete when weather conditions prevent proper placement and consolidation, in uncovered areas during periods of precipitation, or in standing water. Prior to placing concrete, remove dirt, construction debris, water, snow, and ice from within the forms. Deposit concrete as close as practicable to the final position in the forms. Place concrete in one continuous operation from one end of the structure towards the other

B. Ensure reinforcement is not disturbed during concrete placement.

C. Do not allow concrete temperature to decrease below 50 °F while curing. Cover concrete and provide sufficient heat to maintain 50 °F minimum adjacent to both the formwork and the structure while curing. Limit the rate of cooling to 5 °F in any 1 hour and 50 °F per 24 hours after heat application.

D. Do not spread concrete with vibrators. Concrete shall be placed in final position without being moved laterally more than 5 feet.

E. When placing of concrete is temporarily halted or delayed, provide construction joints.

F. Concrete shall not be dropped a distance greater than 5 feet.

G. Place concrete with aid of internal mechanical vibrator equipment capable of 9,000 cycles/minute. Transmit vibration directly to concrete.

H. Hot Weather:

1. Comply with ACI 304R.

2. Concrete temperature shall not exceed 90°F.

3. At air temperatures of 80°F or above, keep concrete as cool as possible during placement and curing. Cool forms by water wash.

4. Evaporation reducer shall be used in accordance with manufacturer recommendations (Subpart 2.02).

3.04 CURING AND PROTECTION

A. Immediately after placement, protect concrete from premature drying, excessively hot or cold temperatures, and mechanical injury in accordance with ACI 308.

B. Immediately after placement, protect concrete from plastic shrinkage by applying evaporation reducer in accordance with manufacturer recommendations (Subpart 2.02).

C. Maintain concrete with minimal moisture loss at relatively constant temperature for period necessary for hydration of cement and hardening of concrete (Subpart 2.02).

D. Protect from damaging mechanical disturbances, particularly load stresses, heavy shock, and excessive vibration.

E. Membrane curing compound shall be spray applied at a coverage of not more than 300 square feet per gallon. Unformed surfaces shall be covered with curing compound within 30 minutes after final finishing. If forms are removed before the end of the specified curing period, curing compound shall be immediately applied to the formed surfaces before they dry out.

F. Curing compound shall be suitably protected against abrasion during the curing period.

G. Film curing will not be allowed.

3.05 FORMS

A. Formwork shall prevent leakage of mortar and shall conform to the requirements of ACI 347R.

B. Do not disturb forms until concrete is adequately cured.

C. Form system design shall be the Contractor’s responsibility.

3.06 CONTROL JOINTS

A. Control joints shall consist of plastic strips set flush with finished surface or ¼-inch wide joints formed with a trowel immediately after pouring or cut with a diamond saw within 12 hours after pouring.

B. Control joints shall be installed in a 15 foot by 15 foot grid spacing along the slab unless otherwise approved by the Design Engineer. Control joints shall be no greater than 1 ½ inches below the surface.

3.07 SLAB FINISHES

A. Unformed surfaces of concrete shall be screeded and given an initial float finish followed by additional floating, and troweling where required.

B. Concrete shall be broom finished.

3.08 SURVEY

A. The Surveyor shall locate the features of the concrete structure. The dimensions, locations and elevations of the features shall be presented on the Surveyor’s Record Drawings.

PART 4 – MEASUREMENT AND PAYMENT

4.01 GENERAL

A. Providing for and complying with the requirements set forth in this Section for Cast-In-Place Concrete will be measured as lump sum (LS) and payment will be based on the unit price provided on the Bid Schedule.

B. The following are considered incidental to the work:

- Mobilization.
- Submittals.
- Quality Control.
- Excavation.
- Subgrade preparation.
- Concrete batching, mixing, and delivery.
- Layout and as-built Record Survey.
- Subgrade preparation.
- Reinforcing steel.
- Formwork.
- Concrete placement and finishing.
- Saw cutting and control joints.
- Rejected material removal, handling, re-testing, repair, and replacement.

[END OF SECTION]

APPENDIX D

Design Calculations

Geosyntec consultants

COMPUTATION COVER SHEET

Client:	**EF**	Project:	**White Mesa Mill – Cells 5A-5B**	Project/ Proposal No.: Task No.	**SC0634**

Title of Computations **ACTION LEAKAGE RATE**

Computations by:	Signature	[signature]	12/18/12 Date
	Printed Name	Rebecca Flynn	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature	[signature]	12/20/12 Date
	Printed Name	Keaton Botelho	
	Title	Project Engineer	
Computations Checked by:	Signature	[signature]	12/18/12 Date
	Printed Name	Gregory T. Corcoran, P.E.	
	Title	Principal Engineer	
Computations backchecked by: (originator)	Signature	[signature]	12/18/12 Date
	Printed Name	Rebecca Flynn	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature	[signature]	12/18/12 Date
	Printed Name	Gregory T. Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	12/09/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A & 5B	Project/ Proposal No.:	SC0634	Task No.:	

CALCULATION OF ACTION LEAKAGE RATE THROUGH THE LEAKAGE DETECTION SYSTEM UNDERLYING A GEOMEMBRANE LINER.

OBJECTIVE

In accordance with Part 254.302 of the USEPA Code of Federal Regulations, determine the action leakage rate (ALR) that a leak detection system (LDS) can remove, and not allow the maximum fluid head on the bottom liner to exceed 1 foot. The ALR shall be given as an average daily flow rate in gallons per day per acre for the sumps associated with the primary and secondary LDS. The calculation shall include a margin of safety sufficient to allow for design uncertainties, operational changes, and material characteristics.

On the cell floors, the triple liner systems for Cells 5A and 5B will be comprised of the following from top to bottom (Attachment A):

- Primary Liner: 60-mil smooth high density polyethylene (HDPE) geomembrane;
- 300-mil HDPE geonet;
- Secondary Liner: 60-mil HDPE geomembrane; and
- Tertiary Liner: 60-mil HDPE Drain Liner™ geomembrane with 130-mil asperities.

On the cell slopes, the triple liner systems for Cells 5A and 5B will be comprised of the following from top to bottom (Attachment A):

- Primary Liner: 60-mil smooth high density polyethylene (HDPE) geomembrane;
- Secondary Liner: 60-mil HDPE Drain Liner™ geomembrane with 130-mil asperities; and
- Tertiary Liner: 60-mil HDPE Drain Liner™ geomembrane with 130-mil asperities.

Cells 5A and 5B will have primary and secondary LDSs with surface areas of approximately 42 acres. On the cell floor, the primary LDS will consist of a 300-mil geonet above a 60-mil HDPE geomembrane while the secondary LDS will consist of a Drain Liner™ geomembrane. Both systems will include collection trenches that contain

4-inch diameter perforated PVC pipe, drainage aggregate, and a cushion geotextile (Attachment A). Pipes are spaced at the mid-points of the cells in the north-south and east-west directions, as well as the toes of the 2H:1V side slopes along the lowest portions of the cell floor. There is one sump associated with each LDS. On the slopes, the primary and secondary LDSs will consist of 130-mil Drain Liner™ geomembrane.

In order to evaluate flow through the LDS with geonet and Drain Liner™ deployed in any direction, the flow will be evaluated for the conservatively lowest possible drainage gradient which is the north-south direction. The drainage gradient is reduced in this scenario from 1.75% to 1.1% in Cell 5A and from 1.75% to 1.2% in Cell 5B. This ALR calculation evaluates the "worst-case scenario" of drainage assuming 1.1% slope in Cell 5A along a distance of 563 ft (Attachment B).

In addition, Drain Liner™ panels have smooth sides for seaming, while the ends of each panel will have the studs removed to allow seaming. As a result, flow is inhibited at the sides and ends of deployed panels. A 200-mil thick piece of geonet will be installed above the smooth seam at the butt-ends of the panels to allow liquid to drain along the length of each panel (machine direction) to the LDS collection trench. On the side seams, it is assumed no liquid will pass as there are no "studs" on the surface of the Drain Liner™ and the overlying geomembrane will immediately contact the underlying seam area thereby inhibiting flow (see Attachment A).

The method outlined by Giroud, et al. (1997) will be employed to calculate the ALR and confirm the maximum expected head for each collection layer (Attachment C).

PRIMARY LDS ANALYSIS

Liquid flow through defect in primary geomembrane

Liquid migration through a liner occurs essentially through defects in the geomembrane. According to Giroud, et al. (1997) (see Attachment C, 3/6) the rate of liquid migration through a defect in the geomembrane is given by the following:

$$Q = (2/3)d^2\sqrt{gh_{prim}} \qquad \text{Equation (1)}$$

where:

- Q = flow rate through one geomembrane defect, m^3/s
- d = defect diameter, m
- g = acceleration due to gravity, 9.81 m/sec^2
- h_{prim} = head of liquid on top of primary liner, m

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According to the EPA, common practice is to assume that the diameter of a leak in the geomembrane is equal to the thickness of the geomembrane (i.e. 60 mil, 0.0015 m).

Cell Bottom

Based on the proposed grading for Cells 5A (Attachment B) and the operational constraint of maintaining 3 feet of freeboard within the cells, the height of the liquid on primary geomembrane along the critical flow path is 30 feet (9.1 m). Placing the above values into Equation 1 results in the following maximum flow rate per defect:

$$Q = \left(\frac{2}{3}\right)(0.0015m)^2\sqrt{(9.81\ \frac{m}{s^2})(9.1m)}$$

$$Q = 1.42 \text{ x } 10^{-5} \text{ m}^3/\text{sec}$$

$$= 1.23 \text{ m}^3/\text{day}$$

$$= 322 \text{ gal/day}$$

Side Slopes

Based on the proposed grading for Cells 5A and 5B (Attachment B) and the operational constraint of maintaining 3 feet of freeboard within the cells, the height of the liquid on primary geomembrane along the side slope critical flow path is 1 foot (0.3048 m). Placing the above values into Equation 1 results in the following maximum flow rate per defect:

$$Q = \left(\frac{2}{3}\right)(0.0015m)^2\sqrt{(9.81\ \frac{m}{s^2})(0.3048m)}$$

$$Q = 2.59\text{x}10^{-6} \text{ m}^3/\text{sec}$$

$$= 0.22 \text{ m}^3/\text{day}$$

$$= 59.2 \text{ gal/day}$$

Maximum flow rate on Secondary Geomembrane, Cell Bottom

According to Giroud, et al. (1997) (see Attachment C, p. 2/6) the maximum flow rate within the leak detection layer geonet is given by the following:

$Q_{full} = k\ t_{LCL}^2$ Equation (2)

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Where:

Q_{full} = maximum flow rate within the geonet *to be determined, m^3/sec*
k = hydraulic conductivity of geonet; *see below, m/sec*
t_{LCL} = thickness of leak detection layer; *300 mil, 0.0076 m*

Hydraulic conductivity of Cell Bottom Geonet, k

Attachment D shows a permeability curve for a 300 mil thick geonet with an HDPE geomembrane with a normal load of 10,000 psf. Based on the site grading (Attachment B), a maximum thickness of waste material (tailings/slimes) will result in the following normal stresses in Cells 5A and 5B:

Cell 5A	Cell 5B
Total Height of Material: 41 ft of tailings + 9 ft of cover	Total Height of Material: 43 ft of tailings + 9 ft of cover
Normal Stress: 50 ft x 125 lb/ft* = 6,250 pounds per square foot (psf)	Normal Stress: 52 ft x 125 lb/ft* = 6,500 pounds per square foot (psf)

*Assumed

Normal stresses of approximately 6,250 psf and 6,500 psf will be exerted on the geosynthetics in Cells 5A and 5B, respectively. The loading to be exerted on the deployed geonet is less than the 10,000 psf normal load during transmissivity testing; therefore, utilizing the results of transmissivity data is conservative for this loading condition.

Graphing the permeability data for the 300 mil geonet under a normal stress of approximately 10,000 psf (Attachment D), results in the following equation of the line:

$$k = 0.0854i^{-0.406} \qquad \text{Equation (3)}$$

This equation accounts for intrusion (RF_{IN}), creep (RF_{CR}), chemical clogging (RF_{CC}), and biological clogging (RF_{BC}), Koerner (Attachment E, 3/3) suggests the following partial factor of safety values for leak detection systems:

RF_{IN}	1.5 to 2.0	use 1.0 (no geotextiles on either side to intrude, test data accounts for geomembrane intrusion)
RF_{CR}	1.4 to 2.0	use 1.2 (low normal stress)
RF_{CC}	1.5 to 2.0	use 2.0 (very low pH)
RF_{BC}	1.5 to 2.0	use 1.0 (very low pH should preclude biological activity)

The hydraulic gradient is based on the longest, critical drainage path (563 feet), slope of the geonet (1.1%), and height of liquid above the liner system at the deepest point along the flow path (5,585-5,555 = 30 feet, which accounts for the 3 foot freeboard, Attachment B). Based on this information, the hydraulic gradient can be estimated as follows:

$$i = (30 \text{ ft} + 563 \text{ ft} \times 0.011) / 563 \text{ ft} = 0.064$$

Placing the estimated hydraulic gradient of 0.064 into Equation 3 results in a hydraulic conductivity of 0.26 m/sec.

Placing the geonet hydraulic conductivity and thickness into Equation 2 results in the following:

$$\mathbf{Q_{liner}} = (0.26 \text{ m/sec}) \times (0.0076 \text{ m})^2 = \mathbf{1.5 \times 10^{-5}\ m^3/sec > 1.42 \times 10^{-5}\ m^3/sec}$$

The flow through the geonet is greater than the flow through the defect; therefore, the geonet is appropriate as a leak detection layer on the cell bottom.

Maximum flow rate on Secondary Geomembrane, Side Slopes

According to Giroud, et al. (1997) (see Attachment C, p. 2/6) the maximum flow rate within the side slope leak detection layer Drain Liner™ is given by the following:

$$Q_{full} = k\, t_{LCL}^{2} \qquad \text{Equation (2)}$$

Where:

Q_{full} = maximum flow rate within the Drain Liner™ *to be determined, m^3/sec*
k = hydraulic conductivity of Drain Liner™; *see below, m/sec*
t_{LCL} = thickness of leak detection layer; 130 *mil, 0.0033 m*

Hydraulic conductivity of Side Slope Drain Liner™, k

Attachment F shows a hydraulic conductivity curve for a 130 mil thick Drain Liner™ geomembrane with an HDPE geomembrane under a normal load of 15,000 psf.

As calculated previously, normal stresses of 6,250 psf and 6,500 psf will be exerted on the Drain Liner™ geomembrane in Cells 5A and 5B, respectively; therefore, utilizing the hydraulic conductivity of the Drain Liner™ under a normal load of 15,000 psf is conservative.

Graphing the permeability data for the 130 mil thick Drain Liner™ under a normal stress of approximately 15,000 psf (Attachment F), results in the following equation of the line:

$$k = 0.2388i^{-0.413} \qquad \text{Equation (3)}$$

This equation accounts for intrusion (RF_{IN}), creep (RF_{CR}), chemical clogging (RF_{CC}), and biological clogging (RF_{BC}), Koerner (Attachment E) suggests the following partial factor of safety values for leak detection systems:

RF_{IN}	1.5 to 2.0	use 1.0 (no geotextiles on either side to intrude, test data accounts for geomembrane intrusion)
RF_{CR}	1.4 to 2.0	use 1.2 (low normal stress)
RF_{CC}	1.5 to 2.0	use 2.0 (very low pH)
RF_{BC}	1.5 to 2.0	use 1.0 (very low pH should preclude biological activity)

The hydraulic gradient is based on the longest, critical drainage path (92 feet), slope of the Drain Liner™ (50%), and height of liquid above the liner system at the point furthest from the collection pipe, 1 ft (Attachment B). Based on this information, the hydraulic gradient can be estimated as follows:

$$i = (1 \text{ ft} + 92 \text{ ft} \times 0.50) / 92 \text{ ft} = 0.511$$

Placing the estimated hydraulic gradient of 0.511 into Equation 3 results in a hydraulic conductivity of 0.32m/sec.

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Placing the Drain Liner™ hydraulic conductivity and thickness into Equation 2 results in the following:

$Q_{liner} = (0.32 \text{ m/sec}) \times (0.0033 \text{ m})^2 = \mathbf{3.4 \times 10^{-6} \text{ m}^3\text{/sec} > 2.59\times10^{-6} \text{ m}^3\text{/sec}}$

The flow through the Drain Liner™ is greater than the flow through the defect; therefore, the Drain Liner™ is appropriate as a leak detection layer on the side slopes.

Action Leakage Rate (ALR)

The number of defects in a geomembrane is given by Giroud, et al (Attachment C, 4/6), as the following:

$$N = (F)(A_{LCL}) \qquad \text{Equation (4)}$$

where:

- N = number of defects
- F = frequency of defects (per m^2 of geomembrane)
- A_{LCL} = area of leakage collection layer; *42 acres, 169,970 m^2*

Using an assumed F = 1/2,500 m^2 (Attachment A, 4/6), the number of defects assumed in the primary geomembrane is as follows:

$$N = \frac{1 \text{ defect}}{2{,}500 \text{ m}^2} \times (169{,}970\text{m}^2) = 68 \text{ (rounded up to nearest whole number)}$$

$$ALR = (Q)(N)/\text{acre}$$

$$= \frac{(1.23\text{m}^3\text{/day})(68)}{42 \text{ acres}} = 1.99 \text{ m}^3\text{/day/acre}$$

$$= \mathbf{526 \text{ gal/day/acre}}$$

Q = flow through defect on the cell bottom, 1.23 m^3/day, *conservatively high for entire cell since side slopes defects flows are lower.*

Both Cells 5A and 5B are the same size, 42 acres; therefore, the ALR of 526 gal/day/acre is valid for both cells.

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Maximum flow rate to sump

Based on the area of the liner systems, the following maximum flow rate to the sump is anticipated:

Q_{sump} = (526 gal/day/acre) (42 acres) = 22,100 gal/day = 15.3 gpm

A sump pump capable of a minimum flow rate of 20 gallons per minute at the head conditions present (approximately 46 vertical feet plus piping losses [Cell 5B conditions, conservative for Cell 5A], Attachment B) will be utilized to remove liquids from the LDS.

Time of travel

According to Giroud, et al. (1997) (see Attachment C, 6/6) the travel time for the liquid to reach the LDS piping system from the defect in the primary geomembrane is given by the following:

$$t_{travel} = (nx) / (k \sin \beta \cos \beta)$$

The time of travel is evaluated for the worst-case scenario, when the Cell 5A liner system is deployed in north-south orientation and assuming the longest drainage path to the sump (1050 ft, 320m); actual deployment direction will be determined by the Contractor.

$$t_{travel} = (nx) / (k \sin \beta \cos \beta)$$

where:

t_{travel} = time for liquid to travel from defect in primary geomembrane to the LDS piping; *to be determined, sec*

n = porosity of geonet, 0.8

x = maximum distance from defect in primary geomembrane to LDS piping; 1050 *ft, 320 m*

k = hydraulic conductivity of the geonet; *0.26 m/sec from above*

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β = slope of floor; *1.1%, 0.011 radians*

t_{travel} = (0.80) (320m) / (0.26 m/sec) (sin 0.011) (cos 0.011)
= 89,521 sec
= **24.9 hours**

Therefore, the leak detection system geonet will allow for timely detection of liquids.

Head Above Secondary Liner, Cell Bottom (h):

Knowing the maximum potential flow rate through a specific defect in the primary geomembrane, and assuming a worst case condition where the liner defect is located at the higher end of the leakage collection layer slope, liquid head build-up on the secondary geomembrane is calculated using the following equation from Giroud, et al. (1997) (see Attachment A, 5/6):

$$t_{avgworst} = \frac{NQ}{kiB} \qquad \text{Equation (6)}$$

where:

- $t_{avg\ worst}$ = average thickness of liquid above secondary (bottom) geomembrane under worst case scenario; *to be determined, m*
- N = total number of defects in primary geomembrane; *68*
- Q = flow rate through one defect in primary geomembrane; *1.42×10^{-5} m^3/sec*
- k = hydraulic conductivity of geonet; *0.26 m/sec from above*
- i = hydraulic gradient in leakage collection layer; *0.064 from above*
- B = width of leakage collection layer; *563 feet, 172 m (Attachment B)*

Placing the estimated geonet hydraulic conductivity, average thickness of liquid in the LDS, and the thickness of the leak detection layer geonet into Equation 6 results in the following:

$$t_{avgworst} = \frac{(68)(1.42x10^{-5})}{(2.6x10^{-1}\,\mathrm{m/sec})(0.064)(172\mathrm{m})} \qquad t_{avgworst} = 0.00034\ \mathrm{m} = 0.34\ \mathrm{mm}$$

Written by:	R. Flynn	Date:	12/09/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A & 5B	Project/ Proposal No.:	SC0634	Task No.:	

The head on the secondary does not exceed 0.34 mm (13.4 mil), much less than the 300 mil geonet thickness.

Head Above Secondary Liner, Side Slope Drain Liner™ (h):

The head above the liner is evaluated to determine if the side slope liner system is flowing full. In this evaluation, the 22 ft wide Drain Liner™ strip is evaluated for Cell 5A. This results in a drainage area of 2,992 sf (assuming a panel length equivalent to the slope length, 136 ft, and a panel width of 22 ft). Using the same defect evaluation identified for the ALR calculation, this would result in no more than 1 defects per strip.

Knowing the maximum potential flow rate through a specific defect in the primary geomembrane, and assuming a worst case condition where the 1 primary liner defect is located at the higher end of the leakage collection layer slope, liquid head build-up on the secondary geomembrane is calculated using the following equation from Giroud, et al. (1997) (see Attachment C, 5/6):

$$t_{avgworst} = \frac{NQ}{kiB}$$ Equation (6)

where:

$t_{avg\ worst}$	= average thickness of liquid above secondary (bottom) geomembrane under worst case scenario; *to be determined, m*
N	= total number of defects in primary geomembrane; *1*
Q	= flow rate through one defect in primary geomembrane; *2.59 x 10⁻⁶ m³/sec*
k	= hydraulic conductivity of primary Drain Liner™ geomembrane; *0.32m/sec from above*
i	= hydraulic gradient in leakage collection layer; *0.511 from above*
B	= width of leakage collection layer; *22 feet, 6.7 m (Attachment A)*

Placing the estimated Drain Liner™ hydraulic conductivity, average thickness of liquid in the LDS, and the thickness of the leak detection layer Drain Liner™ into Equation 6 results in the following:

$$t_{avgworst} = \frac{(1)(2.59x10^{-6})}{(0.32\text{m}/\text{sec})(0.511)(6.7\text{m})}$$

$$t_{avgworst} = 2.36\text{x}10^{-6}\text{ m} = 0.0024\text{ mm}$$

Written by:	R. Flynn	Date:	12/09/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A & 5B	Project/ Proposal No.:	SC0634	Task No.:	

The head on the secondary liner does not exceed 0.0024 mm (0.09 mil), much less than the 130-mil Drain Liner™ asperity height; therefore, the assumption that the drainage collection layer is not flowing full is valid.

SECONDARY LDS ANALYSIS

Liquid flow through defect in secondary geomembrane

Using Equation 1, defined previously, the rate of liquid migration through a defect in the secondary geomembrane is given by the following:

$$Q = (2/3)d^2\sqrt{gh_{prim}}$$ Equation (1)

where:

Q = flow rate through one geomembrane defect, m^3/s
d = defect diameter, m
g = acceleration due to gravity, 9.81 m/sec^2
h_{prim} = head of liquid on top of primary liner, m

Based on the thickness of the primary leak detection, 300-mil, the head on the secondary liner will not be greater than 300-mil. Because this condition is the same for both Cells bottoms and conservative for cell side slopes, this evaluation is only performed once. Placing this value into Equation 1 results in the following maximum flow rate per defect:

$$Q = \left(\frac{2}{3}\right)(0.0015m)^2\sqrt{(9.81\ \frac{m}{s^2})(7.6 \times 10^{-3}m)}$$

$$Q = 4.10 \times 10^{-7}\ m^3/sec$$
$$= 3.5 \times 10^{-2}\ m^3/day$$
$$= 9.25\ gal/day$$

Maximum flow rate on Drain Liner™

According to Giroud, et al. (1997) (see Attachment C, p. 2/6) the maximum flow rate within the leak detection layer Drain Liner™ is given by the following:

$Q_{full} = k\ t_{LCL}^2$ Equation (2)

Where:

Q_{full} = maximum flow rate within the Drain Liner™; *to be determined, m^3/sec*
k = hydraulic conductivity of Drain Liner™; *see below, m/sec*
t_{LCL} = thickness of leak detection layer; *130 mil, 0.0033 m*

Hydraulic conductivity of Drain Liner™, k

The hydraulic conductivity of the Drain Liner™ was evaluated under a normal load of 15,000 psf for the primary side slope LDS. The following equation was identified for determining the hydraulic conductivity based on the gradient with appropriate factors of safety.

$k = 0.2388i^{-0.413}$ Equation (3)

Similar to the primary leak detection system analysis, the hydraulic gradient is based on the longest, critical drainage path (563 feet), slope of the geonet (1.1%), and height of liquid above the liner system at the deepest point along the flow path based on the geonet thickness, 300 mil (Attachment B). Based on this information, the hydraulic gradient can be estimated as follows:

$i = (0.025\text{ ft} + 563\text{ ft} \times 0.011) / 563\text{ ft} = 0.011$

Placing the estimated hydraulic gradient of 0.011 into Equation 3 results in a hydraulic conductivity of 1.54 m/sec.

Placing the Drain Liner™ hydraulic conductivity and thickness into Equation 2 results in the following:

$\mathbf{Q_{liner}} = (1.54\text{ m/sec}) \times (0.0033\text{ m})^2 = \mathbf{1.68 \times 10^{-5}\ m^3/sec}$

Action Leakage Rate (ALR)

The number of defects in a geomembrane is given by Giroud, et al (Attachment C), as the following:

$N = (F)(A_{LCL})$ Equation (4)

Written by:	R. Flynn	Date:	12/09/12	Reviewed by:	G. Corcoran	Date:	12/19/12
Client:	EF	Project:	Cells 5A & 5B	Project/ Proposal No.:	SC0634	Task No.:	

where:

N = number of defects
F = frequency of defects (per m^2 of geomembrane)
A_{LCL} = area of leakage collection layer; *42 acres, 169,970 m^2*

Using an assumed F = 1/2,500 m^2 (Attachment C, 4/6), the number of defects assumed in the primary geomembrane is as follows:

$$N = \frac{1 \text{ defect}}{2{,}500 \text{ m}^2} \times (169{,}970 \text{m}^2) = 68$$ (rounded up to nearest whole number)

$$ALR = (Q)(N)/\text{acre}$$

$$= \frac{(3.5 \times 10^{-2})(68)}{42} = \frac{0.057 \frac{m^3}{day}}{acre}$$

$$= \mathbf{15.1 \text{ gal/day/acre}}$$

Both Cells 5A and 5B are the same size, 42 acres; therefore, the ALR of 15.1 gal/day/acre is valid for both cells.

Maximum flow rate to sump

Based on the area of the liner systems, the following maximum flow rate to the sump is anticipated:

Q_{sump} = (15.1 gal/day/acre) (42 acres) = 634 gal/day = 0.44 gpm

A sump pump capable of a minimum flow rate of 1 gallon per minute at the head conditions present (approximately 46 vertical feet plus piping losses [Cell 5B conditions, conservative for Cell 5A], Attachment B) will be utilized to remove liquids from the LDS.

Written by:	R. Flynn	Date:	12/09/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A & 5B	Project/ Proposal No.:	SC0634	Task No.:	

Time of travel

According to Giroud, et al. (1997) (see Attachment C, 6/6) the travel time for the liquid to reach the LDS piping system from the defect in the secondary geomembrane is given by the following:

$$t_{travel} = (nx) / (k \sin \beta \cos \beta)$$

t_{travel} = (0.97) (320 m) / (1.54 m/sec) (sin 0.63) (cos 0.63)
= 18,332 sec
= **5.09 hours**

where:

t_{travel} = time for liquid to travel from defect in primary geomembrane to the LDS piping; *to be determined, sec*
n = porosity of Drain Liner™, 97% (Attachment G)
x = distance from defect in secondary geomembrane to LDS piping; *1050ft, 320 m* (Assumed worst-case if panels are oriented NE to SW)
k = hydraulic conductivity of the geonet; *1.54 m/sec from above*
β = slope of floor; *1.1%, 0.63 degrees, 0.011 radians*

Therefore, the leak detection system Drain Liner™ will allow for timely detection of liquids.

Head Above Tertiary Liner, (h):

Knowing the maximum potential flow rate through a specific defect in the primary geomembrane, and assuming a worst case condition where the 68 tertiary liner defects are located at the higher end of the leakage collection layer slope, liquid head build-up on the secondary geomembrane is calculated using the following equation from Giroud, et al. (1997) (see Attachment C, 5/6):

$$t_{avgworst} = \frac{NQ}{kiB} \qquad \text{Equation (6)}$$

where:

$t_{avg\ worst}$ = average thickness of liquid above secondary (bottom) geomembrane under worst case scenario; *to be determined, m*
N = total number of defects in primary geomembrane; *68*

Written by:	R. Flynn	Date:	12/09/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A & 5B	Project/ Proposal No.:	SC0634	Task No.:	

Q = flow rate through one defect in secondary geomembrane; *2.7 x 10^{-7} m^3/sec*

k = hydraulic conductivity of primary Drain Liner™ geomembrane; *1.54 m/sec from above*

i = hydraulic gradient in leakage collection layer; *0.011 from above*

B = width of leakage collection layer; *563 feet, 172 m (Attachment B)*

Placing the estimated Drain Liner™ hydraulic conductivity, average thickness of liquid in the LDS, and the thickness of the leak detection layer Drain Liner™ into Equation 6 results in the following:

$$t_{avgworst} = \frac{(68)(4.1x10^{-7})}{(1.54\text{m}/\text{sec})(0.011)(172\text{m})} \qquad t_{avgworst} = 9.57\text{x}10^{-6}\text{ m} = 0.0096\text{ mm}$$

The head on the secondary does not exceed 0.0096 mm (0.4 mil), much less than the 130-mil Drain Liner™ asperity height; therefore, the assumption that the drainage collection layer is not flowing full is valid.

SUMMARY AND CONCLUSIONS

- Using the method outlined by Giroud, et al. (1997), and an N = 68, the ALR was calculated to be 526 gal/day/acre for the primary LDS system and 15.1 gal/day/acre for the secondary LDS.
- Liquids entering the LDS layers will take approximately one day or less to travel from the leak to the LDS piping systems.
- Assuming worst case scenarios for the primary cell bottom, primary side slopes, and secondary cell bottoms, the liquid head on the secondary and tertiary liners do not exceed the thickness of the drainage collection layer.
- The Drain Liner™ and 300-mil Geonet provides sufficient flow rate to accommodate the ALR.

REFERENCES

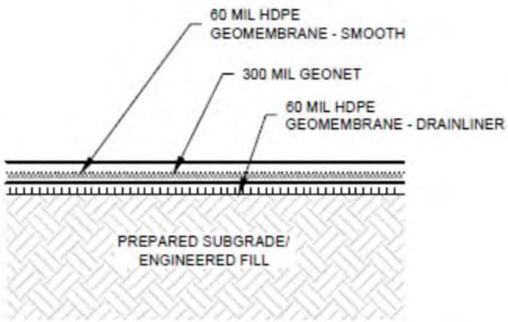
AGRU America, High Density Polyethylene Drain Liner™ Product Data, 2009 - 2011 *(Attachment F)*

Giroud, J.P., Gross, B.A., Bonaparte, R., and McKelvey, J.A. (1997), "Leachate Flow in Leakage Collection Layers Due to Defects in Geomembrane Liners," Geosynthetic International, Vol. 4, No. 3-4, pp. 215-292. *(Attachment C)*

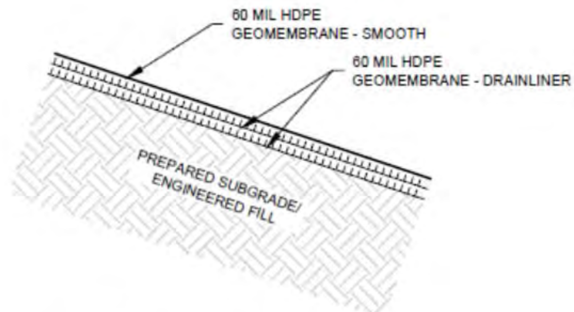
GSE, 2012. Drainage Design Manual. Available online at: www.gseworld.com *(Attachment D)*

Koerner, R. M., Designing with Geosynthetics, Prentice Hall, Upper Saddle River, NJ, 1998. *(Attachment E)*

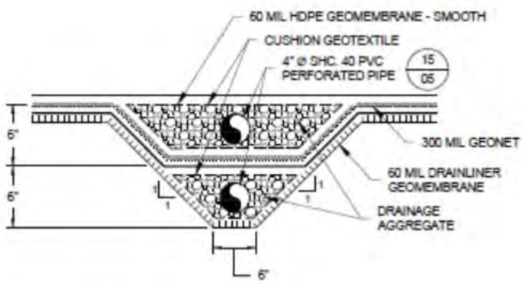
Attachment A – Liner System Details



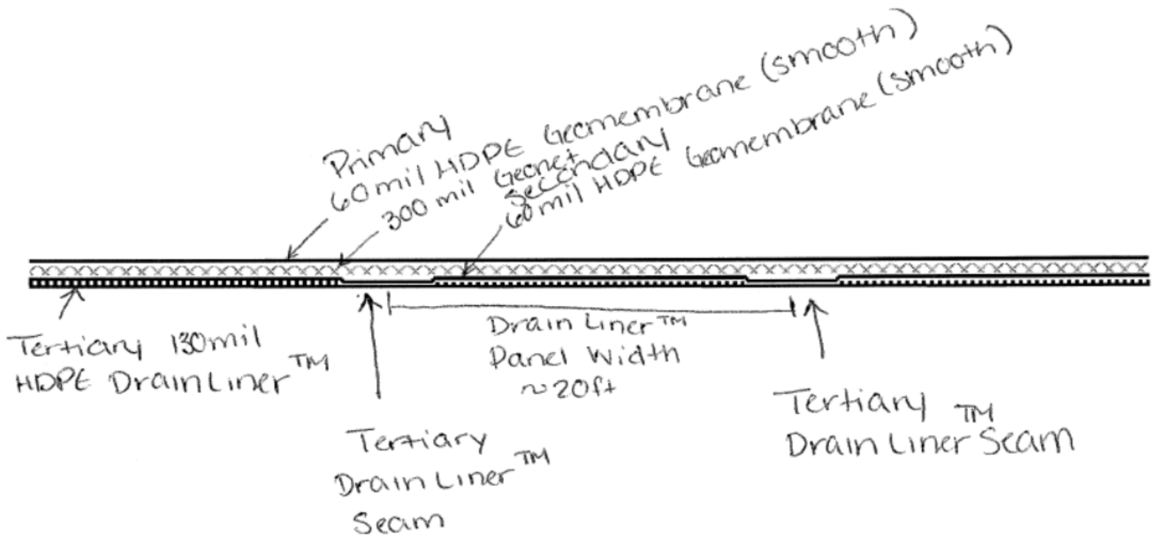
DETAIL
BASE LINER SYSTEM



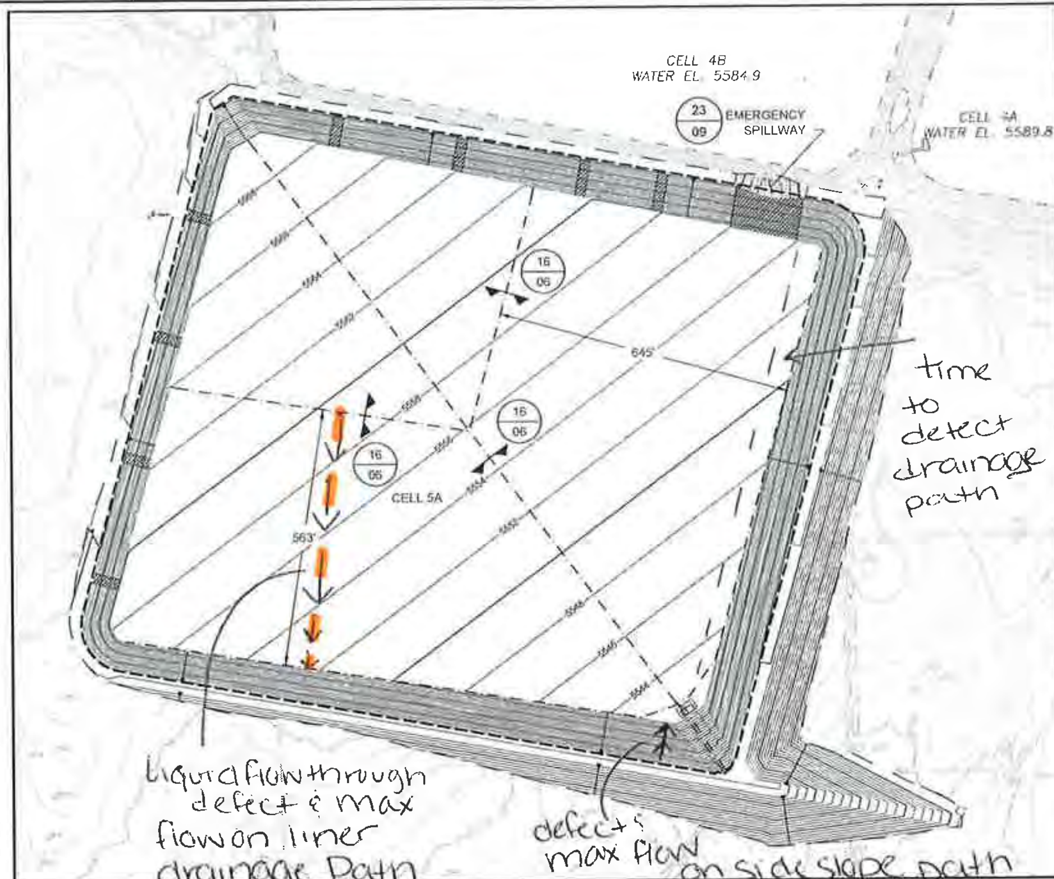
DETAIL
SIDE SLOPE LINER SYSTEM



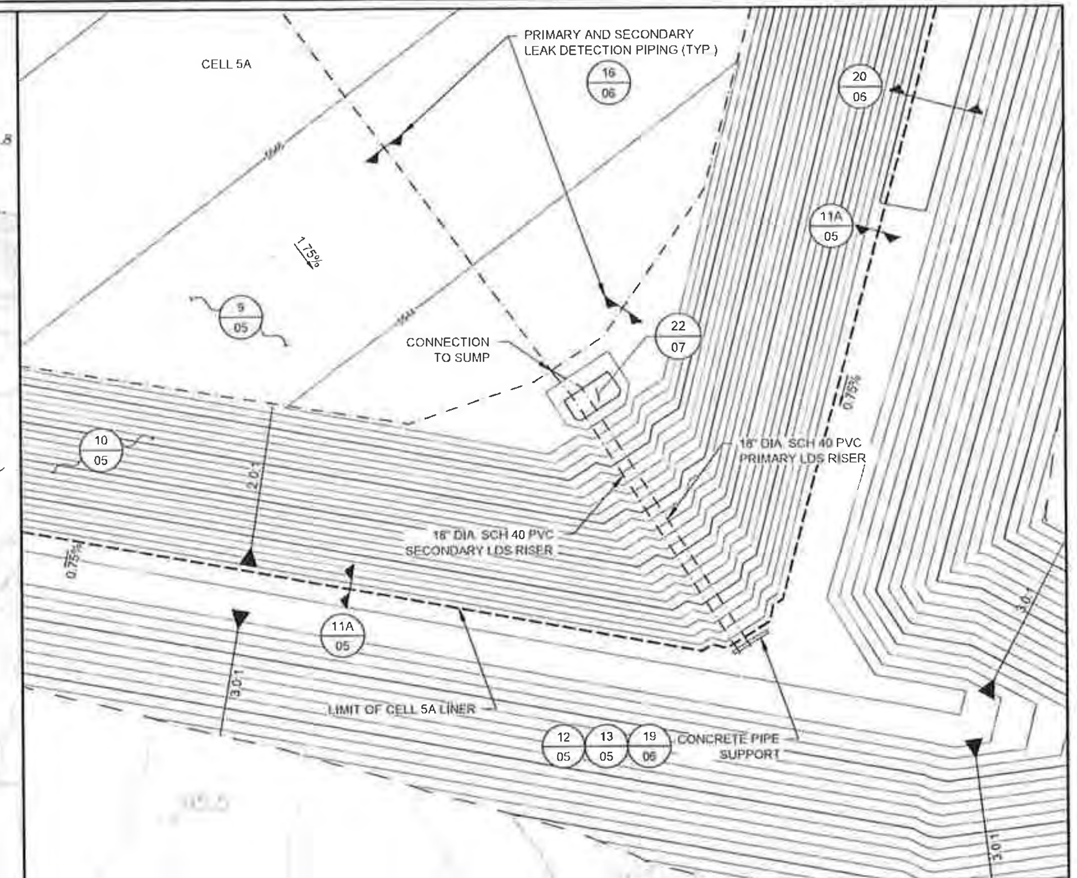
DETAIL
LEAK DETECTION SYSTEM TRENCHES



Detail
TERTIARY DRAIN LINER TM PANEL WIDTH



1
04A
PLAN
CELL 5A LEAK DETECTION SYSTEM
SCALE 1" = 200'



3
04A
DETAIL
CELL 5A LEAK DETECTION SYSTEM
SCALE 1" = 50'

LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- 5602 — PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- LIMIT OF LINER SYSTEM
- PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- SPLASH PAD (21/06)

NOTES

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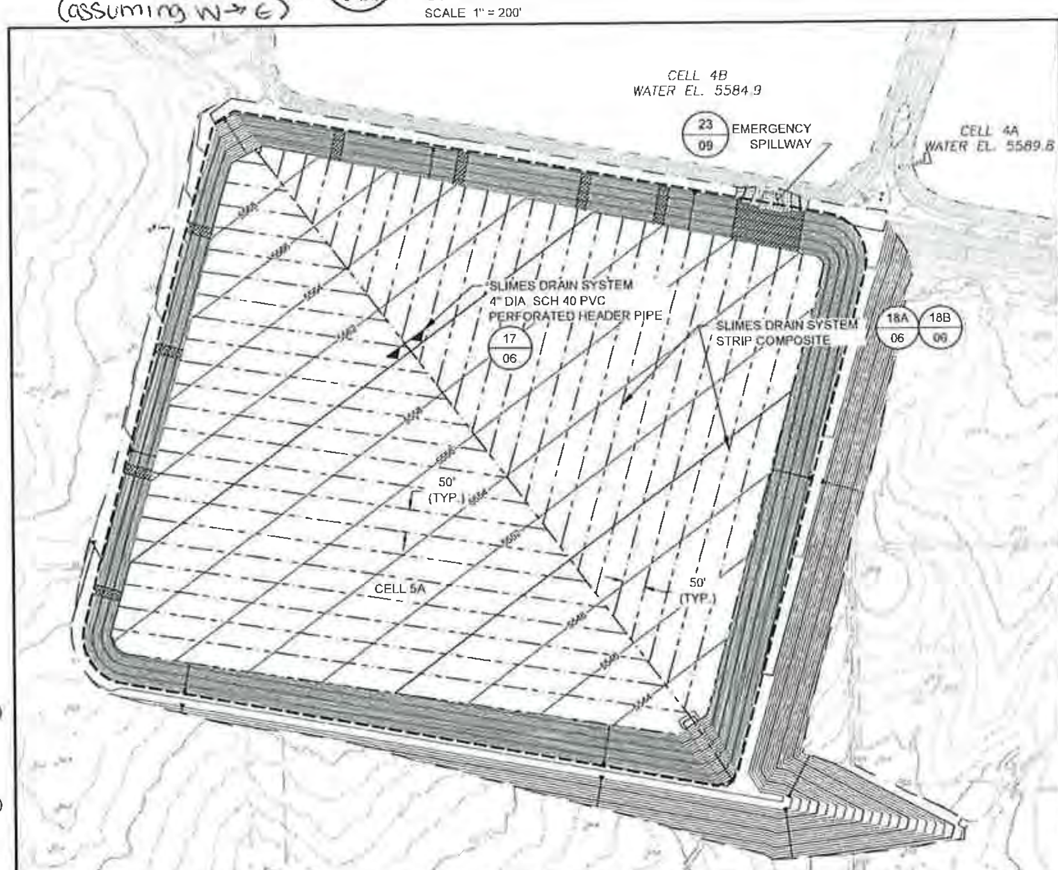
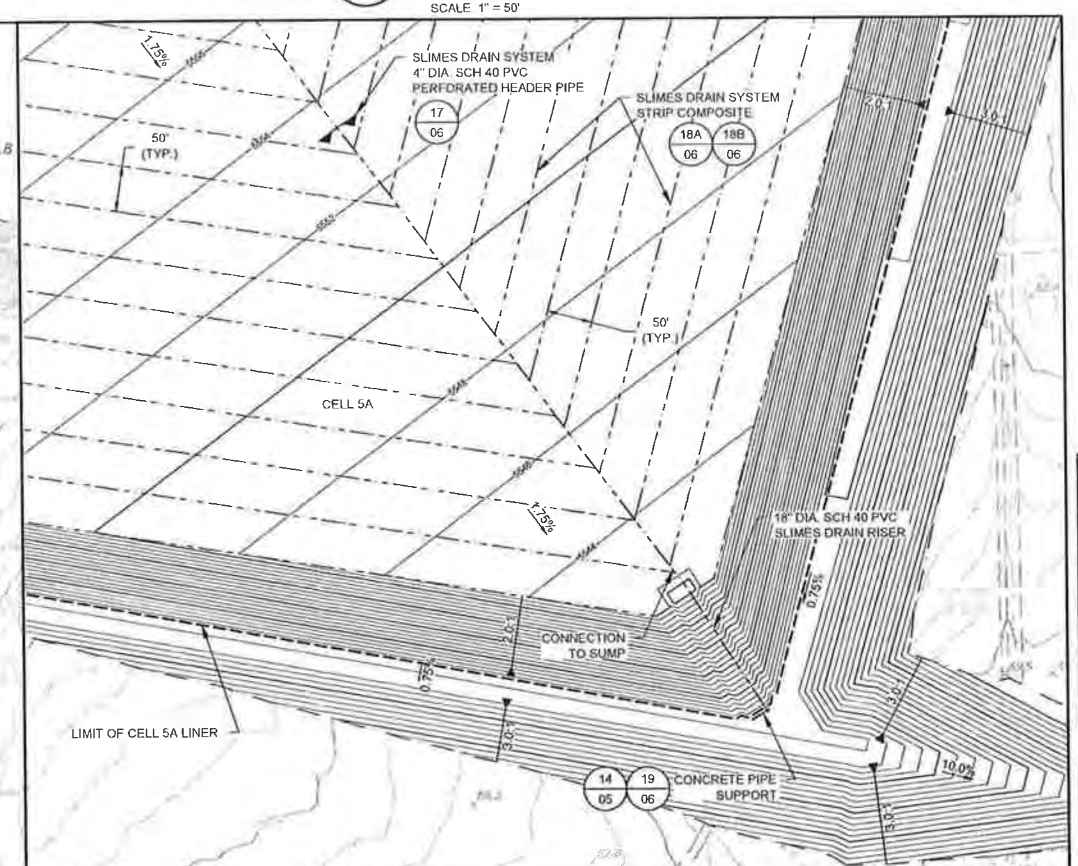
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.



2
04A
PLAN
CELL 5A SLIMES DRAIN SYSTEM
SCALE 1" = 200'
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



4
04A
DETAIL
CELL 5A SLIMES DRAIN SYSTEM
SCALE 1" = 100'

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
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PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5A
PROJECT: CONSTRUCTION OF CELLS 5A AND 5B
SITE: WHITE MESA MILL, BLANDING, UTAH

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SIGNATURE
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REVIEWED BY:	GTC	DRAWING NO.:	04A OF 12
APPROVED BY:	GTC		

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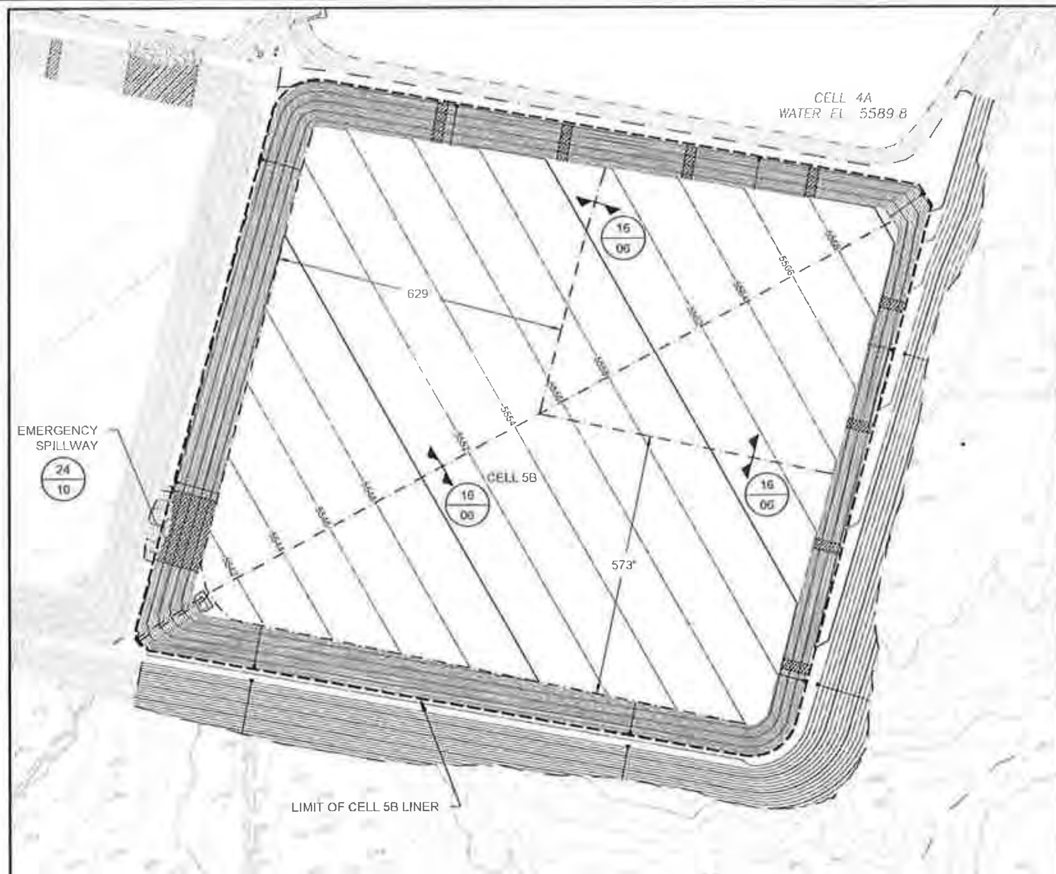
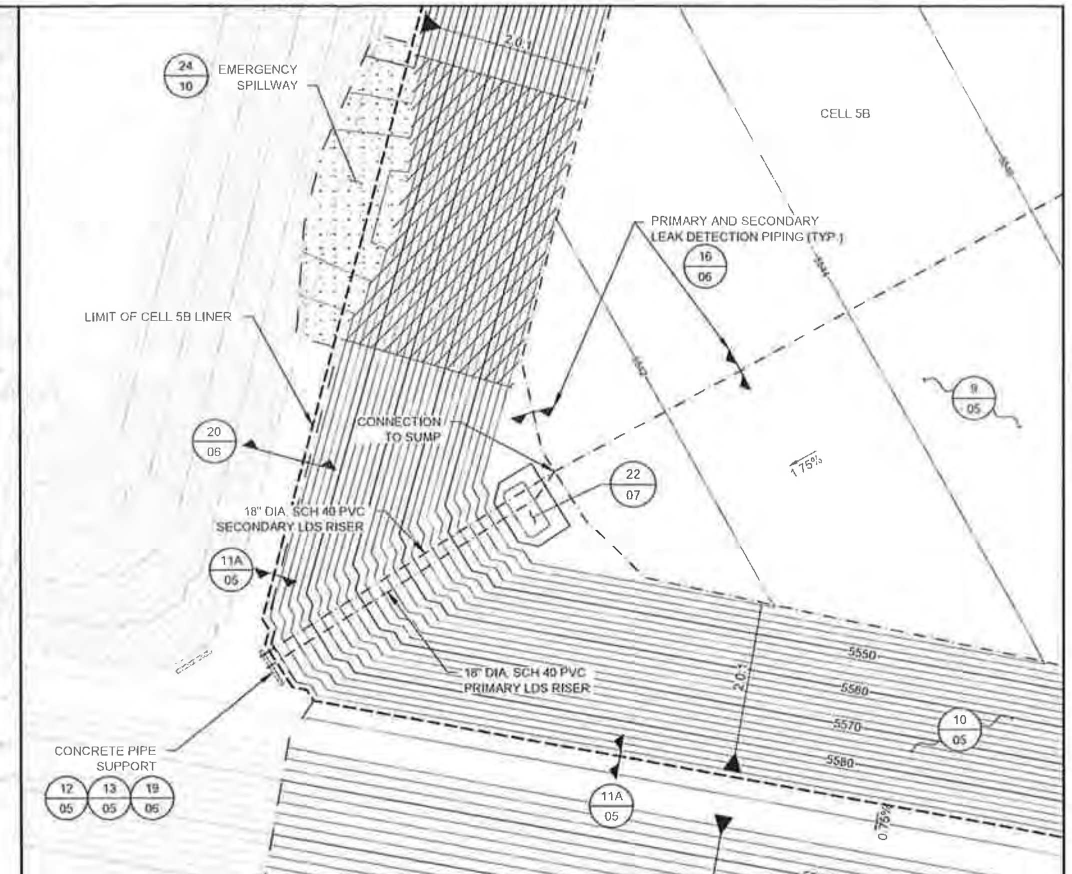
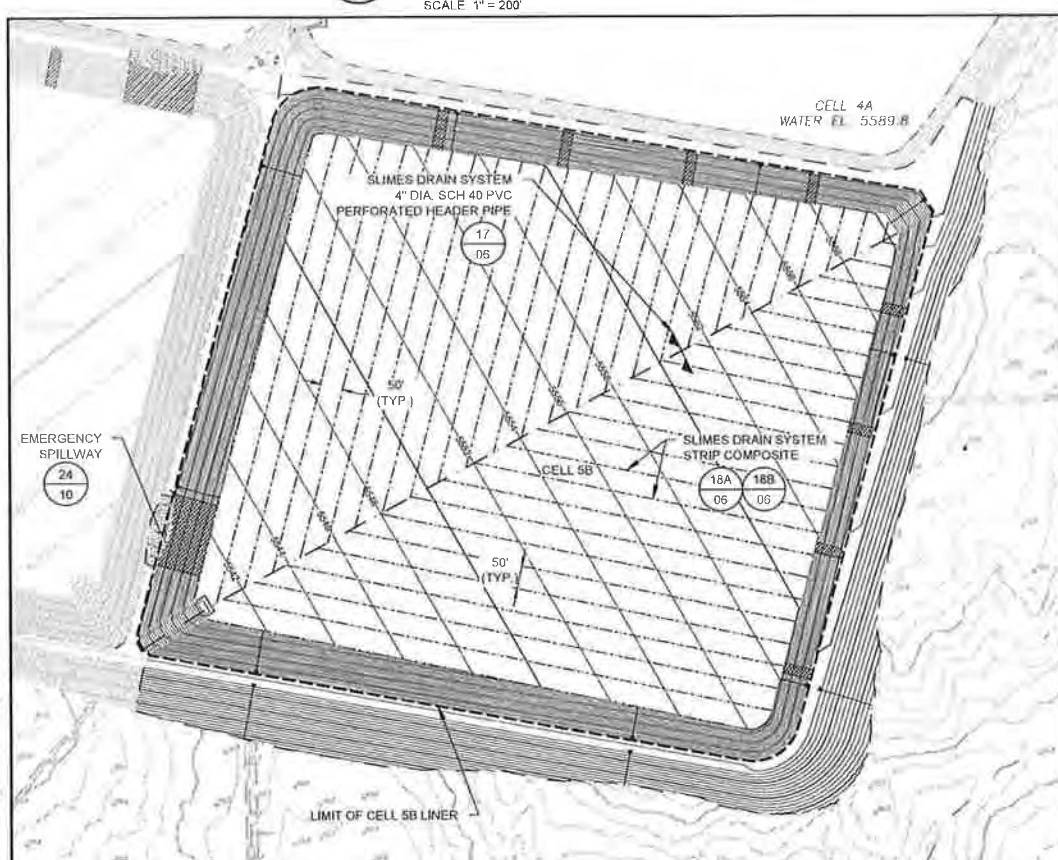
Attachment B(13)



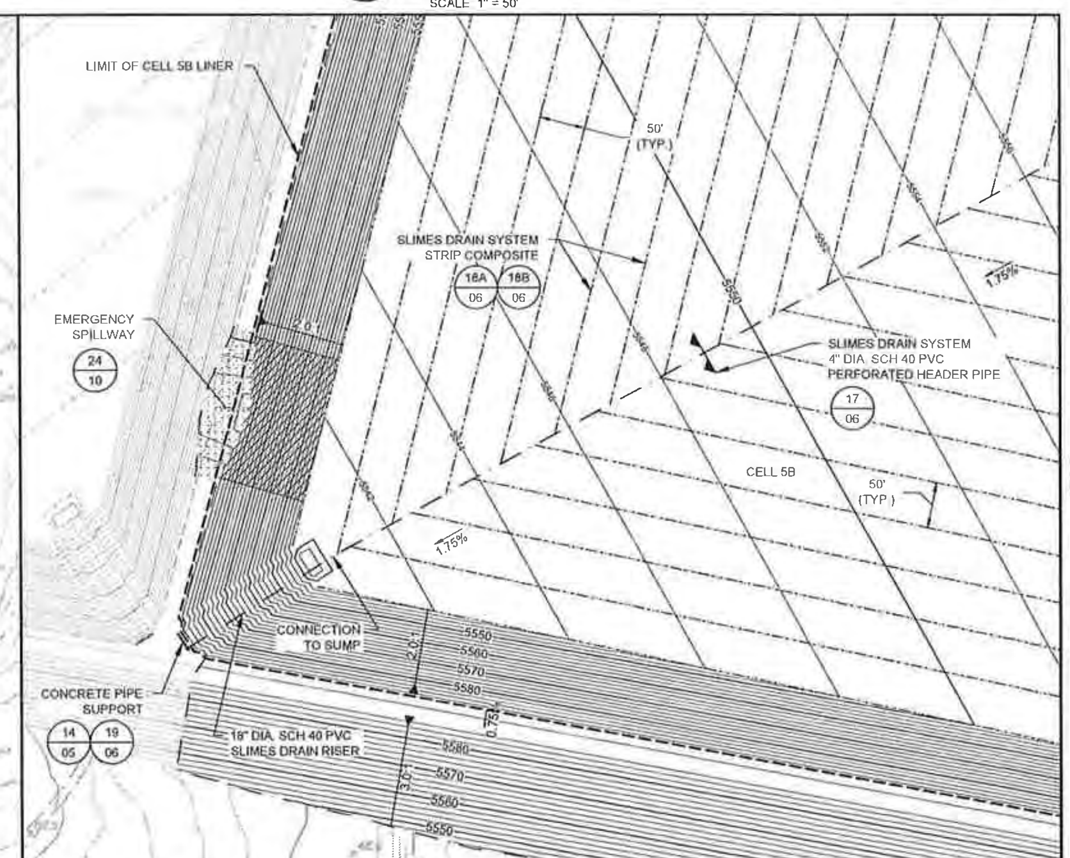
21 / 04B PLAN
CELL 5B LEAK DETECTION SYSTEM
SCALE 1" = 200'



6 / 04B DETAIL
CELL 5B LEAK DETECTION SYSTEM
SCALE 1" = 50'



7 / 04B PLAN
CELL 5B SLIMES DRAIN SYSTEM
SCALE 1" = 200'



8 / 04B DETAIL
CELL 5B SLIMES DRAIN SYSTEM
SCALE 1" = 100'

LEGEND

- JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
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- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- SPLASH PAD 21/06

NOTES

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REV	DATE	DESCRIPTION	DRN	APP

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10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
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Energy Fuels Resources (USA) Inc.

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5B

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL
BLANDING, UTAH

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DATE

DESIGN BY:	GTC	DATE:	JANUARY 2013
DRAWN BY:	MMC	PROJECT NO.:	SC0634
CHECKED BY:	RBF	FILE:	SC0634 - 03A-04B
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	04B OF 12	

PERMIT LEVEL DESIGN
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(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

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Attachment B (2/3)

Geosyntec consultants

Written by: J. GRIFFIN Date: 19/12/12 (DD MM YY) Reviewed by: G. CORCORAN Date: __/__/__ (DD MM YY)

Client: EF Project: CELLS 5A & 5B Project/Proposal No. SC0634 Task No. 02

FLOOR GRADE SLOPES: CELL 5A

NORTH - SOUTH

5559.25' - 5553' = 6.25'

$\frac{6.25'}{563'} = 0.011$

(0.011)(100) = **1.1 %**

EAST - WEST

5558.5' - 5549.75' = 8.75'

$\frac{8.75'}{645'} = 0.0135$

(0.0135)(100) = **1.35 %**

FLOOR GRADE SLOPES: CELL 5B

NORTH - SOUTH

5558.5 - 5551.5' = 7.0'

$\frac{7.0'}{573'} = 0.0122$

(0.0122)(100) = **1.2 %**

EAST - WEST

5557.5' - 5549' = 8.5'

$\frac{8.5'}{629} = 0.0135$

(0.0135)(100) = **1.4 %**

ATTACHMENT B (3/3)

vledge the support of GeoSyntec Consultants for the preparation of and express my gratitude to its Chief Executive Officer and Presi-:, and its Principals, T.R. Sanglerat, J.F. Beech, R.C. Bachus, T.N. a, R.J. Dunn, E. Kavazanjian and D.M. Hendron. I also want to say ı of this issue would not have been possible without the contribution T.D. King, from Tesoro Petroleum Company, and the others from tants: K. Badu-Tweneboah (2 papers), R. Bonaparte, B.A. Gross, T. ' Khire (3 papers), J.A. McKelvey (3 papers), N.S. Rad, T.R. Sang-erman (3 papers). It is certainly very rewarding for me to work with is caliber. Finally, I am grateful to S.L. Berdy who produced the ex- K. Holcomb who ensured flawless word processing, with the help N. Pierce for several of the papers. I also want to acknowledge the ıe by the unknown soldiers of *Geosynthetics International*, the anon-/ho reviewed the papers and provided so many valuable comments. I express my gratitude to T.S. Ingold, Editor, and R.J. Bathurst, Co-*ietics International* for giving me the opportunity of grouping these same issue published as a Special Issue, and to K. Labinaz, Produc-*synthetics International*, who provided two rounds of editing, with , to ensure not only the correctness of each paper, but, also, the con-:cial Issue.

J.P.G.

Technical Paper by J.P. Giroud, B.A. Gross, R. Bonaparte and J.A. McKelvey

LEACHATE FLOW IN LEAKAGE COLLECTION LAYERS DUE TO DEFECTS IN GEOMEMBRANE LINERS

ABSTRACT: This paper provides analytical and graphical solutions related to the flow of leachate in a leakage collection layer due to defects in the overlying liner (i.e. the primary liner of a double liner system). The defects are assumed to be small (e.g. holes in geomembrane liners). It is shown that leachate flows in a zone of the leakage collection layer (the wetted zone) that is limited by a parabola. A simple relationship is established between the rate of leachate migration through the defect and the maximum thickness of leachate in the leakage collection layer; this relationship depends on the hydraulic conductivity (but not on the slope) of the leakage collection layer. Equations are provided to calculate the average head of leachate on top of the liner underlying the leakage collection layer (i.e. the secondary liner of a double liner system), which is useful for calculating the rate of leachate migration through that liner. Finally, the case of several leaks randomly distributed is considered, and equations for the surface area of the wetted zone and the average head are given for this case. Parametric analyses and design examples provide useful comparisons between the three types of materials used in leakage collection layers: gravel, sand and geonets.

KEYWORDS: Geomembrane, Defect, Leachate migration, Leachate collection, Leakage, Leakage collection, Liner system, Double liner, Geosynthetic leakage collection layer.

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It appears that, when the leakage collection layer is not full, there is an extremely sim-
le relationship between the rate of leachate migration through the primary liner defect,
), and the thickness of leachate in the leakage collection layer beneath the defect, t_o.
t is interesting to note that this relationship does not depend on the size of the defect
1 the primary liner or on the slope of the leakage collection layer.

An approximation that was made to establish Equations 9 and 10 was to assume that
1e downslope flow line from A (i.e. AB in Figure 4a) is parallel to the liner. This as-
umption is close to reality as discussed in Section 2.2. However, the actual flow line
rom A is below Line AB as the flow thickness decreases in the downslope direction,
s discussed at the end of Section 5.1.2. Therefore, t_o should only be regarded as the flow
1ickness at a primary liner defect, and it is the maximum flow thickness.

Since the simple relationship expressed by Equations 9 and 10 was demonstrated for
1e case when the leakage collection layer is not full, the condition expressed by Equa-
ion 1 must be met for Equations 9 and 10 to be valid. Combining Equations 1 and 10
ives the following equation, which is another way to express the condition that should
e met to ensure that the leakage collection layer is not full:

$$t_{LCL} \geq t_{LCLfull} = \sqrt{\frac{Q}{k}} \qquad (11)$$

vhere $t_{LCLfull}$ is the *minimum* thickness that a leakage collection layer with a hydraulic
onductivity k should have to contain, without being full at any location, the leachate
low which results from a defect in the primary liner.

The following equation, derived from Equation 11, is another way to express the con-
lition that should be met to ensure that the leakage collection layer is not full:

$$Q \leq Q_{full} = k\, t_{LCL}^2 \qquad (12)$$

vhere Q_{full} is the *maximum* steady-state rate of leachate migration through a defect in
he primary liner that a leakage collection layer, with a thickness t_{LCL} and a hydraulic
onductivity k, can accommodate without being filled with leachate.

It is important to remember that the subscript *full* corresponds to a *minimum* thickness
of the leakage collection layer and to a *maximum* rate of leachate migration (which is
ilso the *maximum* flow rate in the leakage collection layer). It is noteworthy that the
ninimum thickness of the leakage collection layer, $t_{LCLfull}$, and the maximum flow rate,
Q_{full}, which are required to ensure that the leakage collection layer can contain, without
being full, the flow that results from a defect in the primary liner, do not depend on the
slope of the leakage collection layer.

It is not impossible to design a leakage collection layer with a thickness less than the
value $t_{LCLfull}$ given by Equation 11, i.e. where the flow rate is greater than Q_{full} defined
by Equation 12. In this case, the leakage collection layer is filled with leachate in a cer-
ain area around the defect of the primary liner (i.e. "the leachate collection layer is
full"). This case is discussed in Section 3.2.

2/

3.2 Rate of Leachate Flow When the Leachate Collection Layer is Fu

If the thickness of the leakage collection layer is less than $t_{LCLfull}$ expressed
tion 11 (or if the rate of leachate migration through a primary liner defect is gre
Q_{full} expressed by Equation 12, which is equivalent), the leakage collection
filled with leachate in a certain area around the defect. Following the appr
scribed in Section 2.2, it may then be assumed that the leachate phreatic surfa
leakage collection layer is a truncated cone (Figure 5). The virtual apex of the t
cone, A′, is above the leakage collection layer (i.e. above the primary liner,
the upper boundary of the leakage collection layer). The virtual leachate depth
the virtual leachate thickness, t_o, are related to the actual leachate head, h_o,
Equation 4, and the virtual leachate thickness t_o is greater than the thickness o
chate collection layer:

$$t_o > t_{LCL}$$

The surface area of the vertical cross section of the flow in the leakage collect
(Figure 5) is expressed by:

$$S = \frac{D_o^2}{\tan\beta} - \frac{(D_o - D_{LCL})^2}{\tan\beta} = \frac{D_{LCL}(2D_o - D_{LCL})}{\tan\beta}$$

where D_{LCL} is the depth of the leakage collection layer.

The depth is measured vertically whereas the thickness is measured perpenc
to the slope, hence, in accordance with Equation 3:

$$t_{LCL} = D_{LCL} \cos\beta$$

Using the demonstration presented in Section 2.2, i.e. combining Equations
8, 14 and 15, gives:

$$Q = k\, t_{LCL}(2t_o - t_{LCL})$$

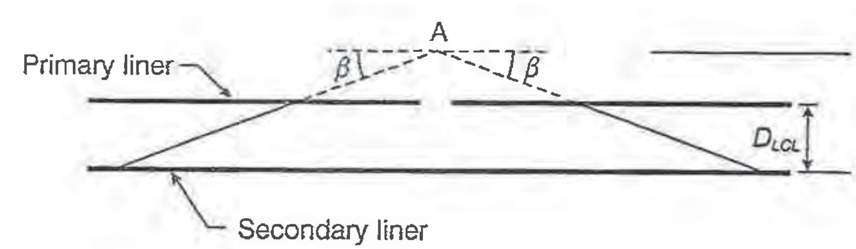


Figure 5. Vertical cross section of the assumed phreatic surface in the leakage co layer in the case where the leakage collection layer is filled with leachate in a certa around the primary liner defect.

ring (or assuming) the leachate head, h_o, on top of the secondary liner vertically the primary liner defect, one may derive the virtual leachate thickness, t_o, using n 4. Then, knowing t_o, t_{LCL} and k, one may use Equation 16 to calculate the rate ate flow through a defect that the leakage collection layer can convey.
ollowing equation can be derived from Equation 16:

$$t_o = \frac{t_{LCL}}{2}\left(1 + \frac{Q}{k\, t_{LCL}^2}\right) \quad (17)$$

ollowing equation can be derived from Equations 13 and 16:

$$t_{LCL} = t_o\left(1 - \sqrt{1 - \frac{Q}{k\, t_o^2}}\right) \quad (18)$$

ion 18 is valid only if the following condition is met:

$$Q \le k\, t_o^2 \quad (19)$$

uld be noted that if $t_{LCL} = t_o$, i.e. if the leakage collection layer is filled with lea- only one point, i.e. at the location of the primary liner defect, Equation 16 is ent to Equation 9.

Parametric Study

the equations presented in Sections 3.1 and 3.2 it is possible to compare the pacity of different leakage collection layers in case of a defect in the primary Table 1, three different leakage collection layers are compared:

net with a thickness of 5 mm and a hydraulic transmissivity resulting in a hy- ic conductivity (obtained by dividing the hydraulic transmissivity by the thick- of 1×10^{-1} m/s;

vel layer with a thickness of 300 mm and a hydraulic conductivity of 1×10^{-1} and

l layer with a thickness of 300 mm and a hydraulic conductivity of 1×10^{-3} m/s.

irst two leakage collection layers have the same hydraulic conductivity and the have the same thickness. In the case of the geonet, the virtual leachate thick- , considered in Table 1 is greater than, or equal to, the thickness of the leachate on layer, t_{LCL}; therefore, in all cases considered in Table 1, the geonet is filled chate over a certain area around the defect (this area being zero for t_o = 5 mm). ase of the gravel and sand layers, the leachate thicknesses considered in Table ss than, or equal to, the thickness of the leakage collection layer; therefore, in s considered in Table 1, the gravel and sand layer are not filled (or just filled) chate, and for these two materials the leachate thicknesses, t_o, shown in Table tual (not virtual) thicknesses.

Table 1. Rate of leachate flow in three different leachate collection layers resulting from a defect in the primary liner.

Leachate thickness (actual or virtual)		Leakage collection layer material: Geonet t_{LCL} = 5 mm, $k = 1 \times 10^{-1}$ m/s		Gravel t_{LCL} = 300 mm, $k = 1 \times 10^{-1}$ m/s		Sand t_{LCL} = 300 mm, $k = 1 \times 10^{-3}$ m/s	
t_o		Q		Q		Q	
(m)	(mm)	(m³/s)	(lpd)	(m³/s)	(lpd)	(m³/s)	(lpd)
0.005	5	2.5×10^{-6}	216	2.5×10^{-6}	216	2.5×10^{-8}	2.16
0.01	10	7.5×10^{-6}	648	1.0×10^{-5}	864	1.0×10^{-7}	8.64
0.05	50	4.75×10^{-5}	4,104	2.5×10^{-4}	21,600	2.5×10^{-6}	216
0.1	100	9.75×10^{-5}	8,424	1.0×10^{-3}	86,400	1.0×10^{-5}	864
0.3	300	2.975×10^{-4}	25,704	9.0×10^{-3}	777,600	9.0×10^{-5}	7,776

Notes: The leachate thickness, t_o, can be derived from the leachate head on top of the secondary liner using Equation 4. The leachate thickness, t_o, is the actual leachate thickness if $t_o < t_{LCL}$ and a virtual leachate thickness if $t_o > t_{LCL}$. The tabulated values of the rate of leachate flow, Q, were calculated using Equation 9 when $t_o < t_{LCL}$ and Equation 16 when $t_o > t_{LCL}$. Units: 1 m³/s = 86,400,000 liters per day (lpd).

It appears from Table 1, that for a given value of t_o, i.e. a given value of the head of leachate on top of the secondary liner, h_o (see Equation 4), the gravel and the geonet can convey significantly more leachate than the sand. It is interesting to compare the flow rates of Table 1 with rates of leachate migration through defects of geomembranes used alone (i.e. not part of a composite liner) calculated using Bernoulli's equation, which is expressed as follows:

$$Q = 0.6\, a \sqrt{2\, g\, h_{prim}} = 0.6\, \pi (d^2/4) \sqrt{2\, g\, h_{prim}} \approx (2/3)\, d^2 \sqrt{g\, h_{prim}} \quad (20)$$

where: a = defect area; d = defect diameter; g = acceleration due to gravity; and h_{prim} = head of leachate on top of the primary liner.

Table 2 gives rates of leachate migration through geomembrane defects calculated using Equation 20. It appears that, with the leachate heads that typically exist on the primary liners of actively operating landfills (i.e. landfills that are receiving waste), and provided that the geomembrane is used alone (i.e. is not part of a composite liner):

- a small geomembrane defect (e.g. 1 to 2 mm diameter), which may occasionally be undetected during construction, results in a rate of leakage on the order of 100 liters per day (lpd);
- a geomembrane defect (e.g. 3 to 5 mm diameter), which may occasionally occur during construction phases where defect detection may not be possible (e.g. placement of granular leachate collection material on geomembrane), results in a rate of leakage on the order of 1000 lpd (1 m³/day); and
- a large geomembrane defect (e.g. 10 mm diameter or more), which may occur under

4 Wetted Fraction

4.1 *Scope of Section 4.4*

To calculate the rate of leakage through the secondary liner, it is useful to know what ıction of the total surface area of the secondary liner is wetted and what is the average ad of leachate over this fraction of the secondary liner. The wetted fraction is deter- ined in Sections 4.4.3 and 4.4.4, and the average head will be determined in Sections 1 and 5.2.

In the preceding sections, only one defect in the primary liner was considered. This no longer the case in Section 4.4 because the wetted fraction depends on the number defects per unit area. In Section 4.4, two scenarios of defect location will be consid- ed: a scenario where the defects are located to give the maximum wetted fraction, and scenario where the defects are at random.

In Section 4.4, a leakage collection layer whose length in the direction of the flow s a horizontal projection L, and whose width in the direction perpendicular is B, is nsidered (Figure 9). The projected surface area of this leakage collection layer is erefore:

$$A_{LCL} = L\,B \qquad (98)$$

4.2 *Definitions*

etted Fraction. The wetted fraction, R_w, is defined as the ratio between the surface ea of the total wetted zone and the surface area of the leakage collection layer:

$$R_w = \frac{\sum_{n=1}^{n=N} A_w}{A_{LCL}} \qquad (99)$$

As shown by the numerator of the fraction, the surface area of the total wetted zone the sum of the surface areas of the wetted zones that correspond to every defect in e primary liner, the number of defects being N.

efect Frequency. The frequency of defects, F, in the primary liner (i.e. the liner over- ing the leakage collection layer) is defined as the ratio of the total number of defects, in the liner and the surface area of the liner, which is equal to the surface area of the akage collection layer:

$$F = \frac{N}{A_{LCL}} \qquad (100)$$

In typical design calculations the frequency of the defects in the primary liner, F, is sumed to be known. For example, if there are four defects per hectare (10,000 m^2),

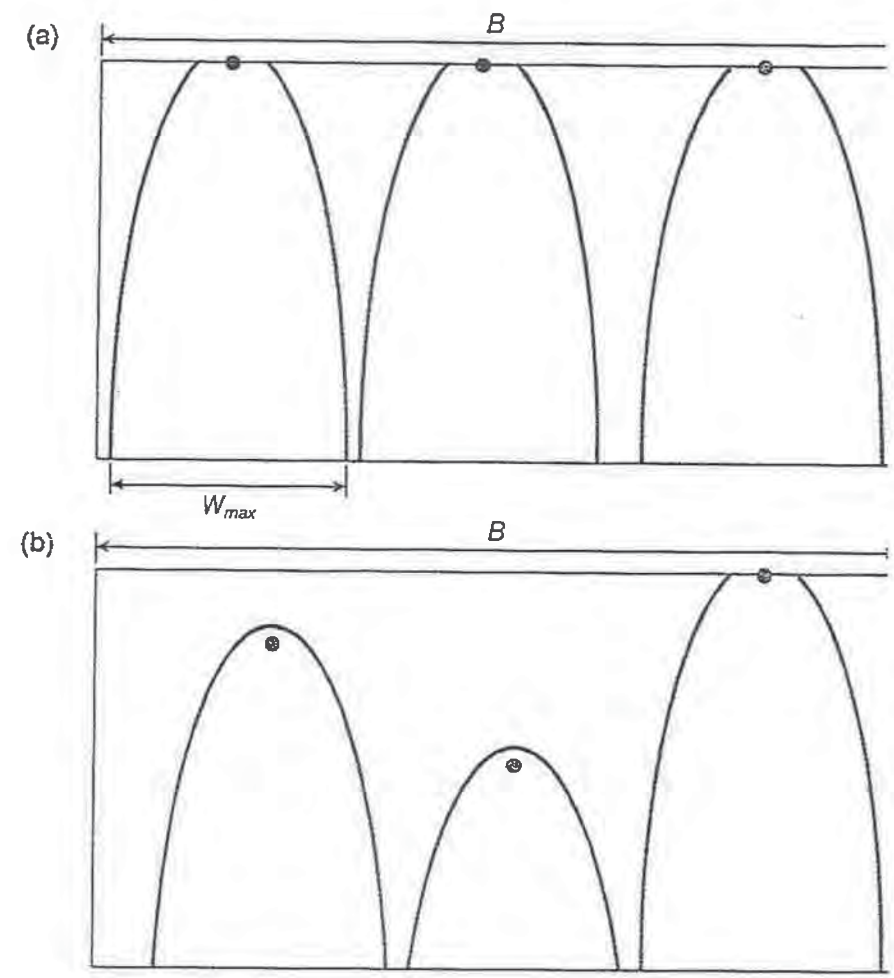


Figure 9. Leakage collection layer zones wetted by leachate migrating through se defects in the primary liner, assuming no overlapping of wetted zones: (a) scenario where all the defects are located at the high end of the leachate collection slope; (b) random scenario where the defects are randomly distributed.

Notes: L is the horizontal projection of the length of the leakage collection layer in the direction of the and B is the width of the leakage collection layer. The dots represent the horizontal projection of the loca of the primary liner defects.

Scenarios. Two defect location scenarios will be considered: (i) the worst sce where all of the defects are at the high end of the leakage collection layer slope (Fi 9a); and (ii) the random scenario where the defects are randomly distributed (Fi

$$\frac{t_{avg\ rand}\ \lambda_{rand}}{t_{avg\ worst}\ \lambda_{worst}} = \frac{2\ \mu}{9} + \frac{x_{rand}}{L} = \frac{\mu^{5/3}}{\left(10\sqrt{2}\right)^{2/3}}\left[\left(1+\frac{2}{\mu}\right)^{5/2} - 2\right]^{2/3} - \frac{5\mu}{18} \quad (192)$$

Equation 192 is valid only for $\mu \leq 1.0696$. Values calculated using Equation 192 are given in Table 6. Values of $t_{avg\ rand}\,\lambda_{rand}/(t_{avg\ worst}\,\lambda_{worst})$ given in Table 6 for $\mu > 1.0696$ were calculated from numerical values of $\lambda_{worst}/\lambda_{rand}$ given in Table 4 and numerical values of $t_{avg\ rand}/t_{avg\ worst}$ given in Table 6.

.2.4 *Average Leachate Thickness When Wetted Zones Overlap*

The values of the average leachate thickness given in Sections 5.2.2 and 5.2.3 are val-d only if there is no overlapping of different wetted zones, i.e. if, as shown in Section .4.5:

$$R_{w\,worst} \leq \text{Crit}\,(R_{w\,worst}) \quad (193)$$

$$R_{w\,rand} \leq \text{Crit}\,(R_{w\,rand}) \quad (194)$$

If the conditions expressed by Equations 193 and 194 are not satisfied, there is over-apping between adjacent wetted zones. In this case, the best approach, from a practical tandpoint, is to assume that the entire area of the leakage collection layer is wetted. gain, the worst scenario and the random scenario are considered. These two scenarios re defined in Section 4.4.2.

Vorst Scenario. In the worst scenario all of the primary liner defects are located at e higher end of the leakage collection layer slope. Since the wetted zones have been ssumed to overlap, it is approximately correct to consider that the entire leakage ollection layer area is wetted. As a result, the leachate thickness is approximately uni-rm over the entire leakage collection layer area provided that the defects are uniform- distributed at the high end of the leakage collection layer slope. The average leachate ickness is then derived using the classical Darcy's equation, resulting in:

$$t_{avg\ worst} = \frac{N\ Q}{k\ i\ B} \quad (195)$$

here: N = total number of defects in the primary liner; Q = rate of leachate migration rough one defect of the primary liner, all defects being assumed identical and sub-cted to the same leachate head over the entire surface area of the primary liner; k = ydraulic conductivity of the leakage collection layer material; i = hydraulic gradient the leakage collection layer; and B = width of the leakage collection layer.

Combining Equations 8 and 195 gives:

$$t_{avg\ worst} = \frac{N\ Q}{k\ B\ \sin\beta} \quad (196)$$

Combining Equations 98, 100 and 197 gives:

$$t_{avg\ worst} = \frac{F\ L\ Q}{k\ \sin\beta}$$

Equations 195 to 197 are valid only if the leakage collection layer is not the condition expressed by Equation 11 (or Equation 12 which is equivalent) case where the leakage collection layer is *full over its entire surface area* i (i) Equations 16 to 18, which where established for the case where the leak tion layer is *full in a limited area* around the primary liner defect, are not and (ii) assuming that the virtual thickness of leachate is a constant (t_{avg}) ove area of the leakage collection layer allows Darcy's equation to be written :

$$N\ Q = k\ B\ t_{LCL}\ \sin\beta$$

which shows that there is no relationship between Q and t_{avg}. In other words indeterminate. Therefore, no solution is proposed for the average leachate virtual thickness) for the case where the leakage collection layer is filled wit

Random Scenario. In the random scenario, the primary liner defects are at random. In the case where there are enough defects to assume that the ent collection layer area is wetted, the design of a leakage collection layer becor to the design of a leachate collection layer subjected to a uniform rate of lea eration. As shown by Giroud and Houlihan (1995), in most practical cases, value of the leachate thickness is :

$$\frac{t_{avg}}{L} = \frac{\sum Q/(L\ B)}{2\ k\ \sin\beta}$$

With the notations used in this paper, Equation 199 becomes:

$$t_{avg\ rand} = \frac{N\ Q}{2\ k\ B\ \sin\beta}$$

Combining Equations 98, 100 and 200 gives:

$$t_{avg\ rand} = \frac{F\ L\ Q}{2\ k\ \sin\beta}$$

Comparing Equations 197 and 200 shows that the average leachate thickn greater in the worst scenario than in the random scenario. (It should be remem it has been assumed that, in both cases, the entire surface area of the leakage layer is wetted.)

Equations 199 to 201 are valid only if the leakage collection layer is not the condition is expressed by Equation 11 (or Equation 12 which is equivale Also, for the reasons indicated after Equation 197, no solution is proposed f where the leakage collection layer is full.

e of Primary Liner Defect Frequency on Average Leachate Thickness

difference between Sections 5.2.2 and 5.2.3 on one hand, and Section er hand should be noted. Equations for $t_{avg\,worst}$ and $t_{avg\,rand}$ do not depend equency, F, in Sections 5.2.2 and 5.2.3, whereas they depend on F in The reason for that is the following:

.2.2 and 5.2.3, the wetted zones, that correspond to various defects in ner, do not overlap. The average leachate thickness is the same in any idual wetted zones and it is calculated for any of them. Consequently, achate thickness does not depend on the frequency of defects. However, of defects governs the wetted fraction (i.e. the ratio between the total f all wetted zones and the surface area of the leakage collection layer). .4, it is assumed that the entire surface area of the leakage collection l. In other words, it is assumed that the wetted fraction is equal to one. average leachate thickness is a function of all of the defects in the pri- d, consequently, is a function of the defect frequency.

to note that, when the wetted fraction exceeds the critical value (Sec- lesign engineer must assume that the individual wetted zones (i.e. the t correspond to the individual defects in the primary liner) overlap and iations given in Section 5.2.4 to calculate the average leachate thick- when the wetted fraction does not exceed the critical value, the design her use the equations given in Section 5.2.4 or use the equations given and 5.2.3. The approach described in Section 5.2.4 is simpler: it con- g that the entire leakage collection layer area is wetted. The approach tions 5.2.2 and 5.2.3 is more complex but closer to reality: only a frac- ge collection layer is wetted and, in addition to calculating the average ss as shown in Sections 5.2.2 and 5.2.3, it is necessary to determine the on using equations provided in Section 4.4. The use of both approaches Example 6 in Section 6.1.

aches give values of the leachate thickness (and head) that are different etted zones do not overlap, only the approach described in Sections gives a correct value of the leachate thickness (or head). However, in age leachate thickness is only calculated as a first step in the calcula- leakage through the secondary liner. In this case, both approaches are pproach described in Section 5.2.4 gives a leachate thickness that is nly distributed over the entire secondary liner, while the approach de- as 5.2.2 and 5.2.3 gives a greater leachate thickness in the wetted area utside the wetted area. The leakage rates calculated using the leachate ined as indicated in Section 5.2.4 are conservative (i.e. greater than using the leachate thickness determined as indicated in Sections 5.2.2 ultiplied by the wetted fraction) because leakage rates typically vary the head to a power less than one. This will be illustrated quantitative- after Example 6.

5.3 Time Required to Reach Steady-State Flow Conditions

5.3.1 *Equations*

The volume of liquid in a porous medium is less than the volume of porous medium that contains the liquid. As indicated by Equation 143, the volume of leachate in the leakage collection layer is equal to the volume of the leakage collection layer that contains the leachate multiplied by the porosity, n, of the leakage collection layer material. The time required for such a volume to pass through the primary liner defect, $\bar{t}_{req}$, gives a lower boundary of the time required to reach steady-state flow conditions, hence:

$$\bar{t}_{req} > \frac{nV}{Q} \tag{202}$$

Combining Equations 10, 153 and 202 gives the following equation for the case where the leakage collection layer is not full:

$$\bar{t}_{req} > \frac{n\,x}{k \sin\beta \cos\beta} + \frac{2\,n\,Q^{1/2}}{9 \sin^2\beta \cos\beta\, k^{3/2}} \tag{203}$$

The last term is generally negligible, because it represents the time required to fill the volume of the leakage collection layer that contains leachate between axes Oy and VY (Figure 6). This volume is either small or reduced by truncation (Figure 8). Therefore:

$$\bar{t}_{req} > \frac{n\,x}{k \sin\beta \cos\beta} \tag{204}$$

Equation 204 may be written as follows:

$$\bar{t}_{req} > \frac{x / \cos\beta}{k \sin\beta / n} \tag{205}$$

Combining Equations 8 and 205 gives:

$$\bar{t}_{req} > \frac{x / \cos\beta}{k\,i / n} \tag{206}$$

where the numerator is the distance between the primary liner defect and the low end of the leakage collection layer slope, and the denominator is the actual liquid velocity derived from Darcy's equation. Therefore, the right hand member of Equation 204 is the travel time, $\bar{t}_{travel}$, i.e. the time required by a drop of leachate to travel from the primary liner defect to the low end of the leakage collection layer, assuming that flow is not hampered by capillarity in the leakage collection layer:

$$\bar{t}_{req} > \bar{t}_{travel} = \frac{n\,x}{k \sin\beta \cos\beta} \tag{207}$$

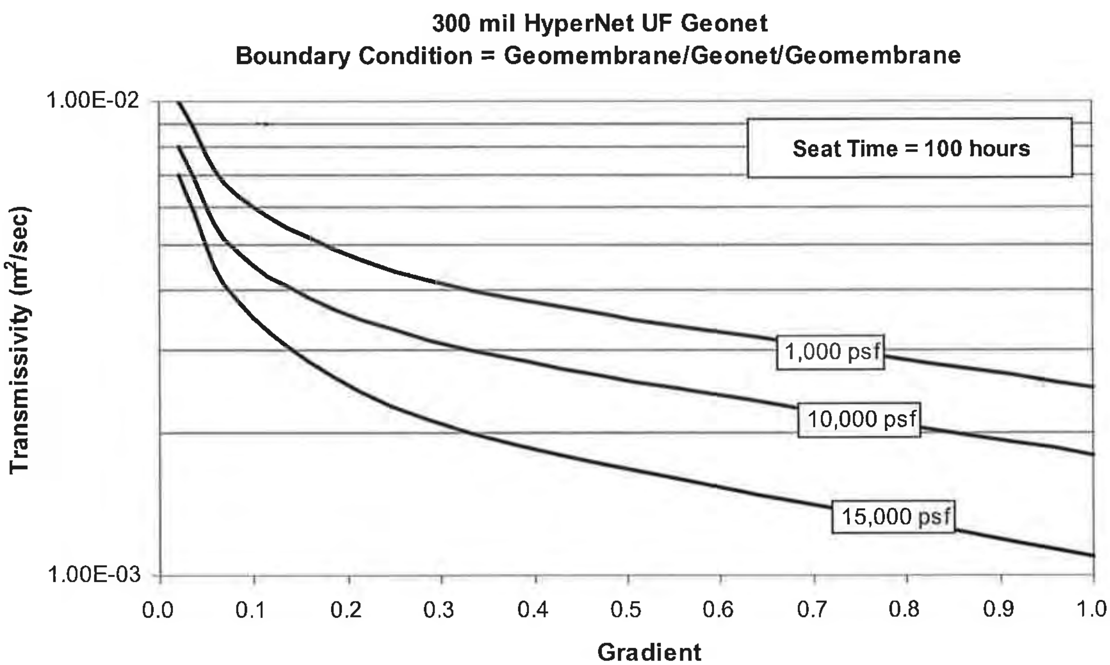


Figure A-7 Performance Transmissivity of a 300 mil HyperNet UF Geonet.

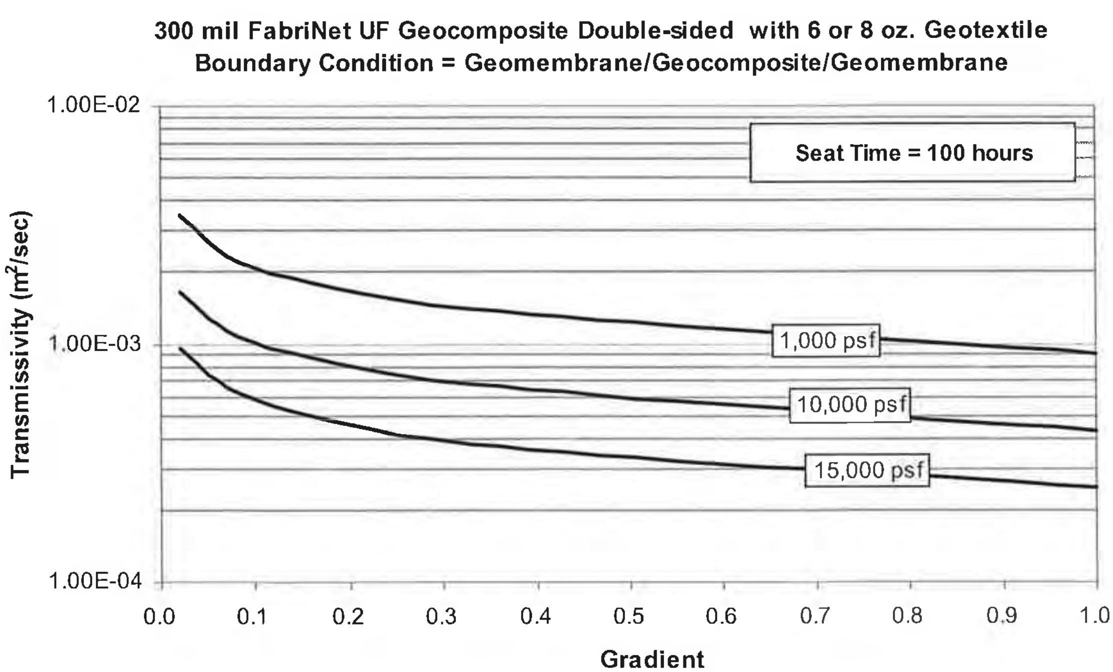


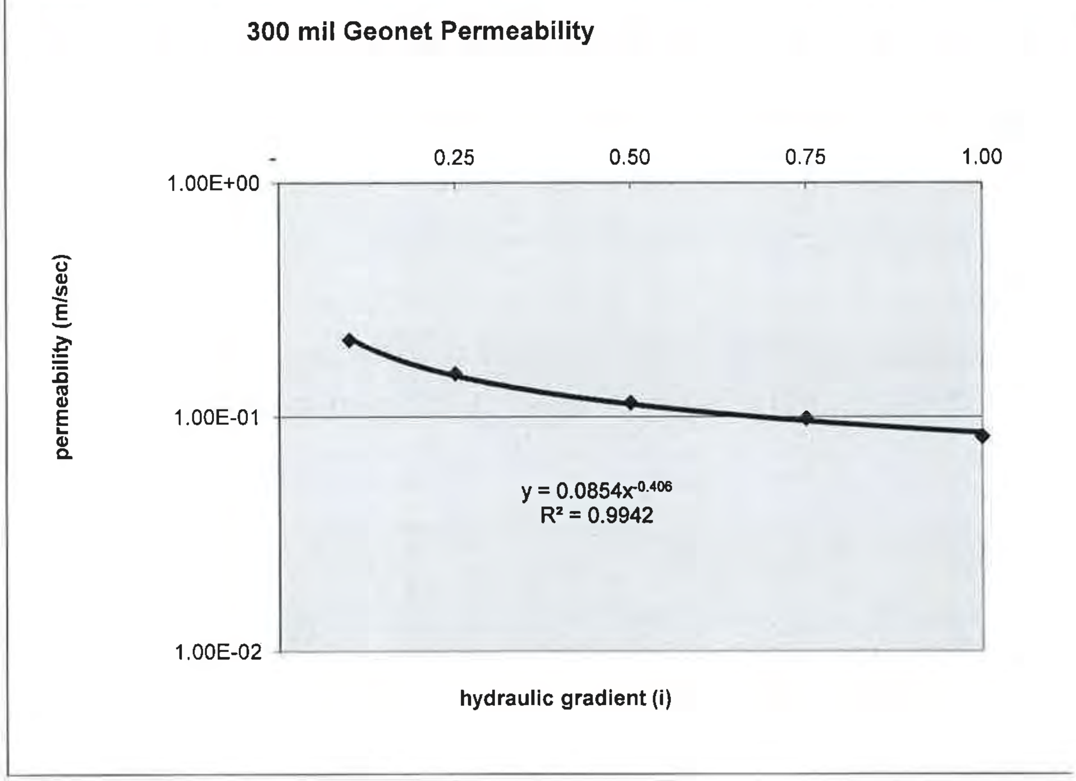
Figure A-8 Performance Transmissivity of a 300 mil FabriNet UF Geocomposite between Plates.

Source: http://www.gseworld.com/Online-Drainage-Design-Manual/Transmissivity/

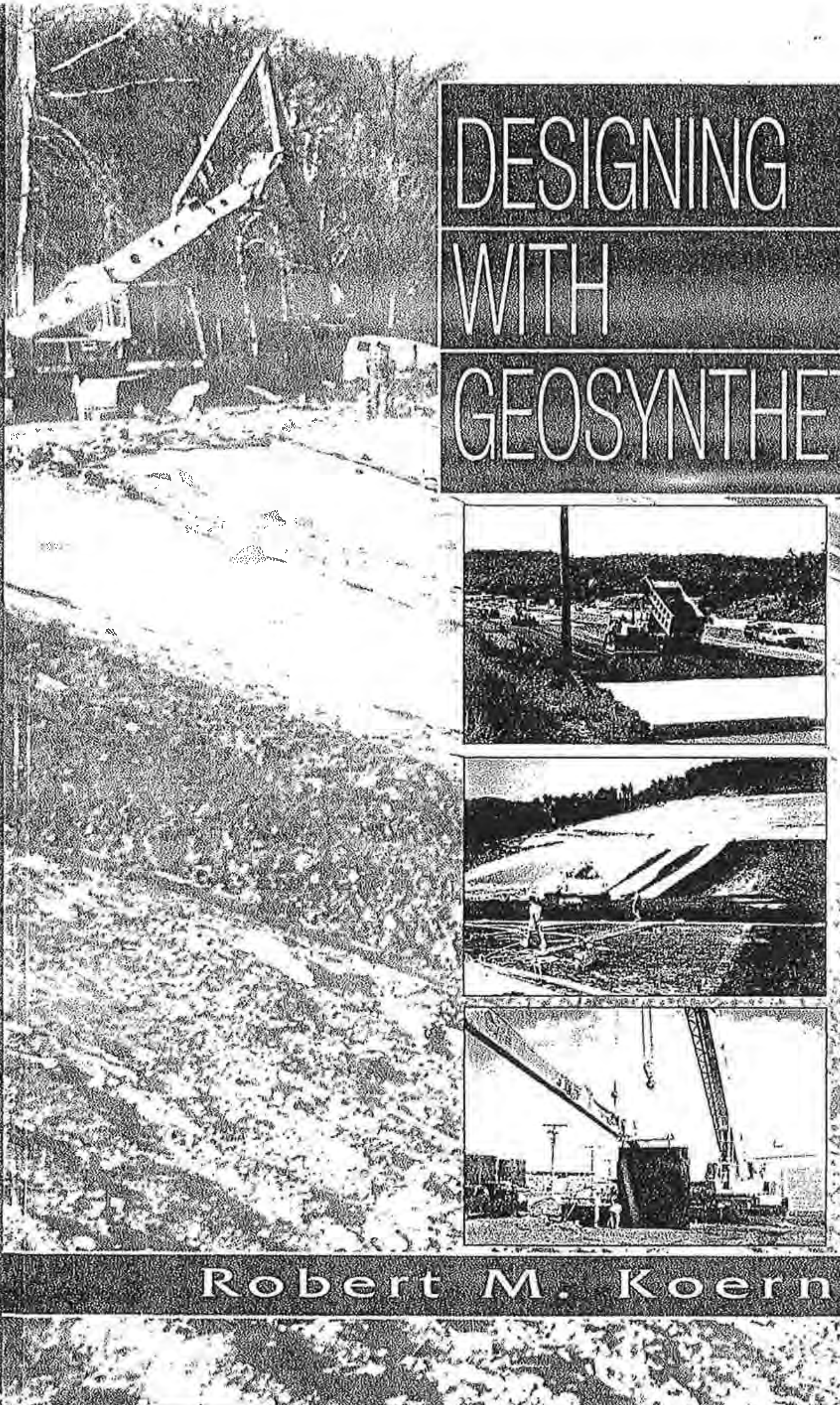
Attachment D (1/2)

GSE 300 mil HyperNet UF (HDPE/GN/HDPE)

i	Normal Stress (psf)	Transmissivity (m2/sec)	Thickness (mil)	Thickness (mm)	Partial Factor of Safety IN	CR	CC	BC	Permeability (m/sec)
0.10	10,000	3.90E-03	300	7.62	1.0	1.2	2.0	1.0	2.13E-01
0.25	10,000	2.80E-03	300	7.62	1.0	1.2	2.0	1.0	1.53E-01
0.50	10,000	2.10E-03	300	7.62	1.0	1.2	2.0	1.0	1.15E-01
0.75	10,000	1.80E-03	300	7.62	1.0	1.2	2.0	1.0	9.84E-02
1.00	10,000	1.50E-03	300	7.62	1.0	1.2	2.0	1.0	8.20E-02



Attachment D 2/2



DESIGNING WITH GEOSYNTHETICS

Fourth Edition

Robert M. Koerner

ATTACHMENT E, 1/3

4.1.6 Allowable Flow Rate

As described previously, the very essence of the design-by-function concept is the establishment of an adequate factor of safety. For geonets, where flow rate is the primary function, this takes the following form.

$$FS = \frac{q_{allow}}{q_{reqd}} \tag{4.3}$$

where

FS = factor of safety (to handle unknown loading conditions or uncertainties in the design method, etc.),
q_{allow} = allowable flow rate as obtained from laboratory testing, and
q_{reqd} = required flow rate as obtained from design of the actual system.

Alternatively, we could work from transmissivity to obtain the equivalent relationship.

$$FS = \frac{\theta_{allow}}{\theta_{reqd}} \tag{4.4}$$

where θ is the transmissivity, under definitions as above. As discussed previously, however, it is preferable to design with flow rate rather than with transmissivity because of nonlaminar flow conditions in geonets.

Concerning the allowable flow rate or transmissivity value, which comes from hydraulic testing of the type described in Section 4.1.3, we must assess the realism of the test setup in contrast to the actual field system. If the test setup does not model site-specific conditions adequately, then adjustments to the laboratory value must be made. This is usually the case. Thus the laboratory-generated value is an ultimate value that must be reduced before use in design; that is,

$$q_{allow} < q_{ult}$$

One way of doing this is to ascribe reduction factors on each of the items not adequately assessed in the laboratory test. For example,

$$q_{allow} = q_{ult}\left[\frac{1}{RF_{IN} \times RF_{CR} \times RF_{CC} \times RF_{BC}}\right] \tag{4.5}$$

or if all of the reduction factors are considered together,

$$q_{allow} = q_{ult}\left[\frac{1}{\Pi RF}\right] \tag{4.6}$$

where

q_{ult} = flow rate determined using ASTM D4716 or ISO/DIS 12958 for short-term tests between solid platens using water as the transported liquid under laboratory test temperatures,

Sec. 4.1
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ATTACHMENT E, 2/3

q_{allow} = allowable flow rate to be used in Eq. (4.3) for final design purposes,
RF_{IN} = reduction factor for elastic deformation, or intrusion, of the adjacent geosynthetics into the geonet's core space,
RF_{CR} = reduction factor for creep deformation of the geonet and/or adjacent geosynthetics into the geonet's core space,
RF_{CC} = reduction factor for chemical clogging and/or precipitation of chemicals in the geonet's core space,
RF_{BC} = reduction factor for biological clogging in the geonet's core space, and
ΠRF = product of all reduction factors for the site-specific conditions.

Some guidelines for the various reduction factors to be used in different situations are given in Table 4.2. Please note that some of these values are based on relatively sparse information. Other reduction factors, such as installation damage, temperature effects, and liquid turbidity, could also be included. If needed, they can be included on a site-specific basis. On the other hand, if the actual laboratory test procedure has included the particular item, it would appear in the above formulation as a value of unity. Examples 4.2 and 4.3 illustrate the use of geonets and serve to point out that high reduction factors are warranted in critical situations.

Example 4.2

What is the allowable geonet flow rate to be used in the design of a capillary break beneath a roadway to prevent frost heave? Assume that laboratory testing was done at the proper design load and hydraulic gradient and that this testing yielded a short-term between-rigid-plates value of 2.5×10^{-4} m²/s.

Solution: Since better information is not known, average values from Table 4.2 are used in Eq. (4.5).

TABLE 4.2 RECOMMENDED PRELIMINARY REDUCTION FACTOR VALUES FOR EQ. (4.5) FOR DETERMINING ALLOWABLE FLOW RATE OR TRANSMISSIVITY OF GEONETS

Application Area	RF_{IN}	RF_{CR}*	RF_{CC}	RF_{BC}
Sport fields	1.0 to 1.2	1.0 to 1.5	1.0 to 1.2	1.1 to 1.3
Capillary breaks	1.1 to 1.3	1.0 to 1.2	1.1 to 1.5	1.1 to 1.3
Roof and plaza decks	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2	1.1 to 1.3
Retaining walls, seeping rock, and soil slopes	1.3 to 1.5	1.2 to 1.4	1.1 to 1.5	1.0 to 1.5
Drainage blankets	1.3 to 1.5	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2
Surface water drains for landfill covers	1.3 to 1.5	1.1 to 1.4	1.0 to 1.2	1.2 to 1.5
Secondary leachate collection (landfills)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 2.0
Primary leachate collection (landfills)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 2.0

*These values are sensitive to the density of the resin used in the geonet's manufacture. The higher the density, the lower the reduction factor. Creep of the covering geotextile(s) is a product-specific issue.

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

GEOMEMBRANE TEST RESULTS

TRI Client: Agru America
Project: Product Characterization

Material: Agru Geomembrane - 60 mil HDPE Smooth / 60 mil HDPE Drain Liner
Sample Identification: No Label
TRI Log #: E2231-68-01

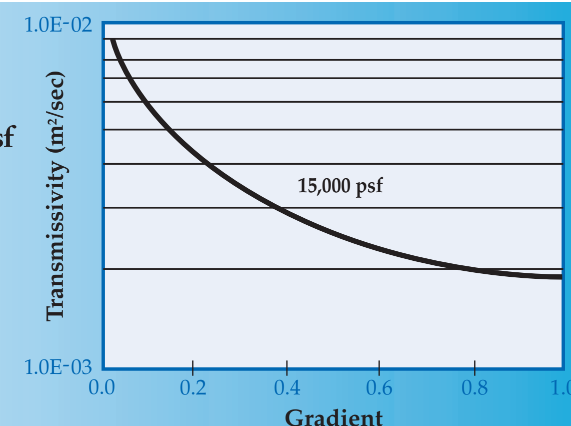
PARAMETER							MEAN	STD. DEV.	PROJ SPEC
Hydraulic Transmissivity (ASTM D 4716)									
Direction Tested: Machine Direction									
Profile (Top to Bottom): Plate/60 mil Smooth HDPE Geomembrane/60 mil Drain Liner HDPE Geomembrane (Studs Up)/Plate									
Permeant: Water									
Compressive Load (psf):	15000								
Hydraulic Gradient:	1.0								
Seat Time (hours):	0.25								
Test Temperature (C)	23								
Flow Rate/Unit Width (GPM/ft width)	9.27	9.45	9.19	10.24	9.99	9.95	9.68	0.397	
Hydraulic Transmissivity (m2/s)	1.8E-03	1.8E-03	1.8E-03	2.0E-03	1.9E-03	1.9E-03	1.9E-03	7.6E-05	8E-04 min
Compressive Load (psf):	15000								
Hydraulic Gradient:	0.5								
Seat Time (hours):	0.25								
Test Temperature (C)	23								
Flow Rate/Unit Width (GPM/ft width)	6.09	6.37	6.16	6.51	6.59	6.68	6.40	0.217	
Hydraulic Transmissivity (m2/s)	2.3E-03	2.5E-03	2.4E-03	2.5E-03	2.5E-03	2.6E-03	2.5E-03	8.3E-05	8E-04 min
Compressive Load (psf):	15000								
Hydraulic Gradient:	0.33								
Seat Time (hours):	0.25								
Test Temperature (C)	23								
Flow Rate/Unit Width (GPM/ft width)	4.95	4.90	5.08	5.39	5.30	5.30	5.16	0.188	
Hydraulic Transmissivity (m2/s)	2.9E-03	2.8E-03	2.9E-03	3.1E-03	3.1E-03	3.1E-03	3.0E-03	1.1E-04	8E-04 min
Compressive Load (psf):	15000								
Hydraulic Gradient:	0.1								
Seat Time (hours):	0.25								
Test Temperature (C)	23								
Flow Rate/Unit Width (GPM/ft width)	2.52	2.52	2.51	2.50	2.66	2.68	2.57	0.076	
Hydraulic Transmissivity (m2/s)	4.9E-03	4.9E-03	4.8E-03	4.8E-03	5.1E-03	5.2E-03	4.9E-03	1.5E-04	8E-04 min

Drain Liner™/Smooth HDPE

Transmissivity under 15,000 psf

Normal stress

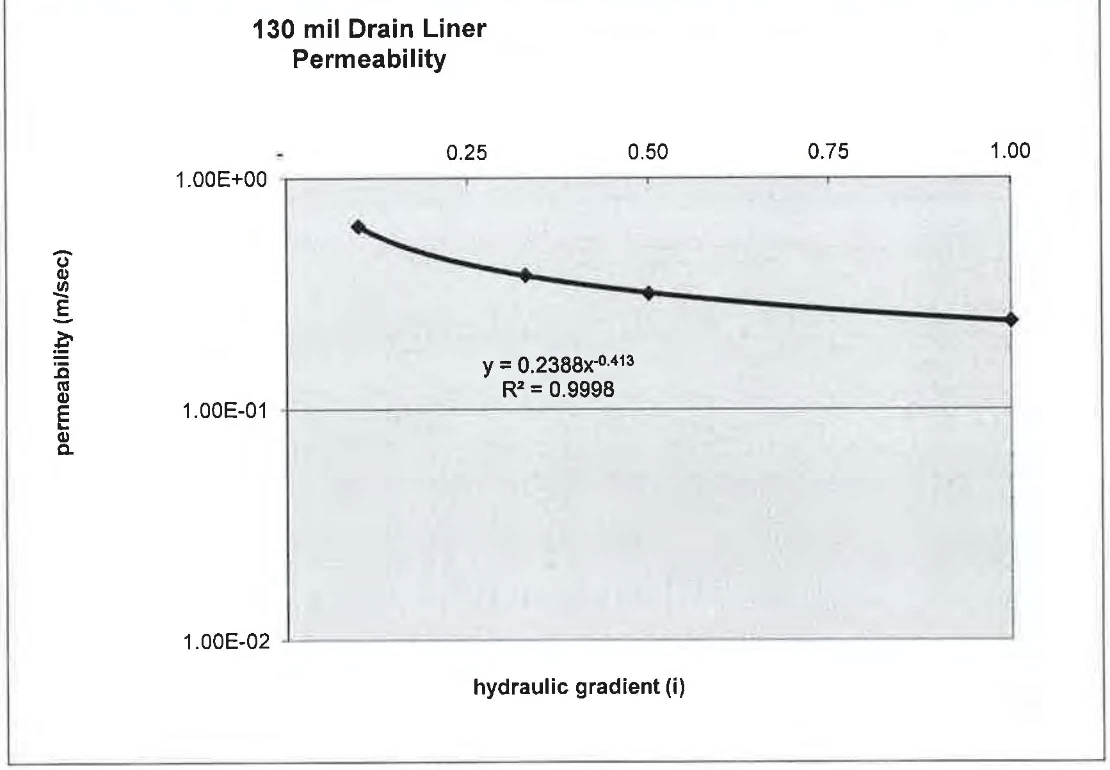
ASTM D4716



Appendix F (2/3)

Agru Drain Liner 130 mil (HDPE/HDPE)

i	Normal Stress (psf)	Transmissivity (m2/sec)	Thickness (mil)	Thickness (mm)	Partial Factor of Safety IN	CR	CC	BC	Permeability (m/sec)
0.10	15,000	4.90E-03	130	3.3	1.0	1.2	2.0	1.0	6.18E-01
0.33	15,000	3.00E-03	130	3.3	1.0	1.2	2.0	1.0	3.79E-01
0.50	15,000	2.50E-03	130	3.3	1.0	1.2	2.0	1.0	3.15E-01
1.00	15,000	1.90E-03	130	3.3	1.0	1.2	2.0	1.0	2.40E-01



Attachment F 3/3

Written by: ____________ Date: __/__/__ (DD MM YY) Reviewed by: ____________ Date: __/__/__ (DD MM YY)

Client: ________ Project: ________ Project/Proposal No. ________ Task No. ________

SAMPLE

DIMENSIONS: 4" × 6"

AREA: $24 in^2$

Total Void Volume Assuming H = 130 mil

$V_T = 24 in^2 \times 0.13 in = 3.12 in^3$

STUDS

HEIGHT: 130 mil = 0.13 in

DIAMETER: 0.10 in

Volume: $\left(\frac{0.10}{2}\right)^2 \pi (0.13) = 0.00102 in^3$

No. Studs on 4"×6" panel: 80

Total Stud Volume, V_s

$80 \times 0.00102 in^3$

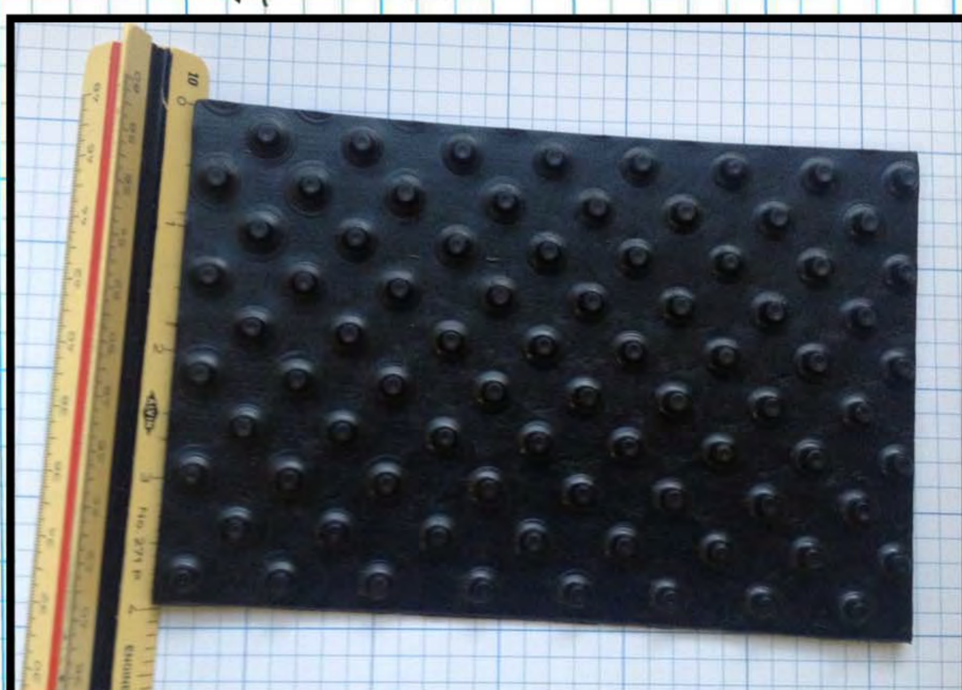
$V_S = 0.0816 in^3$

Volume of Voids, V_V

$V_V = V_T - V_S = 3.12 - 0.0816 = 3.04 in^3$

Porosity, ϕ

$\phi = \frac{V_V}{V_T} = \frac{3.04}{3.12} = 0.97 = 97\%$



Attachment G

Geosyntec
consultants

COMPUTATION COVER SHEET

Client: **EF** Project: **White Mesa Mill – Cells 5A and 5B** Project/ Proposal No.: **SC0634A** Task No. **02**

Title of Computations **EVALUATION OF LINER SYSTEM ANCHOR TRENCH CAPACITY – Option B**

Computations by:	Signature	[signature]	6/21/18
	Printed Name	Rebecca Oliver	Date
	Title	Principal Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature	[signature]	6/21/18
	Printed Name	Keaton Botelho	Date
	Title	Senior Engineer	
Computations Checked by:	Signature	[signature]	6/21/18
	Printed Name	Keaton Botelho	Date
	Title	Senior Engineer	
Computations backchecked by: (originator)	Signature	[signature]	6/21/18
	Printed Name	Rebecca Oliver	Date
	Title	Principal Engineer	
Approved by: (pm or designate)	Signature	[signature]	06/22/2018
	Printed Name	Gregory T. Corcoran	Date
	Title	Senior Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

SC0634.Anchorage.20180621.d.calc

Written by:	R. Oliver	Date:	6/21/18	Reviewed by:	G. Corcoran	Date:	
Client:	EF	Project:	WMM- Cells 5A & 5B	Project/ Proposal No.:	SC0634A	Task No.:	02

EVALUATION OF LINER SYSTEM ANCHOR TRENCH CAPACITY
OPTION B
WHITE MESA MILL
BLANDING, UTAH

OBJECTIVE

The project includes the installation of a double geomembrane with geosynthetic clay liner (GCL) liner system within Cells 5A and 5B at the White Mesa Mill in Blanding, Utah. The proposed liner system and anchor trench is shown in Attachment A. The objective of this calculation package is to evaluate the tensile strength capacity for anchorage of the liner system at termination locations of the liner system with respect to wind uplift forces on the geomembrane. The anchor capacity presented herein is applicable to geomembrane pullout. The anchor trench is evaluated for two conditions: the interim construction condition and the final condition. In the interim condition, the liner is temporarily secured in the anchor trench with 1 ft of soil cover while the remaining liner components are deployed.

METHOD OF ANALYSIS

Anchor trench capacity is evaluated using methods and equations presented by Koerner (1998) and are included as Attachment B.

Koerner (1998) presents design equations developed from static equilibrium to evaluate the allowable geosynthetic tension from an anchor trench (see Attachment B). The equation considers frictional resistance due to (i) overburden pressures, (ii) anchor trench side slopes, and (iii) base of the anchor trench. The proposed design equation for determination of the allowable geomembrane tension from an anchor trench is:

$$T_{ult} = F_U + F_L + F_{AT\text{-}SIDE1} + F_{AT\text{-}SIDE2} + F_{AT\text{-}BASE1} + F_{AT\text{-}BASE2} \qquad (3)$$

Where: T_{ult} = Ultimate tensile force in the geomembrane;

F_U = Friction force above the geosynthetics;

F_L = Friction force below the geosynthetics;

$F_U, F_L = q \tan\delta(L_{RO})$

q = surcharge pressure due to soil overburden

= depth of soil in anchor trench × unit weight

$\delta_{1,2}$ = minimum friction angle between liner system interfaces and the soil

L_{RO} = Runout length subjected to overburden

$F_{AT\text{-}SIDE}$ = Friction force due to the side of the anchor trench at each interface;

$F_{AT\text{-}SIDE} = (\sigma_h)_{ave} \times \tan\delta\,(d_{AT})$

$(\sigma_h)_{ave}$ = average horizontal stress in the anchor trench = $K_o(\sigma_v)_{ave}$

K_o = coefficient of earth pressure at rest = 1-sinΦ

Φ = friction angle of backfill soil

$(\sigma_v)_{ave}$ = vertical overburden stress (depth of soil at mid-point of trench (plus additional overburden) multiplied by the soil unit weight (γ))

d_{AT} = depth of the anchor trench = 1 ft (interim), 1.5 ft (final)

$F_{AT\text{-}BASE}$ = Friction force due to the base of the anchor trench at each interface;

$F_{AT\text{-}BASE} = q \tan\delta_{1,2}(L_{AT})$

L_{AT} = width of the anchor trench = 2 ft

For this site, wind uplift is the only loading considered for the anchor trench design and overburden will not be placed on top of the liner beyond the anchor trench; therefore, the liner system on the slope and slope angle is not considered and $L_{RO} = 0$. So the equation for the allowable geomembrane tension from an anchor trench now becomes:

$$T_{ult} = F_{AT\text{-}SIDE1} + F_{AT\text{-}SIDE2} + F_{AT\text{-}BASE1} + F_{AT\text{-}BASE2}$$

ANALYSIS

Evaluating Variables

Since tension may develop in the geomembrane (see the calculation package Tension due to Wind Uplift) due to wind uplift forces and thermal forces, frictional forces will be mobilized along the geosynthetic and soil interfaces on the side and base of the anchor trench. The 75 percent of the maximum wind speed at the site was used to evaluate the interim construction conditions (resulting in 18.75 mph). The load due to the interim wind uplift is 9.2 lb/in. (110 lb/ft). The maximum wind speed at the site with a reduction of 25 percent (%) was used to evaluate the final conditions. The load due to the maximum wind uplift is 17.7 lb/in (212.4 lb/ft) (see the calculation package Geomembrane Tension due to Wind Uplift). The maximum load is used for the final condition. For the analysis presented herein, the following three interfaces are evaluated:

1. A friction angle of 18 degrees will be used to represent the interface friction value between the anchor trench backfill and the smooth geomembrane (Attachment C).
2. A friction angle of 15 degrees will be used to represent the interface friction value between the smooth geomembrane and the drain liner (Attachment D).
3. A friction angle of 11 degrees will be used to represent the interface friction value between the geosynthetic clay liner and geomembrane (Attachment E).

For determination of the surcharge due to soil overburden, q, and the vertical and horizontal overburden stresses, σ_h and σ_v, a unit weight of overburden soil of 125 pounds per cubic foot (pcf) was used. For evaluation of the effective horizontal overburden stress based on the coefficient of earth pressure at rest, a friction angle of 26 degrees was used for the soil. See Slope Stability calculation package for material parameter assumptions.

Interim Condition	Final Condition
From Equation (3): $T_{ult} = F_{AT\text{-}SIDE1} + F_{AT\text{-}SIDE2}$ $F_{AT\text{-}BASE1} + F_{AT\text{-}BASE2}$	From Equation (3): $T_{ult} = F_{AT\text{-}SIDE1} + F_{AT\text{-}SIDE2}$ $F_{AT\text{-}BASE1} + F_{AT\text{-}BASE2}$

Written by:	R. Oliver	Date:	6/21/18	Reviewed by:	G. Corcoran	Date:	
Client:	EF	Project:	WMM- Cells 5A & 5B	Project/ Proposal No.:	SC0634A	Task No.:	02

$F_{AT-SIDE1} = (\sigma_h)_{ave} \tan\delta_1 (d_{AT})$ $= K_o(\sigma_{vave}) \tan\delta(d_{AT})$ $= (1-\sin 26°)\left(\frac{1}{2}(1\text{ ft})\right)\times$ $(125\text{ pcf})\tan 18°(1\text{ ft})$ $= 11\text{ lb/ft}$ $F_{AT-SIDE2} = (\sigma_h)_{ave} \tan\delta_2 (d_{AT})$ $= K_o(\sigma_{vave}) \tan\delta(d_{AT})$ $= (1-\sin 26°)\left(\frac{1}{2}(1\text{ ft})\right)\times$ $(125\text{ pcf})\tan 11°(1\text{ ft})$ $= 7\text{ lb/ft}$ $F_{AT-BASE1} = q\tan\delta_1 (L_{AT})$ $= 1\text{ ft}(125\text{ pcf})\tan 18°(2\text{ ft})$ $= 81\text{ lb/ft}$ $F_{AT-BASE2} = q\tan\delta_2 (L_{AT})$ $= 1\text{ ft}(125\text{ pcf})\tan 11°(2\text{ ft})$ $= 49\text{ lb/ft}$ $T_{ult} = F_{AT-SIDE1} + F_{AT-SIDE2} + F_{AT-BASE1} + F_{AT-BASE2}$ $= 11 + 7 + 81 + 49$ **T_{ult} = 148 lb/ft > 110 lb/ft OK**	$F_{AT-SIDE1} = (\sigma_h)_{ave} \tan\delta_1 (d_{AT})$ $= K_o(\sigma_v)_{ave} \tan\delta(d_{AT})$ $= (1-\sin 26°)\left(\frac{1}{2}(1.5\text{ ft})\right)\times$ $(125\text{ pcf})\tan 18°(1.5\text{ ft})$ $= 25\text{ lb/ft}$ $F_{AT-SIDE2} = (\sigma_h)_{ave} \tan\delta_2 (d_{AT})$ $= K_o(\sigma_v)_{ave} \tan\delta(d_{AT})$ $= (1-\sin 26°)\left(\frac{1}{2}(1.5\text{ ft})\right)\times$ $(125\text{ pcf})\tan 15°(1.5\text{ ft})$ $= 21\text{ lb/ft}$ $F_{AT-BASE1} = q\tan\delta_1 (L_{AT})$ $= 1.5\text{ ft}(125\text{ pcf})\tan 18°(2\text{ ft})$ $= 122\text{ lb/ft}$ $F_{AT-BASE2} = q\tan\delta_2 (L_{AT})$ $= 1.5\text{ ft}(125\text{ pcf})\tan 15°(2\text{ ft})$ $= 100\text{ lb/ft}$ $T_{ult} = F_{AT-SIDE1} + F_{AT-SIDE2} + F_{AT-BASE1} + F_{AT-BASE2}$ $= 25 + 21 + 122 + 100$ **T_{ult} = 268 lb/ft > 212 lb/ft OK**

Written by:	**R. Oliver**	Date:	**6/21/18**	Reviewed by:	**G. Corcoran**	Date:	
Client:	**EF**	Project:	**WMM- Cells 5A & 5B**	Project/ Proposal No.:	**SC0634A**	Task No.:	**02**

CONCLUSIONS

The tensile capacity of the anchorage system as calculated herein exceeds the expected interim and long-term wind uplift tensile loads (from the calculation package entitled *Evaluation of Tension due to Wind Uplift*). The expected tensile load due to wind uplift was evaluated to be 110 and 212 lb/ft for the interim and final conditions, respectively. The capacity of the interim and long-term anchor trenches are 148 and 268 lb/ ft, respectively. Therefore, the anchorage design for the geomembrane is adequate.

Based on the methods employed herein, results of analysis indicate that the design anchorage evaluated provides adequate tensile capacity to resist geomembrane tension induced by wind uplift forces.

NOTES TO PROJECT DOCUMENTS

The interim anchor trench shall have a minimum of 1 ft soil cover and a minimum 2 ft in width. The final anchor trench shall be a minimum of 1.5 ft deep and 2 ft. If an interim anchor trench is utilized, the total anchor trench depth shall be 3.5 ft in depth and 2 ft in width. The anchor trench shall be located at least 3 ft from the crest of the slope.

REFERENCES

Koerner, R.M. (1998), "*Designing with Geosynthetics*," 4th Edition. Prentice-Hall Inc.: Upper Saddle River, NJ. (*Attachment B)*

GSE Lining Technology. "*GSE FrictionFlex Application Data*." Technical Note. *(Attachment C)*

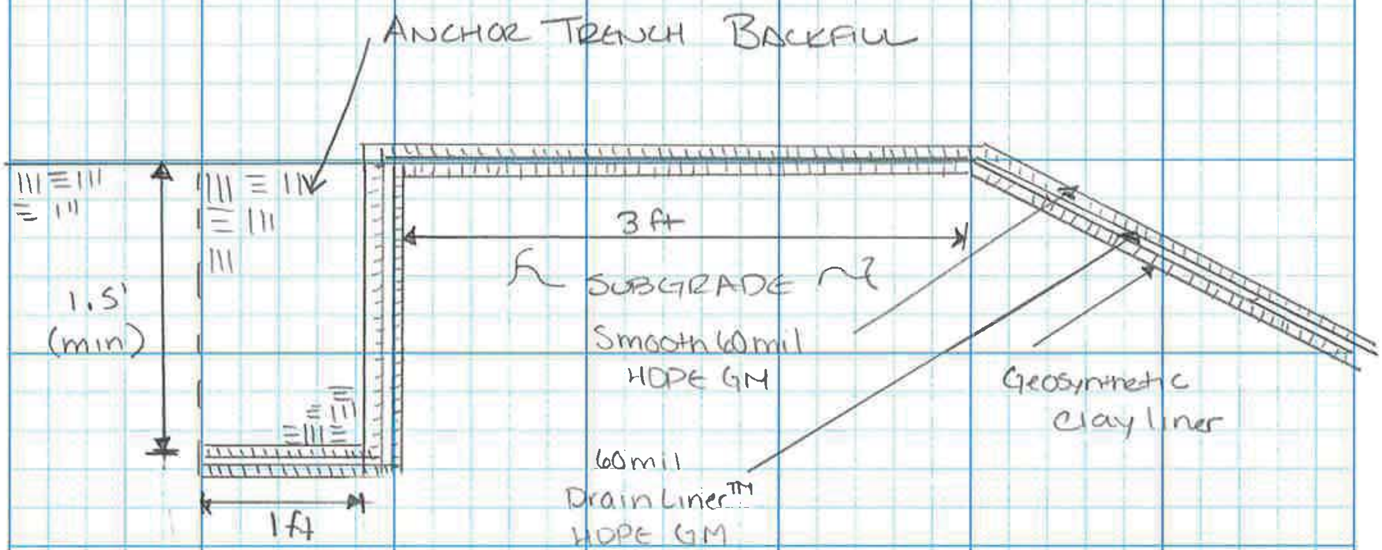
Interface Friction Angle Testing by TRI Environmental carried out in accordance with ASTM D5321. *(Attachment D)*

Hunt, Roy E. (1983). *Geotechnical Engineering Investigation Manual*, McGraw-Hill: New York. *(Attachment F)*

Geosyntec consultants

Written by: R OLIVER Date: 21 / 6 / 18 Reviewed by: ______ Date: ___/___/___

Client: EF Project: WMM-5A/B Project/Proposal No. SC0634A Task No. ______



N.T.S. Typ. Anchor Trench

Attachment A (1/1)

GTC 11/23/05

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

5.3.6 Runout and Anchor Trench Design

As shown in Figure 5.21 and the subsequent profile sections of geomembrane-lined reservoirs the liner comes up from the bottom of the excavation, covers the side slopes, and then runs over the top a short distance. It often terminates vertically down into an anchor trench. This anchor trench is typically dug by a small backhoe or trenching machine; the liner is draped over the edge, and then the trench is backfilled with the same soil that was there originally. The backfilled soil should be compacted in layers as the backfilling proceeds. Although concrete has been used as an anchorage block, it is rarely justified, at least on the basis of calculations, as will be seen in this section.

Regarding design, two separate cases will be analyzed: one with geomembrane runout only and no anchor trench at all (as is often used with canal liners), and the other as described above, with both runout and anchor trench considerations (as with reservoirs and landfills). Figure 5.30 defines the first situation, together with the forces and stresses involved. Note that the cover soil applies normal stress due to its weight, but does not contribute frictional resistance above the geomembrane. This is due to the fact that the soil moves along with the geomembrane as it deforms and undoubtedly cracks, thereby losing its integrity.

From Figure 5.30, the following horizontal force summation results, which leads to the appropriate design equation.

$$\Sigma F_x = 0$$

$$T_{\text{allow}} \cos \beta = F_{U\sigma} + F_{L\sigma} + F_{LT}$$

Attachment B 1/8

GTC
11/23/05

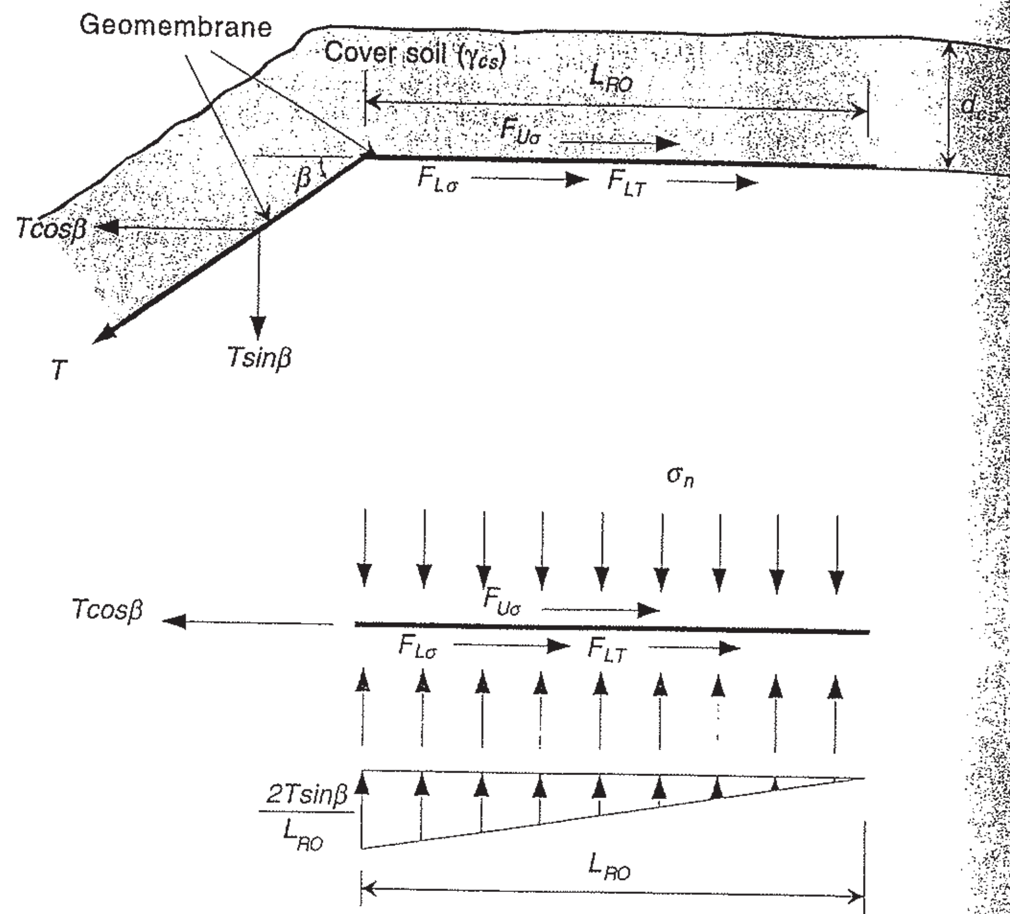


Figure 5.30 Cross section of geomembrane runout section and related stresses and forces involved.

$$= \sigma_n \tan \delta_U(L_{RO}) + \sigma_n \tan \delta_L(L_{RO}) + 0.5\left(\frac{2T_{\text{allow}} \sin \beta}{L_{RO}}\right)(L_{RO}) \tan \delta_L$$

$$L_{RO} = \frac{T_{\text{allow}}(\cos \beta - \sin \beta \tan \delta_L)}{\sigma_n(\tan \delta_U + \tan \delta_L)} \tag{5.25}$$

where

T_{allow} = allowable force in geomembrane stress = $\sigma_{\text{allow}}t$, where
σ_{allow} = allowable stress in geomembrane, and
t = thickness of geomembrane;
β = side slope angle;
$F_{U\sigma}$ = shear force above geomembrane due to cover soil (note that for thin cover soils tensile cracking will occur and this value will be negligible);

Attachment B 2/3

Source: Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.

GEC 11/23/03

$F_{L\sigma}$ = shear force below geomembrane due to cover soil;
F_{LT} = shear force below geomembrane due to vertical component of T_{allow};
σ_n = applied normal stress from cover soil;
δ = angle of shearing resistance between geomembrane and adjacent material (i.e., soil or geotextile); and
L_{RO} = length of geomembrane runout.

Example 5.13 illustrates the use of the concept and the equations just developed.

Example 5.13

Consider a 1.0 mm thick VLDPE geomembrane with a mobilized allowable stress of 7000 kPa, which is on a 3(H) to 1(V) side slope. Determine the required runout length to resist this stress without use of a vertical anchor trench. In this analysis use 300 mm of cover soil weighing 16.5 kN/m³ and a friction angle of 30° with the geomembrane.

Solution: From the design equations just presented,

$$T_{\text{allow}} = \sigma_{\text{allow}} t$$
$$= (7000)(0.001)$$
$$T_{\text{allow}} = 7.0 \text{ kN/m}$$

and

$$L_{RO} = \frac{T_{\text{allow}}(\cos\beta - \sin\beta\tan\delta_L)}{\sigma_n(\tan\delta_U + \tan\delta_L)}$$
$$= \frac{(7.0)[\cos 18.4 - (\sin 18.4)(\tan 30)]}{(16.5)(0.30)[\tan 0 + \tan 30]}$$
$$= \frac{5.37}{2.86}$$
$$L_{RO} = 1.9 \text{ m}$$

Note that this value is strongly dependent on the value of mobilized allowable stress used in the analysis. To mobilize the failure strength of the geomembrane would require a longer runout length or embedment in an anchor trench. This, however, might not be desirable. Pullout without geomembrane failure might be a preferable phenomenon. It is a site-specific situation.

The situation with an anchor trench at the end of the runout section is illustrated in Figure 5.31. The configuration requires some important assumptions regarding the state of stress within the anchor trench and its resistance mechanism. In order to provide lateral resistance, the vertical distance within the anchor trench has lateral forces acting upon it. More specifically, an active earth pressure (P_A) is tending to destabilize the situation, whereas a passive earth pressure (P_P) is tending to resist pullout. As will

Attachment B 3/8

Source: Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.

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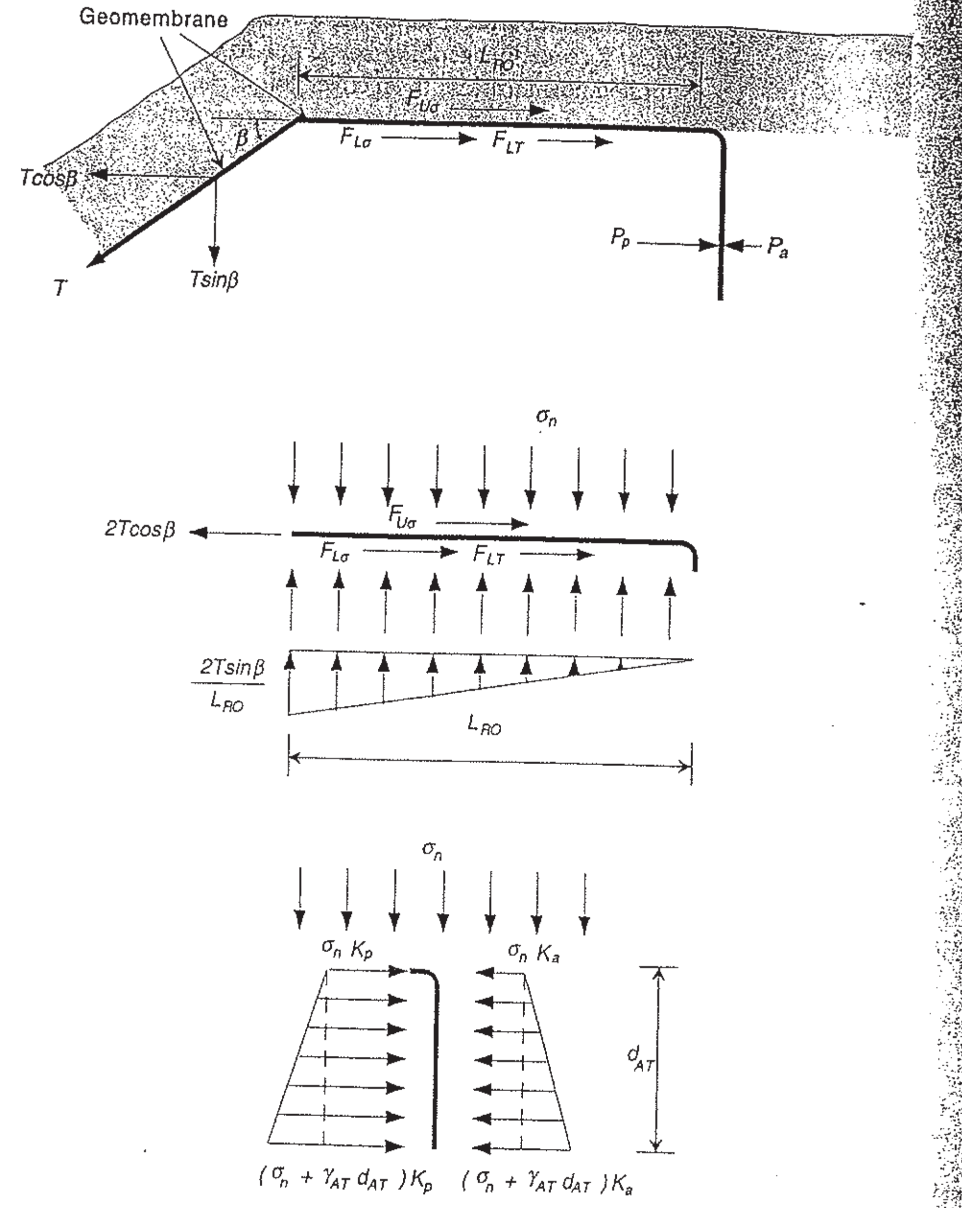

Figure 5.31 Cross section of geomembrane runout section with anchor trench and related stresses and forces involved.

be shown, this passive earth pressure is very effective in providing a resisting force (see Holtz and Kovacs [44]). Using the free-body diagram in Figure 5.31,

$$\Sigma F_x = 0$$

$$* \quad T_{\text{allow}} \cos \beta = F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P \quad * \qquad (5.26)$$

Attachment B 4/8

Source: Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.

GCC
11/23/05

where

T_{allow} = allowable force in geomembrane = $\sigma_{allow}t$, where
σ_{allow} = allowable stress in geomembrane, and
t = thickness of geomembrane;
β = side slope angle;
$F_{U\sigma}$ = shear force above geomembrane due to cover soil (note that for thin cover soils, tensile cracking will occur, and this value will be negligible);
$F_{L\sigma}$ = shear force below geomembrane due to cover soil;
F_{LT} = shear force below geomembrane due to vertical component of T_{allow};
P_A = active each pressure against the backfill side of the anchor trench; and
P_P = passive earth pressure against the in-situ side of the anchor trench.

The values of $F_{U\sigma}$, $F_{L\sigma}$, and F_{LT} have been defined previously. The values of P_A and P_P require the use of lateral earth pressure theory.

$$P_A = \tfrac{1}{2}(\gamma_{AT}d_{AT})K_A d_{AT} + (\sigma_n)K_A d_{AT}$$

$$P_A = (0.5\gamma_{AT}d_{AT} + \sigma_n)K_A d_{AT} \tag{5.27}$$

$$P_P = (0.5\gamma_{AT}d_{AT} + \sigma_n)K_P d_{AT} \tag{5.28}$$

where

γ_{AT} = unit weight of soil in anchor trench,
d_{AT} = depth of the anchor trench,
σ_n = applied normal stress from cover soil,
K_A = coefficient of active earth pressure = $\tan^2(45 - \phi/2)$,
K_P = coefficient of passive earth pressure = $\tan^2(45 + \phi/2)$, and
ϕ = angle of shearing resistance of respective soil.

This situation results in one equation with two unknowns; thus a choice of either L_{RO} or d_{AT} is necessary to calculate the other. As with the previous situation, the factor of safety is placed on the geomembrane force T, which is used as an allowable value, T_{allow}. Example 5.14 illustrates the procedure.

Example 5.14

Consider a 1.5 mm thick HDPE geomembrane extending out of a facility as shown in Figure 5.31. What depth anchor trench is needed if the runout distance is constrained to 1.0 m? In the solution, use a geomembrane allowable stress of 16,000 kPa on a $3(H)$ to $1(V)$ side slope. There are 300 mm of cover soil at 16.5 kN/m³ placed over the geomembrane runout and anchor trench (this is also the unit weight of the anchor trench soil). The friction angle of the geomembrane to the soil is 30° (although assume 0° for the top of the geomembrane under a soil-cracking assumption) and the soil itself is 35°.

Attachment B 5/8

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

Solution: Using the previously developed design equations based on Figure 5.31:

$$T_{\text{allow}} = \sigma_{\text{allow}} t$$
$$= 16000(0.0015)$$
$$= 24.0 \text{ kN/m}$$

and

$$F_{U\sigma} = \sigma_n \tan \delta_U (L_{RO})$$
$$= (0.3)(16.5) \tan 0 (L_{RO})$$
$$= 0$$
$$F_{L\sigma} = \sigma_n \tan \delta_L (L_{RO})$$
$$= (0.3)(16.5) \tan 30 (L_{RO})$$
$$= 2.86 L_{RO}$$
$$F_{LT} = T_{\text{allow}} \sin \beta \tan \delta_L$$
$$= (24.0) \sin 18.4 \tan 30$$
$$= 4.37 \text{ kN/m}$$
$$P_A = (0.5 \gamma_{AT} d_{AT} + \sigma_n) K_A d_{AT}$$
$$= [(0.5)(16.5) d_{AT} + (0.3)(16.5)] \tan^2 (45 - 35/2)\, d_{AT}$$
$$= [8.25 d_{AT} + 4.95](0.271) d_{AT}$$
$$= 2.24 d_{AT}^2 + 1.34 d_{AT}$$
$$P_P = (0.5 \gamma_{AT} d_{AT} + \sigma_n) K_P d_{AT}$$
$$= [(0.5)(16.5) d_{AT} + (0.3)(16.5)] \tan^2 (45 + 35/2)\, d_{AT}$$
$$= [8.25 d_{AT} + 4.95](3.69) d_{AT}$$
$$= 30.4 d_{AT}^2 + 18.3 d_{AT}$$

This is substituted into the general force equation [Eq. (5.26)] to arrive at the solution in terms of the two variables L_{RO} and d_{AT}.

$$T_{\text{allow}} \cos \beta = F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P$$
$$(24.0) \cos 18.4 = 0 + 2.86 L_{RO} + 4.37 - 2.24 d_{AT}^2 - 1.34 d_{AT} + 30.4 d_{AT}^2 + 18.3 d_{AT}$$
$$18.4 = 2.86 L_{RO} + 17.0 d_{AT} + 28.2 d_{AT}^2$$

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

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Since $L_{RO} = 1.0$ m, the equation can be solved for the unknown d_{AT}.

$$d_{AT} = 0.50 \text{ m}$$

Using this formulation we can develop a design chart for a wide range of geomembranes and thicknesses as characterized by different values of T_{allow}. For the specific conditions of Example 5.14,

$$\beta = 18.4°, \text{which is } 3(H) \text{ to } 1(V)$$

$$\sigma_n = d_{cs}\gamma_{cs}$$

$$= (0.30)(16.5)$$

$$= 4.95 \text{ kN/m}^2$$

$$\delta_U = 0°$$

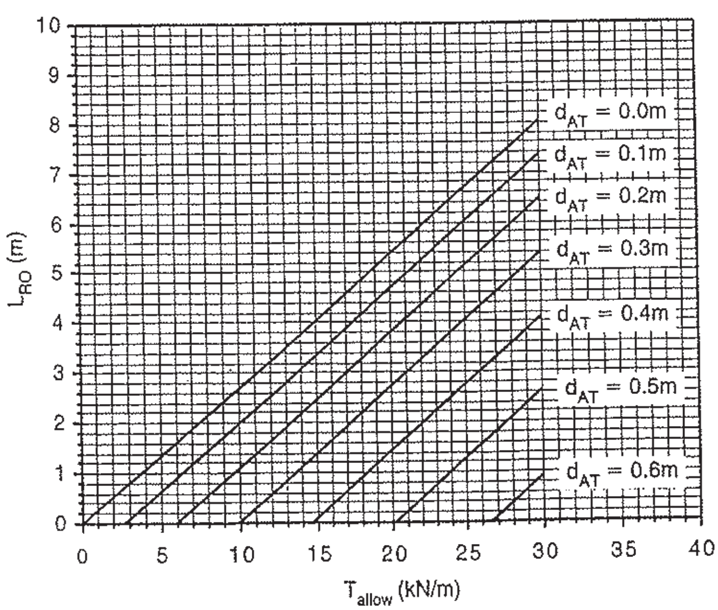
$$\delta_L = 30°$$

$$\phi = 35°$$

$$\gamma_{AT} = 16.5 \text{ kN/m}^3$$

$$\delta_{AT} = 30°$$

the response in terms of the two unknowns L_{RO} and d_{AT} is given in the following figure. Using this figure, Example 5.14 with the 1.5 mm thick HDPE at 24.0 kN/m gives an anchor trench depth of 0.50 m for an assumed runout length of 1.0 m. Other values can be readily selected.



Attachment B 7/8

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

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It should be noted that many manufacturers specify 500 mm deep anchor trenches and 1000 mm long runout sections. As seen above, this is very simplistic, for each membrane type and thickness requires its own analysis. By using a model as presented here, any set of conditions can be used to arrive at a solution. Even situations in which geotextiles and/or geonets are used in conjunction with the geomembrane (under, over, or both) and brought into the anchor trench can be analyzed in a similar manner.

5.3.7 Summary

Projects involving liquid containment using geomembranes are often extremely large. With large size come some inherent advantages over smaller projects. Foremost of these advantages is that most parties involved take the project seriously and approve of and enter into a planned and sequential design procedure. This section was laid out with this in mind, so that the design process proceeded step by step. Each element of design that is made leads to a new issue, which is followed by a new design element. Eventually, the quantitative process is concluded and details, often qualitative by nature, must be attended to. These details, such as seam type, seam layout, piping layout, and appurtenance details, are extremely important. They are, however, common to all geomembrane projects and therefore will be handled in Sections 5.10 and 5.11.

Although such large projects obviously warrant a careful design procedure, it does not follow that smaller projects do not deserve the same attention. Indeed, failures of small liner systems can be significant. Many warrant a design effort comparable to that of large projects, as illustrated in this section.

With this section behind us, we can now focus on other applications involving geomembranes. Where a similar analysis is called for, reference will be made back to this section. Thus only new and/or unique features of geomembrane projects will form the basis of the sections to follow.

5.4 COVERS FOR RESERVOIRS

Geomembrane covers are often used above the liquid surface of storage reservoirs. They are of fixed, floating, or suspended types.

5.4.1 Overview

There are a number of important reasons why liquid containment structures should be covered. These include: losses due to evaporation (up to 84% per year; see Cooley [45]), savings on chlorine treatment (for water reservoirs), savings on algae control chemicals (for water reservoirs), reduced air pollution (for reservoirs holding chemicals), reduced need for drainage and cleaning, increased safety against accidental drowning, protection from natural pollution entering the reservoir (e.g., animal excretion), and protection from intentional pollution (i.e., sabotage).

Obviously, a rigid roof structure could be constructed over the reservoir, but the costs involved are usually prohibitively high. At a far lower cost, both during initial construction or in a retrofitted system, is the use of an impermeable liner. All the materials

Attachment B 8/8

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

TECHNICAL NOTE

GSE*

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*For environmental lining solutions... the world comes to GSE.**

GSE FrictionFlex* Application Data

GSE's FrictionFlex process provided the geomembrane industry's first textured liner. It is the only geomembrane texturing process ever to be granted a U.S. Patent. The FrictionFlex process begins with smooth GSE membrane that is manufactured to stringent industry standards. After the smooth surfaced sheet passes all GSE's standard quality assurance testing, texturing is added to one or both sides as required. The patented manufacturing process enables GSE to produce a textured liner exhibiting the outstanding mechanical and chemical properties demanded of GSE's premium grades of smooth geomembrane liners.

GSE geomembranes textured by the FrictionFlex process can be utilized to improve the factor of safety on steep slopes. This can increase facility design capacity, service life and ultimately, total revenue potential. GSE's textured geomembranes can be used to improve a number of applications.

GSE FrictionFlex geomembranes have an approximate six inch (15 cm) wide edge that remains smooth. This smooth edge means that GSE's seaming procedures are the same for FrictionFlex textured geomembranes and smooth geomembranes therefore requiring no changes in field quality control.

FrictionFlex liner has many performance benefits when in contact with soils and synthetics:

- High coefficient of friction with soils
- High coefficient of friction with other geosynthetic materials
- Premium grade mechanical and chemical properties
- Excellent narrow *and* wide width tensile elongation

The table below shows typical comparative data for smooth and FrictionFlex textured geomembranes. Testing was performed according to ASTM D 5321. GSE recommends that specific data be developed for all application designs. Shearbox testing of the specific geosynthetic and natural components of the composite is necessary to establish an appropriate design basis. GSE will be pleased to provide material samples for such purposes.

Friction Angle Comparison - Smooth vs. FrictionFlex Textured Geomembranes

	Smooth Geomembrane	GSE FrictionFlex Textured Liner Materials	
Material	Friction Angle (deg.)	Adhesion (lb/ft²)	Friction Angle (deg.)
Sandy Glacial Till	20	27	36
* Sandy Clay	18 *	65	35
Smooth Clay	16	39	32
Ottawa Sand	19	21	30
Non-woven Geotextile	12	133	33

This information is provided for reference purposes only and is not intended as a warranty or guarantee. GSE assumes no liability in connection with the use of this information.

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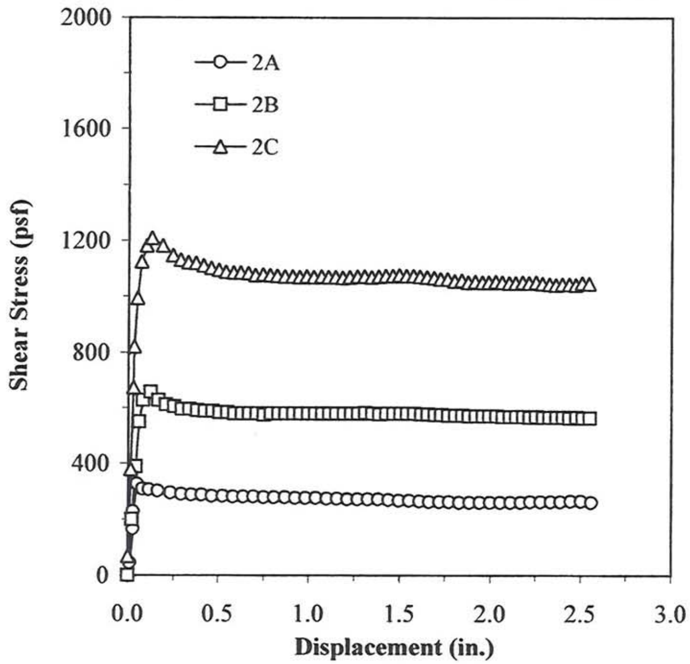
Attachment C

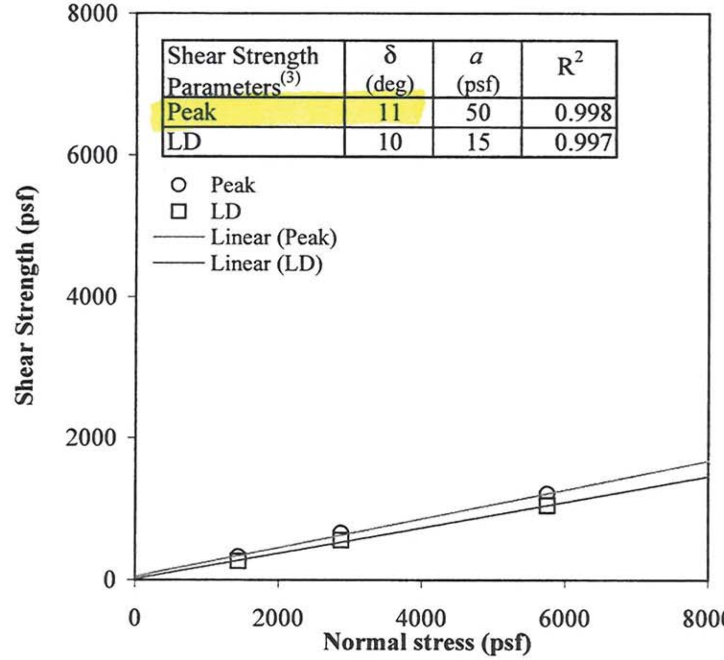
Visit us at www.gseworld.com.

A Gundle/SLT Environmental, Inc. Company

GEOSYNTEC CONSULTANTS - INTERNATIONAL URANIUM CORP PROJECT
DIRECT SHEAR TESTING (ASTM D 5321)

Test Series Number 2: Woven side of Bentomat ST GCL (Lot # 200640LO/Roll #6397) in machine direction against black side of GSE 60-mil black/white smooth HDPE geomembrane (Roll # 105130507) in machine direction under soaked and consolidated conditions





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	GCL Soaking Stress (psf)	GCL Soaking Time (hour)	Consolidation[1] Stress (psf)	Consolidation[1] Time (hour)	Lower Soil γ_d (pcf)	Lower Soil ω_i (%)	Lower Soil ω_f (%)	Upper Soil γ_d (pcf)	Upper Soil ω_i (%)	Upper Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_P (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
2A	12 x 12	1440	0.04	1440	24	1440	24	-	-	-	-	-	-	17.9	68.8	325	259	(2)
2B	12 x 12	2880	0.04	2880	24	2880	24	-	-	-	-	-	-	17.9	55.8	657	562	(2)
2C	12 x 12	5760	0.04	5760	24	5760	24	-	-	-	-	-	-	17.9	48.7	1211	1046	(2)

NOTES:

(1) The hydrated GCL specimen was placed on the geomembrane and consolidated together under each test normal stress for 24 hours prior to shearing. The test specimens were not submerged in water during consolidation.

(2) Sliding (i.e., shear failure) occurred at intended test interface in each test.

(3) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

SGI TESTING SERVICES, LLC

DATE OF TEST:	11/3 to 11/7/2006
FIGURE NO.	B-2
PROJECT NO.	SGI6014-03
DOCUMENT NO.	
FILE NO.	

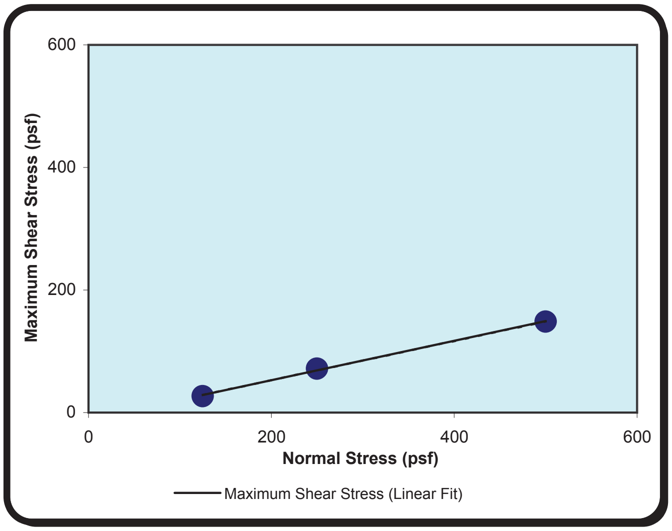
TRI/ENVIRONMENTAL, INC.

A Texas Research International Company

INTERFACE FRICTION TEST REPORT

Client:	**Agru**	TRI Log#:	E2201-75-03
Project:	Anne Steacy	Test Method:	ASTM D 5321
Test Date:	7/5-7/5/05		

Tested Interface: Agru 60 mil Studliner vs. Agru 60 mil Smooth Geomembrane



Upper Box: Agru 60 mil smooth Geomembrane

Lower Box: Agru 60 mil Studliner

Interface Conditioning: Interface soaked and loading applied for a minimum of 3 hours prior to shear

Box Dimension: 12"x12"x4"

Test Condition: Wet

Shearing Rate: 0.2 inches/minute

Trial Number	1	2	3
Bearing Slide Resistance (lbs)	9	10	13
Normal Stress (psf)	125	250	500
Maximum Shear Stress (psf)	36	82	161
Corrected Shear Stre	27	72	148
Secant Angle (degrees)	12.1	16.0	16.5

RESULTS: Maximum Friction Angle and Y-intercept

Regression Friction Angle (degrees): **16.2**

Y-intercept or Regression Adhesion (psf): **0**

Regression Line: Y= 0.290 * X + 0

Regression Coefficient (r squared): 0.986

Note: The regression line includes the origin.

John M. Allen, E.I.T., 07/11/2005

Quality Review/Date

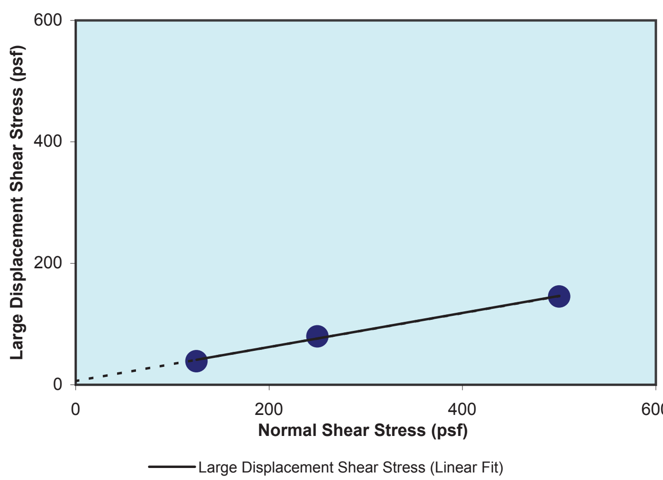
9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

INTERFACE FRICTION TEST REPORT

Client: **Agru**
Project: Anne Steacy
Test Date: 7/5-7/5/05

TRI Log#: E2201-75-03
Test Method: ASTM D 5321

Tested Interface: Agru 60 mil Studliner vs. Agru 60 mil Smooth Geomembrane



Upper Box: Agru 60 mil smooth Geomembrane

Lower Box: Agru 60 mil Studliner

Interface Conditioning: Interface soaked and loading applied for a minimum of 3 hours prior to shear

Box Dimension: 12"x12"x4"

Test Condition: Wet

Shearing Rate: 0.2 inches/minute

Trial Number	1	2	3
Bearing Slide Resistance (lbs)	9	10	13
Normal Stress (psf)	125	250	500
Large Displacment Shear Stress (psf)	48	90	158
Corrected Shear Stress (psf)	39	80	145
Secant Angle (degrees)	17.2	17.7	16.2

RESULTS: Large Displacement Friction Angle and Y-intercept at 3.5-in. of Displacement

Regression Friction Angle (degrees): 15.7
Y-intercept or Regression Adhesion (psf): 6

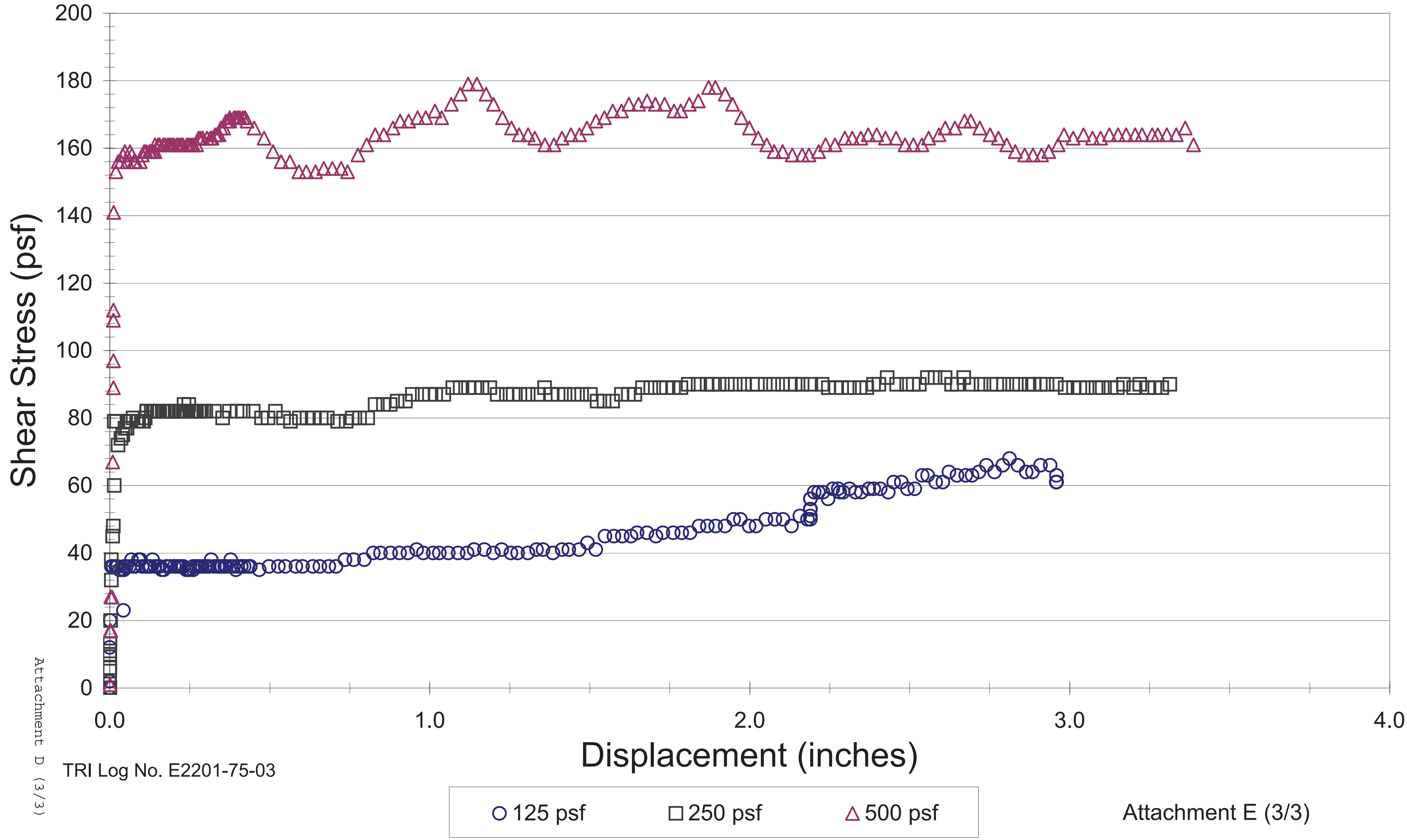
Regression Line: Y= 0.281 * X + 6
Regression Coefficient (r squared): 0.997

John M. Allen, E.I.T., 07/11/2005
Quality Review/Date

Large displacement shear stresses interperted at 2 inches of diplacement due to strain hardening effects.

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

AGRU INTERFACE FRICTION TEST
Agru 60 mil Smooth Geomembrane vs. Agru 60 mil Studliner



Attachment D (3/3)

TRI Log No. E2201-75-03

Attachment E (3/3)

TABLE 5.3
TYPICAL PROPERTIES OF COMPACTED SOILS*

Group symbol	Soil type	Range of maximum dry unit weight, pcf	Range of optimum moisture, %	Typical value of compression: Percent of original height At 1.4 tsf (20 psi)	Typical value of compression: Percent of original height At 3.6 tsf (50 psi)	Typical strength characteristics: Cohesion (as compacted), psf	Typical strength characteristics: Cohesion (saturated), psf	Typical strength characteristics: Effective stress envelope φ, degrees	Typical strength characteristics: tan φ	Typical coefficient of permeability, ft/min	Range of CBR values	Range of subgrade modulus k_s, lb/in³
GW	Well-graded clean gravels, gravel-sand mixtures	125–135	11–8	0.3	0.6	0	0	>38	>0.79	5×10^{-2} [illegible]	40–80	300–500
GP	Poorly graded clean gravels, gravel-sand mix	115–125	14–11	0.4	0.9	0	0	>37	>0.74	10^{-1} [illegible]	30–60	250–400
GM	Silty gravels, poorly graded gravel-sand silt	120–135	12–8	0.5	1.1	...	...	>34	>0.67	$>10^{-6}$ [illegible]	20–60	100–400
GC	Clayey gravels, poorly graded gravel-sand-clay	115–130	14–9	0.7	1.6	...		>31	>0.60	$>10^{-7}$ [illegible]	20–40	100–300
SW	Well-graded clean sands, gravelly sands	110–130	16–9	0.6	1.2	0	0	38	0.79	$>10^{-3}$ [illegible]	20–40	200–300
SP	Poorly-graded clean sands, sand-gravel mix	100–120	21–12	0.8	1.4	0	0	37	0.74	$>10^{-3}$ [illegible]	10–40	200–300
SM	Silty sands, poorly graded sand-silt mix	110–125	16–11	0.8	1.6	1050	420	34	0.67	5×10^{-5} 2.54 × 10^-5 cm/s	10–40	100–300
SM-SC	Sand-silt clay mix with slightly plastic fines	110–130	15–11	0.8	1.4	1050	300	33	0.66	2×10^{-6} 1.02 × 10^-6	...	
SC	Clayey sands, poorly graded sand-clay mix	105–125	19–11	1.1	2.2	1550	230	31	0.60	5×10^{-7} 2.54 × 10^-7	5–20	100–300
ML	Inorganic silts and clayey silts	95–120	24–12	0.9	1.7	1400	190	32	0.62	10^{-5} [illegible]	15 or less	100–200
ML-CL	Mixture of inorganic silt and clay	100–120	22–12	1.0	2.2	1350	460	32	0.62	5×10^{-7} [illegible]	...	
CL	Inorganic clays of low to medium plasticity	95–120	24–12	1.3	2.5	1800	270	28	0.54	10^{-7} [illegible]	15 or less	50–200
OL	Organic silts and silt-clays, low plasticity	80–100	33–21	...	...	...	...	...	...	...	5 or less	50–100
MH	Inorganic clayey silts, elastic silts	70–95	40–24	2.0	3.8	1500	420	25	0.47	5×10^{-7} [illegible]	10 or less	50–100
CH	Inorganic clays of high plasticity	75–105	36–19	2.6	3.9	2150	230	19	0.35	10^{-7} [illegible]	15 or less	50–150
OH	Organic clays and silty clays	65–100	45–21	...	...	...	...	...	...	...	5 or less	25–100

*... NAVFAC Manual DM 7 (1982).[3] All properties are for condition of "standard Proctor" maximum density, except ... strength characteristics are for effective ...

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11/23/05

1984

FI

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF** Project: **White Mesa Mill – Cells 5A and 5B** Project/ Proposal No.: Task No. **SC0634**

Title of Computations **EMERGENCY SPILLWAY CONCRETE PAVEMENT**

Computations by: Signature [signature] Date 12/18/12
Printed Name Rebecca Flynn, P.E.
Title Project Engineer

Assumptions and Procedures Checked by: (peer reviewer) Signature [signature] Date 12/20/12
Printed Name Keaton Botelho, P.E.
Title Project Engineer

Computations Checked by: Signature [signature] Date 12/20/12
Printed Name Keaton Botelho, P.E.
Title Project Engineer

Computations backchecked by: (originator) Signature [signature] Date 12/18/12
Printed Name Rebecca Flynn, P.E.
Title Project Engineer

Approved by: (pm or designate) Signature [signature] Date 12/18/12
Printed Name Gregory T. Corcoran, P.E.
Title Principal Engineer

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client: EF		Project:	WMM- Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	

EMERGENCY SPILLWAY CONCRETE PAVEMENT

OBJECTIVE

An emergency spillway will be constructed as part of Cell 5A and 5B construction at the White Mesa Mill, in Blanding, Utah for Energy Fuels (EF). The emergency spillways are 158 and 120 feet wide for Cells 5A and 5B, respectively, with approximately 19-foot wide access roads across the crest of the spillway. The emergency spillway is shown on Sheet 10 of the Construction Drawings prepared by Geosyntec Consultants. A pick-up truck design loading has been assumed for the pavement of the access road.

The design of the concrete slab will be performed in accordance with American Concrete Institute (ACI) Publications 318 and 360 standards (ACI 318 and ACI360). The objective of this design is to determine the dimensional, reinforcement, and concrete requirements necessary to withstand the applied loading.

SUMMARY OF DESIGN

Based on the assumptions and calculations presented herein, the slab on grade will be 6 inches thick and consist of concrete with compressive strength of 3,000 pounds per square inch (psi), and welded wire reinforcement (WWR) fabric sized as 6x6 – W1.4xW1.4.

ANALYSIS

Loading conditions

The loading conditions for the slab-on-grade for the emergency spillway is assumed to be a 12,000 lb loaded truck, which equates to an assumed 4,000 lb front axle loading and a maximum 8,000 lb rear axle loading. A wheel spacing of 60 inches was assumed.

To determine the required slab thickness, a Wire Reinforcement Institute (WRI) method, which simulates concentrated loads as the loading resulting from a single-axle, will be utilized. The method is presented in a report by ACI on the design of slabs on grade (ACI 360).

Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client: EF		Project:	WMM- Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	

Slab on Grad Design Procedure

WRI presents a slab on grade thickness determination method based on the concentrated loads from the wheels of a forklift (ACI 360). The method accounts for the total axle load and each wheel individually. The method also takes into account the moments on the slab caused by the spacing of the wheels.

The determination of slab thickness can be made by following the example presented in Appendix A of the ACI 360. To utilize this method, some values and properties were required to be assumed. Modifications to the design may be required if the assumptions are determined to not be valid.

The design begins with the assumed values of:

- Concrete modulus (E_c) = 3,500 kips per square inch (ksi)
- Modified subgrade modulus (k_{12}) = 400 pounds per cubic inch (pci)
- Compressive strength of concrete (f_c') = 3,000 psi
- Modulus of rupture (MOR or f_r) = $7.5 \cdot \sqrt{f_c'} \approx 411 psi$
- Slab thickness = 6 inches

Note that 1 kip equals 1,000 lbs. The assumed modified subgrade modulus value is for a sandy soil (Attachment A). The compressive concrete strength, and therefore the modulus of rupture, can be specified when ordering concrete; this assumed value will not likely require modification. The value of 6 inches for the slab thickness is an arbitrary trial "guess", which will be validated or dispelled at the end of applying the method.

Figure A2.2.1 (Attachment B) is utilized to find the relative stiffness parameter (D/k) based on the above assumed values. The first trial results in a D/k value of 1.5 x 10^5 in^4.

Next, the contact area for each wheel must be converted to determine the diameter of a hypothetical circle that has the same area. A tire air pressure of 80 psi was assumed for a loaded truck. The following basic equations were used to determine the equivalent circle diameter:

Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	WMM- Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	

Area of a circle:

$$A = \pi \left(\frac{D}{2} \right)^2$$

Where A is the area of the circle (based on tire pressure and tire load, Attachment E) and D is the diameter of the circle. Rearranging and solving for D:

$$D = 2\sqrt{\frac{A}{\pi}} = 2\sqrt{\frac{50\,in^2}{3.14}} = 8.0\ in$$

Therefore a circle with a 8.0-in. diameter has an area approximately equal to the contact area of one vehicle wheel (50-in^2).

Next, the distance between wheels on the axle must be incorporated into the design method. The length between the back two wheels on a pick-up truck is utilized to determine the equivalent forklift axle wheel spacing. This distance was assumed to be 60-in.

The equivalent wheel base, equivalent contact circle diameter, and the D/k value are then utilized to determine the basic bending moment in the slab (in-lb/in) that results per kip of wheel load applied. From Figure A2.2.2 (Attachment C), we see that the basic bending moment due to the two wheels is 200 plus 5 in-lb/in/kip, which results in a total moment of approximately 205 in-lb/in per kip stress. This value is multiplied by the "wheel" load to give the design moment. Based on a total vehicle operating weight of 10,000 lbs. The wheel load is:

$$"Wheel\ load" = \frac{Total\ axle\ weight}{\#\ of\ wheels} = \frac{8{,}000\ lbs}{2} = 4{,}000\frac{lbs}{wheel} = 4.0\frac{kip}{wheel}$$

Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	WMM- Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	

Multiplying the basic moment by the "wheel load", the resulting design moment is:

$$Design\ moment = basic\ moment \times wheel\ load = \left(205 \frac{\frac{in-lb}{in}}{kip}\right) \times (4.0\,kip) = 820 \frac{in-lb}{in}$$

This design moment and the total allowable flexural stress are utilized to assess if the initial guess for slab thickness is valid. The total allowable flexural stress is the MOR (f_r) divided by a safety factor (SF). For concentrated loads, ACI 360 recommends a SF value between 1.7 and 2.0. For this design, the lower value of 1.7 will be utilized. The 1.7 SF value results in a total allowable tensile stress of:

$$\frac{MOR}{SF} = \frac{411\,psi}{1.7} = 242\,psi$$

Using this MOR/SF value and the design stress with Figure A2.2.3 (Attachment D), we check to see if our initial concrete thickness guess was accurate. With the values calculated above, we see that the resulting thickness is approximately 5 in. The calculations and resulting values are summarized in a spreadsheet, presented on Attachment E.

Temperature & Shrinkage Reinforcement Design

The subgrade drag equation (ACI 360) is used to determine the minimum area of steel reinforcement required to prevent temperature and shrinkage cracking:

$$A_{s,\min} = \frac{F \cdot L \cdot w}{2 \cdot f_s}$$

Where the variables are defined as follows:

$A_{s,min}$ = minimum cross-sectional area of steel per foot width concrete
F = subgrade friction factor, for granular subbase = 1.5 *(Section 6.3))*

Written by:	R. Flynn	Date: 12/18/12	Reviewed by: G. Corcoran	Date: 12/18/12	
Client: EF	Project: WMM- Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	

L = distance between joints in slab = 15 ft
w = dead weight of slab, 12.5 lb per inch of 6-in. slab = 75 lbs
f_y *= yield strength of reinforcement steel, ASTM A610 = 60,000 psi*
f_s *= allowable tensile strength of reinforcement (.75*f_y*) = 45,000 psi*

Substitution of variables in the preceding equation yields:

$$A_{s,\min} = \frac{(1.5)\cdot(15\,\text{ft})\cdot(75\,\text{lb})}{(2)\cdot(45{,}000\,\text{psi})} = 0.019\,\text{in}^2\,/\,\text{ft}$$

The result indicates that a minimum reinforcement area of 0.019-in^2 must be provided per each foot of slab length and width. This value is lower than the A_s value provided by the narrowest rebar (#3) at the maximum recommended spacing (18-in.), which provides an A_s value of 0.073-in (By ACI 318 standards, reinforcement spacing must not exceed 18-in. or the lesser of three times the slab thickness (also 18-in.). According to the WRI Manual of Standard Practice (WRI Manual), if welded reinforcement wire (WWR) were to be utilized, the product size denoted as 6x6 – W1.4xW1.4 would provide an A_s value of 0.028-in^2 (Attachment F). This value slightly exceeds the required $A_{s,min}$ value of 0.019-in^2, and requires considerably less steel than the minimum value provided if rebar were to be used. The WWR 6x6 – W1.4xW1.4 will be utilized.

The development length of the reinforcement steel must be checked to determine whether or not the steel has a chance to fully develop its tensile strength. According to Table 7 of the WRI Manual (Attachment G), the typical minimum development length for 6x6 – W1.4xW1.4 WWR is 8 inches.

REFERENCES

American Concrete Institute, *Design of Slabs on Grade (ACI 360R-92),* ACI: Farmington Hills, Michigan 1997.

Wire Reinforcement Institute, Incorporated, *Manual of Standard Practice: Structural Welded Wire Reinforcement,* WWR-500, 6th Edition, 2001

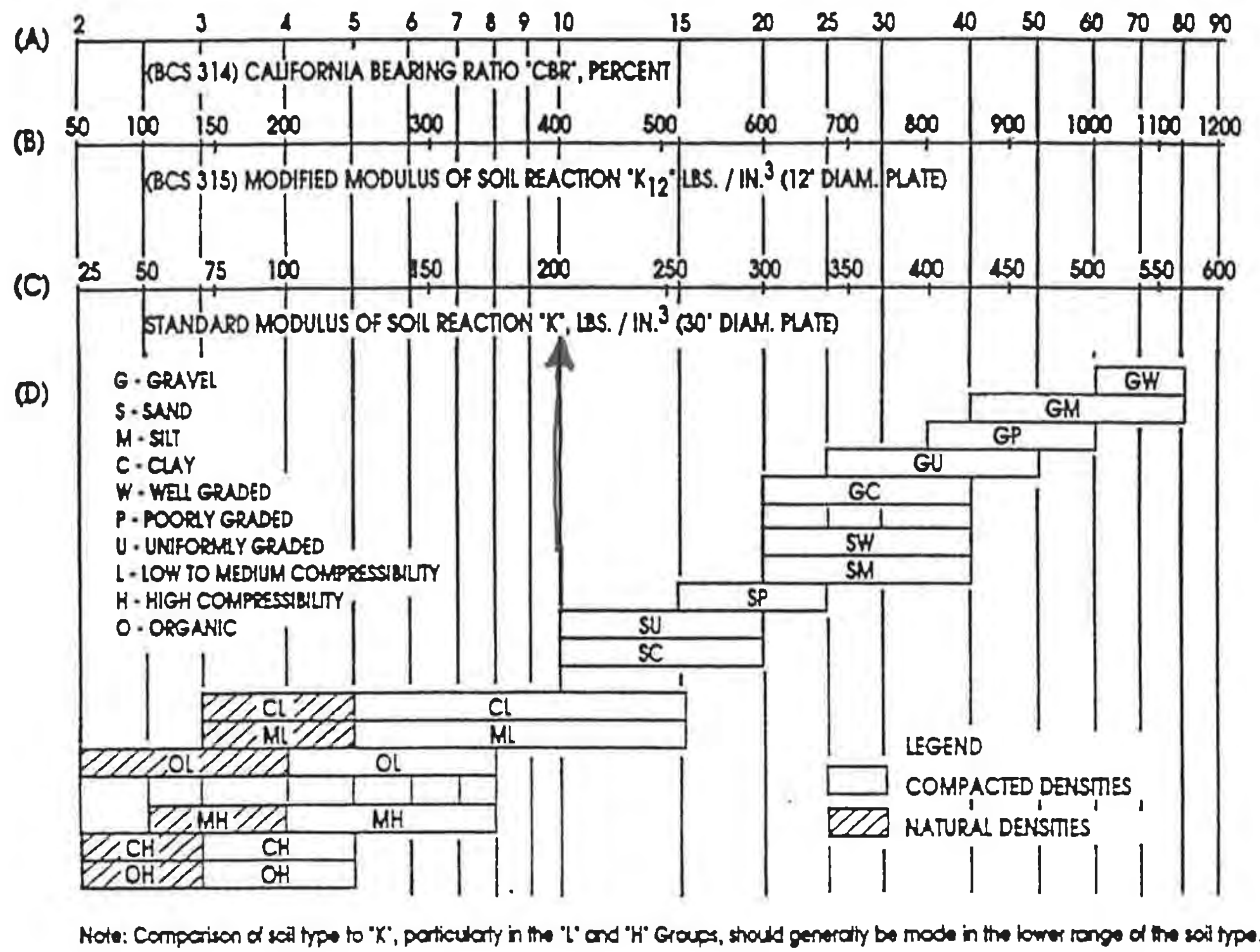


Fig. 3.3.5—Interrelationship of soil classifications and strengths (from Reference 23)

sand or gravel fill, or use the existing material in its in-situ condition.

Normally there is a wide range of soils across the site. The soil support system is rarely uniform. Therefore, some soil work is generally required to provide a more uniform surface to support the slab. The extent of this work, such as the degree of compaction or the addition of a sand-gravel base, is generally a problem of economics. Selection of soils in the wellgraded gravel (GW) and poorly graded gravel (GP) groups as a base material may appear costly. However, the selection of these materials has distinct advantages. Not only do they provide a superior modulus of subgrade reaction, but they also tend to speed construction during inclement weather.

3.4.2 *Economics and simplified design*—Certainly not all projects will require all of the data discussed above. On projects where the slab performance is not critical, engineering judgement should be exercised to reduce costs. A prime prerequisite for the proper design of a slab support system is soils identification. Without this knowledge, the modulus of subgrade reaction is unknown and potential volume change cannot be determined. With knowledge of soil classification, the engineer can select an appropriate k value and design for the specific soil conditions.

For small projects, it may be advantageous to assume a low k factor and add a selected thickness of crushed stone to enhance the safety factor rather than performing an expensive soil analysis. Use of the modified modulus of subgrade reaction test rather than the standard modulus test can also reduce costs. Risk of slab failure at an earlier age increases as the design is rationalized but there are occasions where the simplified design approach is justified. These decisions are a matter of engineering judgment and economics.

Compounding safety factors is a common error. Inclusion of safety factors in the modulus of subgrade reaction, the applied loads, the compressive strength of the concrete, the flexural strength of the concrete and the number of load repetitions will produce an expensive design. The safety factor is normally contained in the flexural strength of the concrete and is a function of the number of load repetitions (see Sec. 4.9).

3.5—Site preparation

3.5.1 *Introduction*—Prior to soil compaction, the top

ATTACHMENT A

CHAPTER A2—SLAB THICKNESS DESIGN BY WRI METHOD

A2.1—Introduction

The following two examples show the determination of thickness for a slab on grade intended to have mild steel reinforcement for shrinkage and temperature stresses. The amount of steel is commonly selected using the subgrade drag theory presented in Chapter 6 and discussed in Reference 53.

The design charts are for a single axle loading with two single wheels and for the controlling moment in an aisle with uniform loading on either side. The first situation is controlled by tension on the bottom of the slab and the second is controlled by tension on the top of the slab. Both procedures start with use of a relative stiffness term *D/k*, and require the initial assumption of the concrete modulus of elasticity *E* and slab thickness *H*, as well as selecting the allowable tensile unit stress and the appropriate subgrade modulus *k*.

A2.2—WRI thickness selection for single-axle wheel load

This procedure selects the concrete slab thickness for a single axle with wheels at each end of the axle, using Fig. A2.2.1, A2.2.2, and A2.2.3. The procedure starts with Fig. A2.2.1 where a concrete modulus of elasticity *E* and slab thickness *H*, and modulus of subgrade reaction *k* are assumed or known. For example, taking

E = 3000 ksi
Thickness = 8 in. (trial value)
Subgrade modulus k = 400 pci

Fig. A.2.2.1 gives the relative stiffness parameter $D/k = 3.4 \times 10^5$ in.^{4} The procedure then uses Fig. A2.2.2.
Wheel Contact Area = 28 sq in.

Diameter of equivalent circle = $\sqrt{[28 x 4]/\pi}$
= 6 in.

Wheel spacing = 45 in.

This gives the basic bending moment of 265 in.-lb/in. of width/kip of wheel load for the wheel load using the larger design chart in Fig. A2.2.2. The smaller chart in the figure gives the additional moment due to the other wheel as 16 in.-lb per in. of width per kip of wheel load.
Moment = 265 + 16 = 281 in.-lb/in./kip
(Note that in.-lb/in. = ft-lb/ft)

Axle Load = 14.6 kips
Wheel Load = 7.3 kips

Design Moment = 281 x 7.3 = 2051 ft-lb/ft

Then from Fig. A2.2.3:
Allowable tensile stress = 190 psi

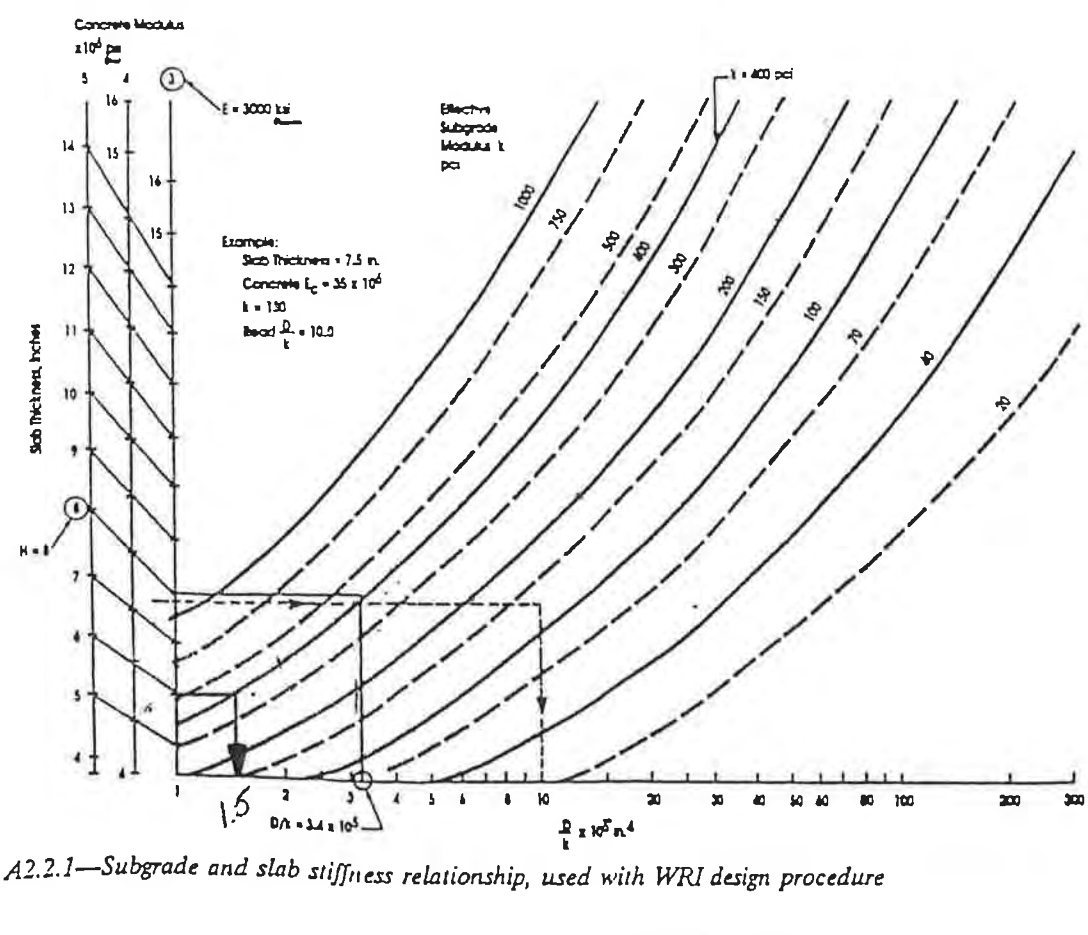


Fig. A2.2.1—Subgrade and slab stiffness relationship, used with WRI design procedure

ATTACHMENT B

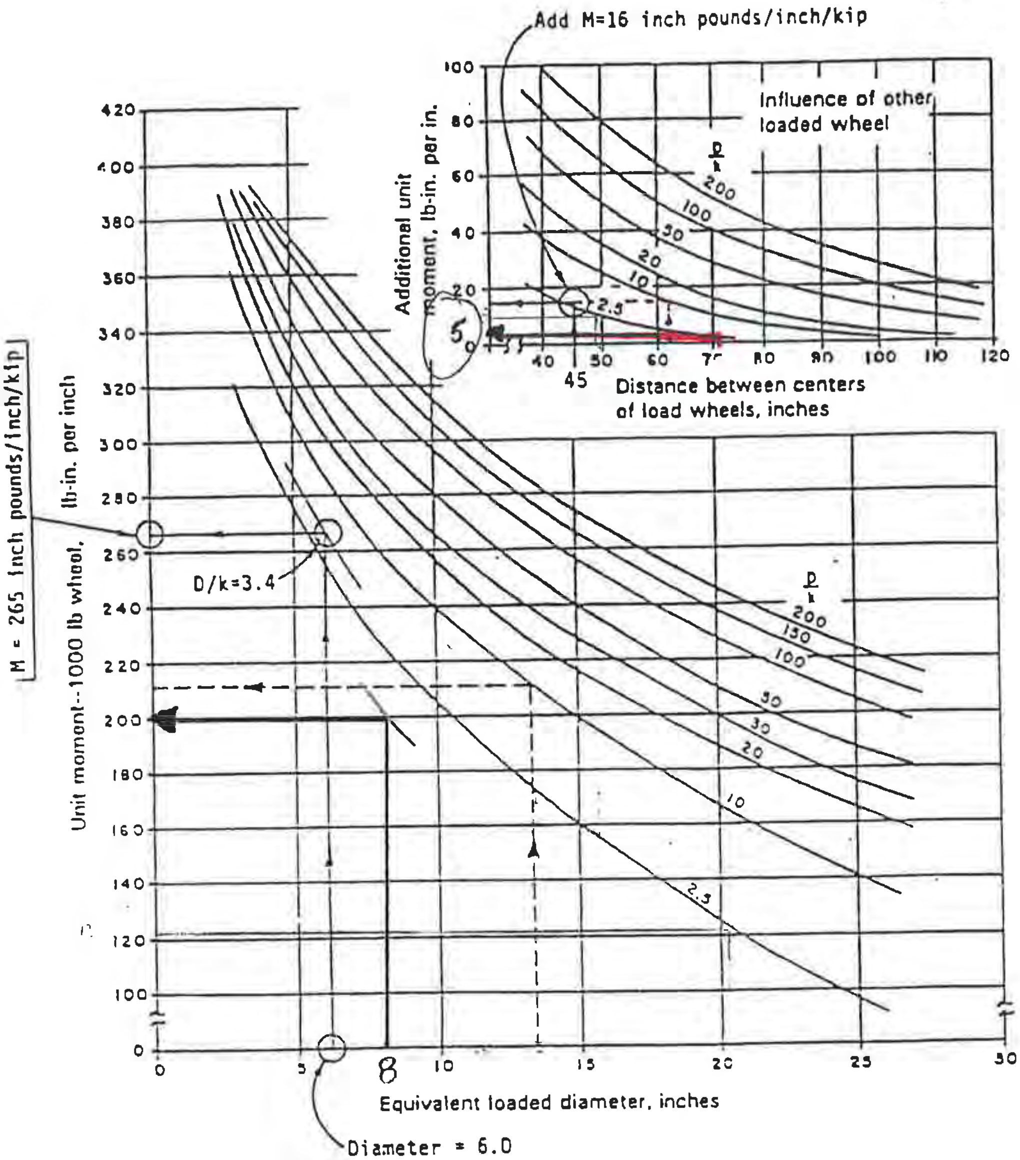


Fig. A2.2.2—Wheel loading design chart used with WRI procedure

Solution:
Slab thickness (H) = 7 7/8 in.

If the design thickness differs substantially from the assumed thickness, the procedure is repeated with a new assumption of thickness.

A2.3—WRI thickness selection for aisle moment due to uniform loading

The procedure for the check of tensile stress in the top of the concrete slab due to this loading uses Fig. A2.2.1 and A2.3. Note that Fig. A2.2.3 is a part of Fig. A2.3., separated here for clarity of procedure.

The procedure starts as before with determination of the term $D/k = 3.4 \times 10^5$ in.^{4} It then goes to Fig. A2.3 as follows:

Aisle width = 10 ft = 120 in.
Uniform load = 2500 psf = 2.5 ksf
Allowable tension = MOR/SF = 190 psi

The solution is found by plotting up from the aisle width to D/k, then to the right-hand plot edge, then down through the uniform load value to the left-hand edge of the next plot, then horizontally to the allow-able stress and down to the design thickness.

Solution: Thickness = 8.0 in.

Again, if the design thickness differs substantially from the assumed value, the process should be repeated until reasonable agreement is obtained.

A2.4—Comments

These procedures assume the use of conventional steel reinforcement in the concrete slab. The applied moments from the loads are not used in selecting the steel reinforcement except in the case of a Type F structurally reinforced slab.

ATTACHMENT C

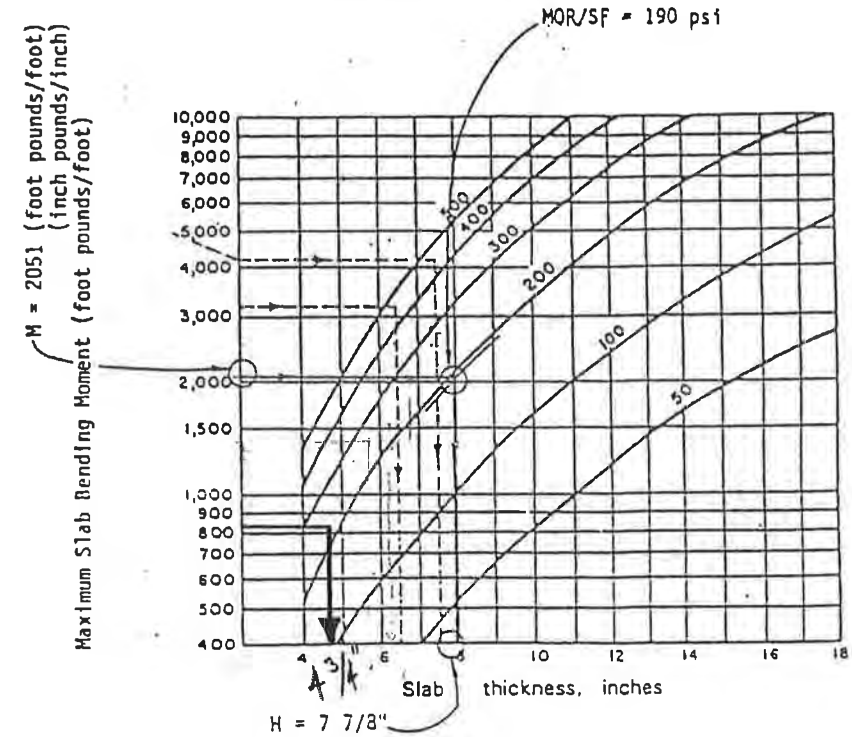


Fig. A2.2.3—Slab tensile stress charts used with WRI design procedure

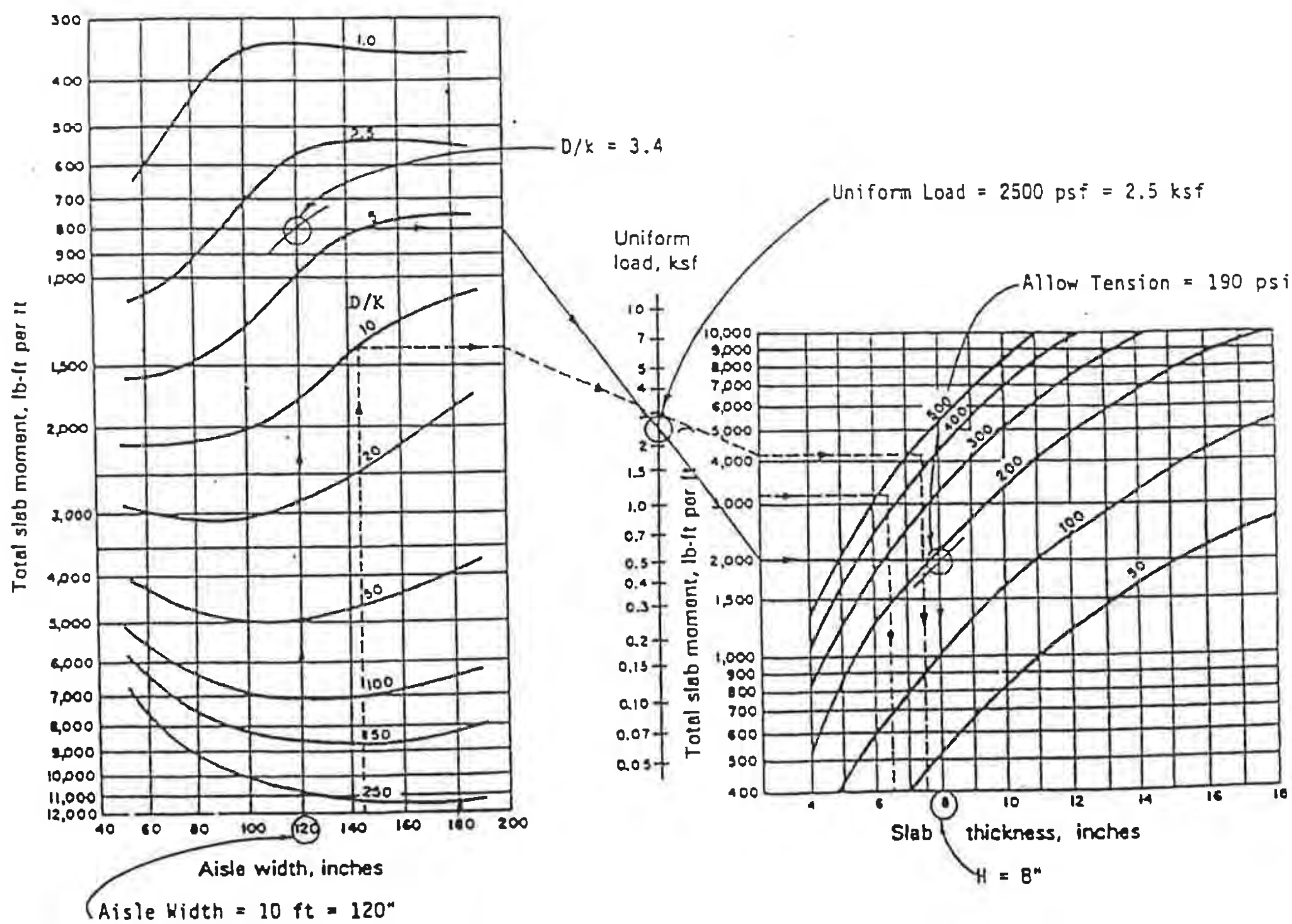


Fig. A2.3—Uniform load design and slab tensile stress charts used with WRI design procedure

ATTACHMENT D

Slab Design Thickness Determination

	Trial 1	Trial 2	Trial 3		
Wheel spacing =	**60**	**60**	**60**	**in**	*distance between wheels on same axle
Total working vehicle weight =	12,000	12,000	12,000	lb	Assume Pick-up Truck Loading
Rear Axle Load =	8,000	8,000	8,000	lb	Assume Pick-up Truck Loading
"Axle" load =	8.0	8.0	8.0	kip	rear axle
"Wheel" load =	4.0	4.0	4.0	kip	half of axle load
Wheel Tire Pressure =	80.0	80.0	80.0	psi	80 to 120 psi for pneumatic tires
Wheel Contact area =	50.0	50.0	50.0	sq in	
Wheel Equivalent Diameter =	8.0	8.0	8.0	in	
Concrete modulus (E) =	3,500	3,500	3,500	ksi	
Compressive strength of concrete (f'c) =	3,000	3,500	4,000	psi	
Subgrade Modulus (k) =	400	400	400	pci	Fig 3.3.5
Concrete Modulus of Rupture (MOR, f_r) =	411	444	474	psi	
Safety Factor (SF) =	1.7	1.7	1.7	---	
Allowable tensile stress (MOR/SF) =	242	261	279	psi	

WRI Method - Single Axle Wheel Load

	Units	Trial 1	Trial 2	Trial 3	
Trial Thickness =	in	6.0	6.0	6.0	
Stiffness parameter (D/k) =	x 10^{-5} in^4	1.5	1.5	1.5	(from Fig A2.2.1)
Basic bending moment per kip stress =	in-lb/in/kip	200	200	200	(from Fig A2.2.2)
Moment due to other wheel =	in-lb/in/kip	5	5	5	(from Fig A2.2.2)
Total moment per kip stress =	in-lb/in/kip	205	205	205	
Design moment =	in-lb/in	820	820	820	
SLAB THICKNESS =	**in**	**5.0**	**4.5**	**4.5**	(from Fig. A2.2.3)

**Highlighted values are calculated from other entered values.*

6-in. is an acceptable design slab thickness.

ATTACHMENT E

Slab Design Thickness Determination

	Trial 1	Trial 2	Trial 3		
Wheel spacing =	**72**	**72**	**72**	**in**	*distance between wheels on same axle
Total working vehicle weight =	12,000	12,000	12,000	lb	Assume Pick-up Truck Loading
Rear Axle Load =	8,000	8,000	8,000	lb	Assume Pick-up Truck Loading
"Axle" load =	8.0	8.0	8.0	kip	rear axle
"Wheel" load =	4.0	4.0	4.0	kip	half of axle load
Wheel Tire Pressure =	80.0	80.0	80.0	psi	80 to 120 psi for pneumatic tires
Wheel Contact area =	50.0	50.0	50.0	sq in	
Wheel Equivalent Diameter =	8.0	8.0	8.0	in	
Concrete modulus (E) =	3,500	3,500	3,500	ksi	
Compressive strength of concrete (*f'c*) =	3,000	3,500	4,000	psi	
Subgrade Modulus (k) =	400	400	400	pci	Fig 3.3.5
Concrete Modulus of Rupture (MOR, f_r) =	411	444	474	psi	
Safety Factor (SF) =	1.7	1.7	1.7	---	
Allowable tensile stress (MOR/SF) =	242	261	279	psi	

WRI Method - Single Axle Wheel Load

		Trial			
	Units	*1*	*2*	*3*	
Trial Thickness =	in	6.0	6.0	6.0	
Stiffness parameter (D/k) =	x 10^{-5} in^4	1.5	1.5	1.5	(from Fig A2.2.1)
Basic bending moment per kip stress =	in-lb/in/kip	200	200	200	(from Fig A2.2.2)
Moment due to other wheel =	in-lb/in/kip	5	5	5	(from Fig A2.2.2)
Total moment per kip stress =	in-lb/in/kip	205	205	205	
Design moment =	in-lb/in	820	820	820	
SLAB THICKNESS =	**in**	**5.0**	**4.5**	**4.5**	(from Fig. A2.2.3)

**Highlighted values are calculated from other entered values.*

6-in. is an acceptable design slab thickness.

ATTACHMENT E

Sectional Areas of Welded Wire Reinforcement

TABLE 5 Customary Units

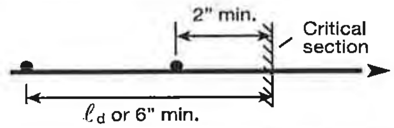
Wire Size Number		Nominal Diameter	Nominal Weight	As - Square Inch Per Linear Feet *Center to Center Spacing*								
Plain	*Deformed*	*Inches*	*Lbs./Lin. Ft.*	2"	3"	4"	6"	8"	10"	12"	16"	18"
W45	D45	0.757	1.530	2.70	1.80	1.35	.909	.68	.54	.45	.34	.30
W31	D31	0.628	1.054	1.86	1.24	.93	.62	.47	.37	.31	.23	.21
W20	D20	0.505	.680	1.20	.80	.60	.40	.30	.24	.20	.15	.13
W18	D18	0.479	.612	1.08	.72	.54	.36	.27	.216	.18	.14	.12
W16	D16	0.451	.544	.96	.64	.48	.32	.24	.192	.16	.12	.11
W14	D14	0.422	.476	.84	.56	.42	.28	.21	.168	.14	.11	.09
W12	D12	0.391	.408	.72	.48	.36	.24	.18	.144	.12	.09	.08
W11	D11	0.374	.374	.66	.44	.33	.22	.165	.132	.11	.08	.07
W10.5		0.366	.357	.63	.42	.315	.21	.157	.126	.105	.08	.07
W10	D10	0.357	.340	.60	.40	.30	.20	.15	.12	.10	.08	.07
W9.5		0.348	.323	.57	.38	.285	.19	.142	.114	.095	.07	.06
W9	D9	0.338	.306	.54	.36	.27	.18	.135	.108	.09	.07	.06
W8.5		0.329	.289	.51	.34	.255	.17	.127	.102	.085	.06	.06
W8	D8	0.319	.272	.48	.32	.24	.16	.12	.096	.08	.06	.05
W7.5		0.309	.255	.45	.30	.225	.15	.112	.09	.075	.056	.05
W7	D7	0.299	.238	.42	.28	.21	.14	.105	.084	.07	.053	.047
W6.5		0.288	.221	.39	.26	.195	.13	.097	.078	.065	.048	.043
W6	D6	0.276	.204	.36	.24	.18	.12	.09	.072	.06	.045	.04
W5.5		0.265	.187	.33	.22	.165	.11	.082	.066	.055	.041	.037
W5	D5	0.252	.170	.30	.20	.15	.10	.075	.06	.05	.038	.033
W4.5		0.239	.153	.27	.18	.135	.09	.067	.054	.045	.034	.03
W4	D4	0.226	.136	.24	.16	.12	.08	.06	.048	.04	.03	.027
W3.5		0.211	.119	.21	.14	.105	.07	.052	.042	.035	.026	.023
W3		0.195	.102	.18	.12	.09	.06	.045	.036	.03	.023	.02
W2.9		0.192	.098	.174	.116	.087	.058	.043	.035	.029	.022	.019
W2.5		0.178	.085	.15	.10	.075	.05	.037	.03	.025	.019	.017
W2.1		0.161	.070	.13	.084	.063	.042	.032	.025	.021	.016	.014
W2		0.160	.068	.12	.08	.06	.04	.03	.024	.02	.015	.013
W1.4		0.134	.049	.084	.056	.042	.028	.028	.017	.014	.011	.009

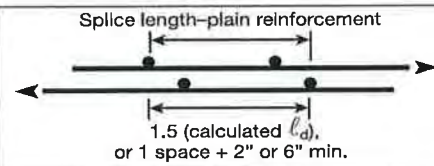
Note: For other available wire sizes other than those listed, contact your nearest WWR manufacturer.

ATTACHMENT F

TABLE 7 Customary Units (in.)
Welded Plain Wire Reinforcement

Typical Development and Splice Lengths, inches
f_y = 60,000 psi f'_c = 4,000 psi





WIRES TO BE DEVELOPED OR SPLICED		Development length when cross-wire spacing is:				Splice length when cross-wire spacing is:			
Wire Size	**Sw, spacing in.**	**4"**	**6"**	**8"**	**12"**	**4"**	**6"**	**8"**	**12"**
W1.4 to W5	4	6	8	10	14	6	8	10	14
	6	6	8	10	14	6	8	10	14
	12	6	8	10	14	6	8	10	14
W6	4	6	8	10	14	6	8	10	14
	6	6	8	10	14	6	8	10	14
	12	6	8	10	14	6	8	10	14
W7	4	6	8	10	14	7	8	10	14
	6	6	8	10	14	6	8	10	14
	12	6	8	10	14	6	8	10	14
W8	4	6	8	10	14	8	8	10	14
	6	6	8	10	14	6	8	10	14
	12	6	8	10	14	6	8	10	14
W9	4	6	8	10	14	9	10	10	14
	6	6	8	10	14	6	8	10	14
	12	6	8	10	14	6	8	10	14
W10	4	7	8	10	14	10	10	10	14
	6	6	8	10	14	7	8	10	14
	12	6	8	10	14	6	8	10	14
W12	4	8	8	10	14	12	12	12	14
	6	6	8	10	14	8	8	10	14
	12	6	8	10	14	6	8	10	14
W14	4	9	9	10	14	14	14	14	14
	6	6	8	10	14	9	9	10	14
	12	6	8	10	14	6	8	10	14
W16	4	11	11	11	14	16	16	16	16
	6	7	8	10	14	11	11	11	14
	12	6	8	10	14	6	8	10	14
W18	4	12	12	12	14	18	18	18	18
	6	8	8	10	14	12	12	12	14
	12	6	8	10	14	6	8	10	14
W20	4	13	13	13	14	20	20	20	20
	6	9	9	10	14	13	13	13	14
	12	6	8	10	14	8	8	10	14
W31	4	20	20	20	20	30	30	30	30
	6	14	14	14	14	20	20	20	20
	12	7	8	10	14	10	10	10	14
W45	4	29	29	29	29	44	44	44	44
	6	19	19	19	19	29	29	29	29
	12	10	10	10	10	15	15	15	15

ATTACHMENT G (1/1)

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF**	Project: **White Mesa Mill – Cells 5A and 5B**	Project/ Proposal No.: **SC0634**	Task No. **02**

Title of Computations: **GEOMEMBRANE TENSION DUE TO WIND UPLIFT**

Computations by:	Signature	[signature]	Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature	[signature]	Date 12/20/12
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations Checked by:	Signature	[signature]	Date 12/20/12
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations backchecked by: (originator)	Signature	[signature]	Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature	[signature]	Date 12/18/12
	Printed Name	Gregory Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	11/12/12	Reviewed by:	G. Corcoran	Date:	12/10/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

GEOMEMBRANE TENSION DUE TO WIND UPLIFT
WHITE MESA MILL
BLANDING, UTAH

OBJECTIVE

The project includes the installation of a triple liner system within Cells 5A and 5B at the White Mesa Mill in Blanding, Utah. Both Cells will have the same proposed liner system as shown in Attachment A. The objective of this calculation is to evaluate tension in the primary geomembrane on the exposed side slopes due to wind uplift. Two conditions are evaluated: the interim condition and the final condition. The interim condition corresponds to the construction period when the geomembranes may be secured within the anchor trench with a partial backfill until all layers are placed and secured in the final anchor trench.

The input variables, slope length, liner type, elevation, etc, which create the greatest tension in the geomembrane was evaluated in the design of both Cells 5A and 5B. The method outlined by Giroud, et al (1995) will be employed herein. Tension generated by wind uplift will be used to design the anchor trench capacity (see companion calculation package titled, *Evaluation of Liner System Anchor Trench Capacity*)

SITE CONDITIONS

The side slope liner system considered in the wind uplift calculation consists (from top to bottom) of:

- 60-mil (1.5 mm) HDPE geomembrane;
- 60-mil HDPE Drain Liner™ geomembrane;
- 60-mil HDPE Drain Liner™ geomembrane; and
- Prepared subgrade.

The capacity of the anchor trench is determined in a separate calculation package.

Written by:	R. Flynn	Date:	11/12/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

ANALYSIS

The analysis will follow the method outlined by Giroud, et al., in "Uplift of Geomembrane by Wind" (Attachment B). Giroud et al. offer the following equation for estimating the effective suction on a geomembrane (Attachment B):

$$S_e = 0.050\lambda V^2 e^{-\left[1.252\times10^{-4}\right]z} - 9.81\mu_{GM}$$ (Attachment B, 1/6)

where: S_e = effective suction (Pa)

λ = suction factor (dimensionless)

V = wind velocity (km/h)

z = altitude above sea level (m)

μ_{GM} = mass per unit area of geomembrane (kg/m^2)

Evaluate Variables

Interim Conditions		Final Conditions	
λ	Suction factor = 0.70 for the entire side slope being considered (Attachment B, page 2)	λ	Suction factor = 0.70 for the entire side slope being considered (Attachment B, page 2)
V	75% of Maximum Wind Speed = 25 x 0.75 mph = 30.2 km/h (IUC, 2003, see Attachment C) 1	V	maximum wind velocity = 25 mph = 40.2 km/h (IUC, 2003, see Attachment C)
z	altitude above sea level (m) A minimum elevation for the base side slopes is approximately 5,542 ft = 1689 meters (Cell 5B bottom elevation)	z	altitude above sea level (m) A minimum elevation for the base side slopes is approximately 5,542 ft = 1689 meters (Cell 5B bottom elevation)
μ_{GM}	mass per unit area of geomembrane (kg/m^2) μ_{GM} = 1.41 kg/m^2 (Attachment B, page 3/6)	μ_{GM}	mass per unit area of geomembrane (kg/m^2) μ_{GM} = 1.41 kg/m^2 (Attachment B, page 3/6)

Written by:	R. Flynn	Date:	11/12/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

Evaluate Suction

$S_e = 0.050(0.70)(30.2)^2 e^{-(1.252x10^{-4})1689} - 9.81(1.41)$ $S_e = 12.0\ Pa$	$S_e = 0.050(0.70)(40.2)^2 e^{-(1.252x10^{-4})1689} - 9.81(1.41)$ $S_e = 31.9\ Pa$

The maximum height of the exposed slope (2H:1V) is approximately 46 vertical feet, so the total length of exposed slope, L, is $L = \sqrt{46^2 + (2(46))^2} = 103\ \text{ft} = 31\ \text{m}$ (see Attachment A for the conceptual base grading plan). Therefore the resultant force of the applied effective suction becomes:

Interim Condition	Final Condition
$S_e L = 12.0 \frac{N}{m^2}(31\ m) \times \frac{1kN}{1000N} = 0.37 \frac{kN}{m}$	$S_e L = 31.9 \frac{N}{m^2}(31\ m) \times \frac{1kN}{1000N} = 0.99 \frac{kN}{m}$

EVALUATION OF TENSION IN GEOMEMBRANE

Geomembrane Properties

The geomembrane properties needed for the calculations herein are tensile stiffness and strain. These values are chosen from manufacturer data for 60-mil HDPE smooth geomembrane (Attachment D). The tensile strength and elongation at yield for a 60-mil, smooth HDPE geomembrane are 132 ppi (23.1 kN/m) and 13%, respectively (Attachment D).

The objective of this analysis is to evaluate wind induced tension in the geomembrane. Tension and strain in the geomembrane are linked by the following relationship, which is applicable to the initial portion of the tension-strain curve of the geomembrane which has been assumed to be linear:

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$T = J\varepsilon$ (Attachment B, page 5)

where: T = Tension

J = Stiffness

ε = Strain

To evaluate tension, we need to first evaluate stiffness and strain.

Stiffness, J

The tensile stiffness is given by:

$$J = Et_{GM}$$

where: E = Elastic Modulus

= 450 MPa, this modulus value corresponds to wide-width tension values, according to Koerner (1998, Attachment E)

t_{GM} = Geomembrane Thickness

= 1.5×10^{-3} m (60 mil)

Therefore:

$J = (450 \text{ MPa})(0.0015 \text{ m}) = 675 \text{ kN/m}$

Strain, ε

The strain on the geomembrane induced by wind uplift loading can be estimated using Table 4 (Attachment B, 6/6):

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Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

Interim Condition	Final Condition
$\frac{J}{S_e L} = \frac{675}{0.37} = 1824$, and from Table 4 (Attachment B, pg. 6), $\varepsilon = 0.24\%$	$\frac{J}{S_e L} = \frac{675}{0.99} = 682$, and from Table 4 (Attachment B, pg. 6), $\varepsilon = 0.46\%$

Therefore, the tension in the geomembrane is:

Interim Condition	Final Condition
$T = J\varepsilon = 675\frac{kN}{m}(0.0024) = 1.62\frac{kN}{m}$ $= 9.2\text{ ppi}$	$T = J\varepsilon = 675\frac{kN}{m}(0.0046) = 3.11\frac{kN}{m}$ $= 17.7\text{ ppi}$

CONCLUSIONS

Based on the calculation performed herein, the geomembrane is acceptable for a wind speed of 18.75 mph (75% of 25 mph) for the interim condition and 25 mph for the final condition, both with a slope length of approximately 103 ft (31 m). The tension in the geomembrane under the design conditions is 9.2 ppi (interim) and 17.7 ppi (final).

The capacity of the anchor trench is determined in a separate calculation package.

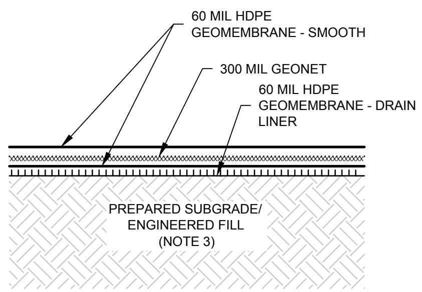
REFERENCES

Giroud, J.P., Pelte., Bathurst, R.J. 1995. *Uplift of Geomembranes by Wind*, Geosynthetic International, Vol. 2, No. 6, pg. 897-952. *(Attachment B)*

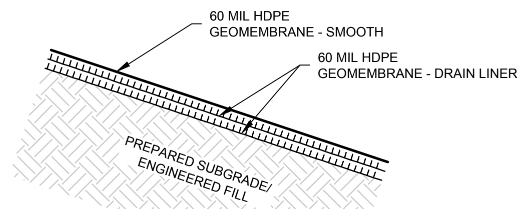
International Uranium (USA) Corporation (IUC). 2003. *Environmental Report*. June 20, 2003, page 3-3. *(Attachment C)*

Geosynthetic Research Institute. 2003. GRI Test Method GM13, Standard Specification for "Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes." Revision 5: May 15, 2003. *(Attachment D)*

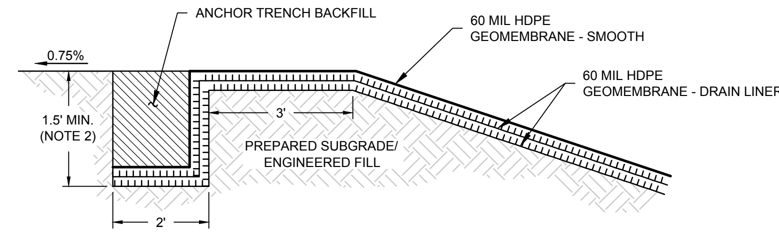
Koerner, R.M. 1998. *Designing with Geosynthetics*, 4th Edition. Prentice-Hall: Upper Saddle River, NJ. *(Attachment E)*



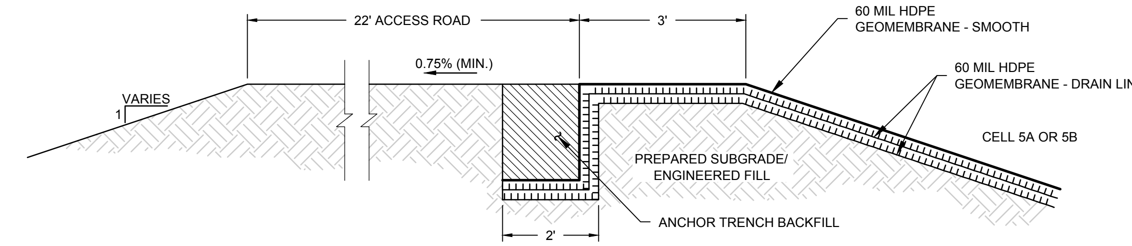
9 — 03A,03B,04A,04B — DETAIL
BASE LINER SYSTEM
SCALE: 1" = 2'



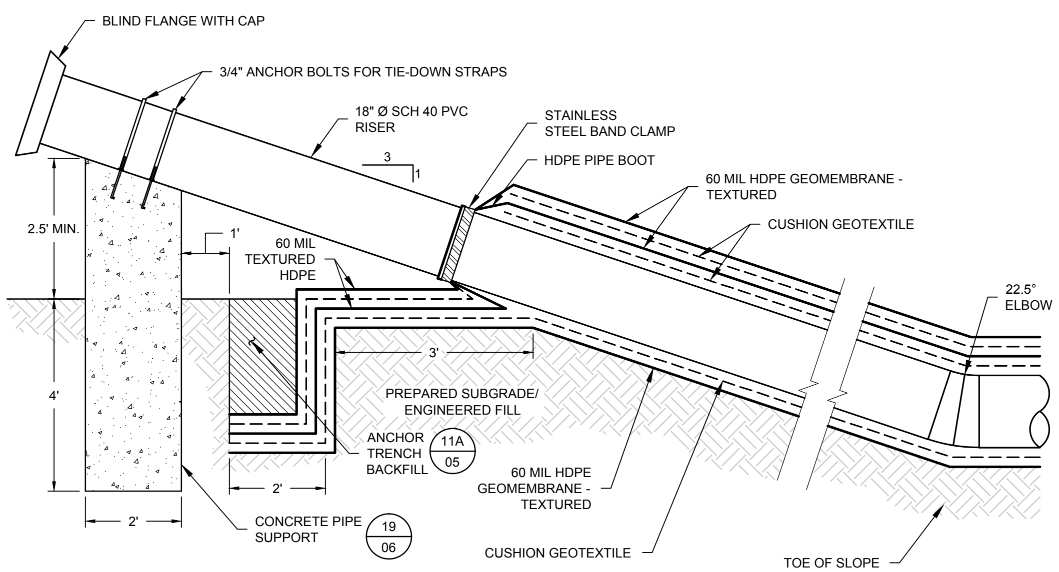
10 — 03A,03B,04A,04B — DETAIL
SIDE SLOPE LINER SYSTEM
SCALE: 1" = 2'



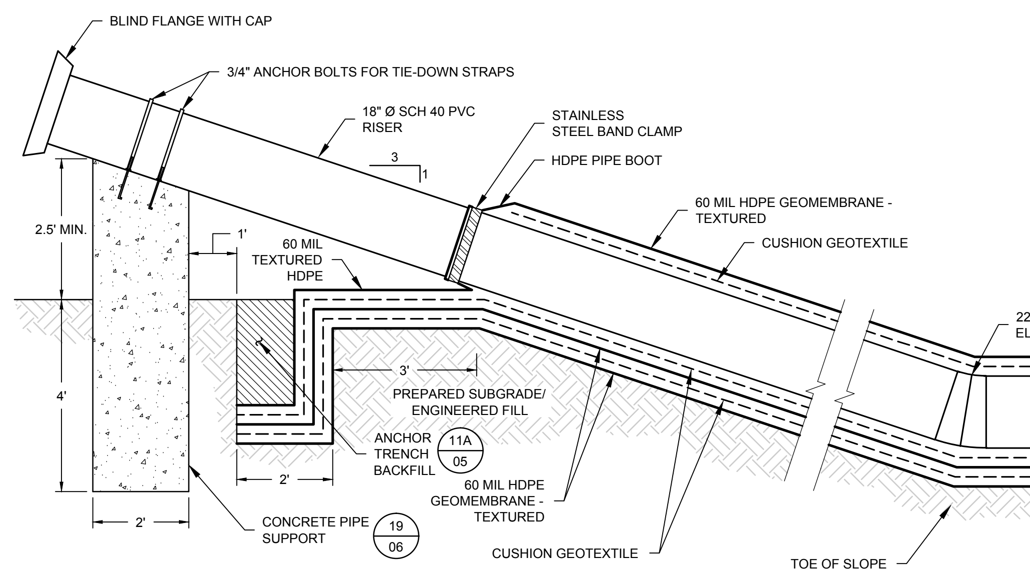
11A — 03A,03B,04A,04B,05,06,09 — DETAIL
ANCHOR TRENCH
SCALE: 1" = 2'



11B — 03A,03B — DETAIL
ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



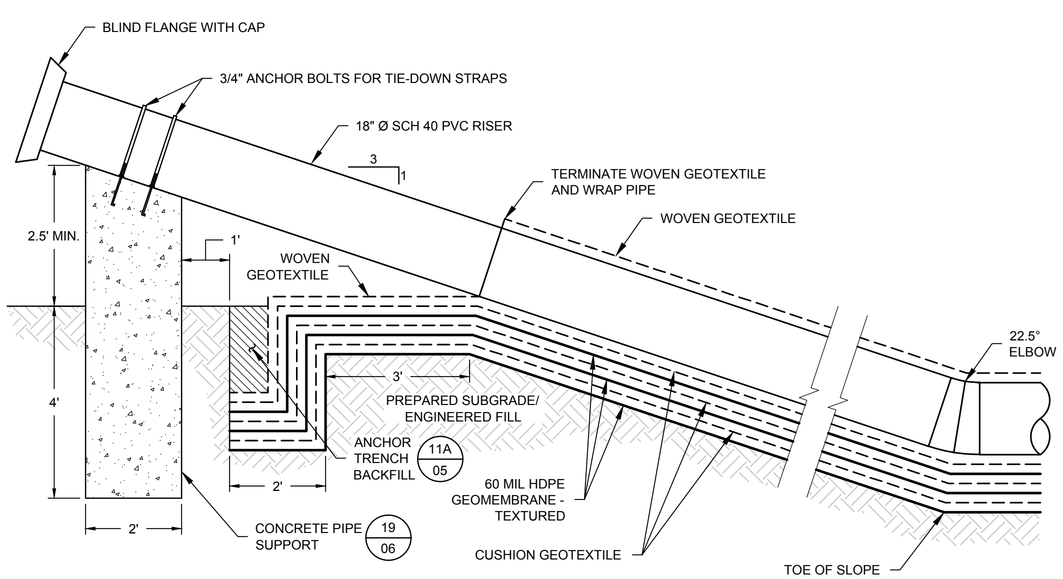
12 — 04A,04B — DETAIL
SECONDARY LEAK DETECTION
RISER PENETRATION
SCALE: 1" = 2'



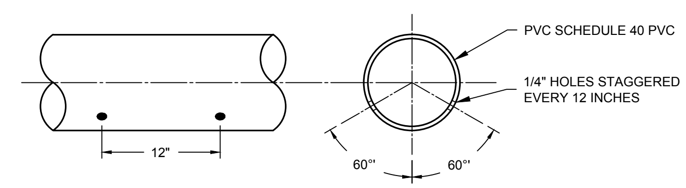
13 — 04A,04B — DETAIL
PRIMARY LEAK DETECTION
SYSTEM RISER PENETRATION
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. ANCHOR TRENCHES MAY BE CONSTRUCTED WITH A MAXIMUM DEPTH OF 3.5 FEET WITH UP TO 1 FOOT OF BACKFILL BETWEEN EACH GEOMEMBRANE IN BOTTOM OF ANCHOR TRENCH.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.



14 — 04A,04B — DETAIL
SLIMES DRAIN RISER
PENETRATION
SCALE: 1" = 2'



15 — 07,08 — DETAIL
PERFORATED PIPE
SCALE: 1" = 1'

Attachment A

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUTE 200
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS I

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	GTC	DATE:	JANUARY 2013
DRAWN BY:	MMC	PROJECT NO.:	SC0634
CHECKED BY:	RBF	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	05 OF 10	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

(3in) (2in) (1in)
(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634-05-07.dwg Last Edited by: MikeC on 12/21/2012 9:51 AM

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- At altitude z above sea level:

$$S_e = 0.6465\lambda V^2 e^{-(1.252 \times 10^{-4})z} - 9.81\mu_{GM} \tag{40}$$

with S_e(Pa), V(m/s), z(m), μ_{GM}(kg/m²)

*

$$S_e = 0.050\lambda V^2 e^{-(1.252 \times 10^{-4})z} - 9.81\mu_{GM} \tag{41}$$

with S_e(Pa), V(km/h), z(m), μ_{GM}(kg/m²)

3.3 Determination of Geomembrane Tension and Strain

According to Equation 36, the effective suction results from two components: a component due to the wind-generated suction, which is normal to the geomembrane; and a component due to the geomembrane mass per unit area, which is not normal to the geomembrane. The component due to the geomembrane mass per unit area is generally small compared to the component due to the wind-generated suction. Therefore, the effective suction is essentially normal to the geomembrane. Since the effective suction is taken as normal to the geomembrane and has been assumed to be uniformly distributed over the length L of geomembrane, and since the problem is considered to be two-dimensional (see Section 3.2.2), the cross section of the uplifted geomembrane has a circular shape (Figure 9). As a result, the resultant F of the applied effective suction is equal to the effective suction multiplied by the length of chord AB, i.e. L:

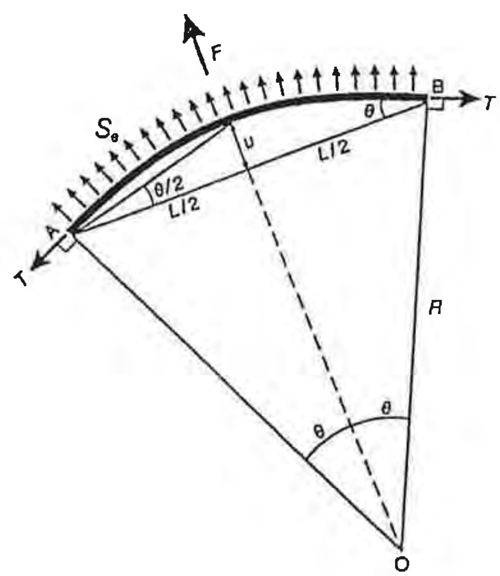

Figure 9. Schematic representation of uplifted geomembrane used for developing equations.

 Attachment B 1/6

- A leeward slope experiences a suction over its entire length. The suction on the leeward slope ranges between 45% of the reference pressure variation at the toe of the slope and 75% at the top of the slope, with an average value of 60%, i.e. $0.45 \le \lambda \le 0.75$ with an average value of 0.6.
- Large portions of the reservoir bottom are subjected to a suction ranging between 20% and 40% of the reference pressure variation ($0.2 \le \lambda \le 0.4$).

The above conclusions result from modeling in a wind tunnel where the wind velocity is constant. In reality, there are gusts of wind that may cause suctions greater than those indicated above, in localized areas for short periods of time.

Considering the conclusions from wind tunnel tests presented above and the need for extra safety due to gusts of wind, the following values of the suction factor, λ, are recommended for design of any slope based on the critical leeward slope:

- $\lambda = 1.00$ if the crest only is considered;
- $\lambda = 0.70$ if an entire side slope is considered;
- $\lambda = 0.85$ for the top third, $\lambda = 0.70$ for the middle third, and $\lambda = 0.55$ for the bottom third for a slope decomposed in three thirds by intermediate benches or anchor trenches as shown in Figure 7c and 7d; and
- $\lambda = 0.40$ at the bottom.

These recommendations are summarized in Figure 5. According to Equation 13, the suction factor, λ, is to be multiplied by Δp_R to obtain the suction S. The reference pressure variation, Δp_R, can be calculated using Equations 7 to 11.

It should be emphasized that the recommendations made above and used in the remainder of this paper rely entirely on the results of small-scale wind tunnel tests reported by Dedrick (1973, 1974a, 1974b, 1975). Nevertheless, the tests can be deemed representative of most practical situations because they were carried out on a wide range of dike cross section geometries and alignments typically associated with reservoir structures. However, a review of data for other shapes including obstacles with sinusoidal or smooth curve geometry can result in suction factors as great as $\lambda = 1.30$. Therefore, for unusual geometries, the designer may elect to increase the values of the suction factor, λ, given in Figure 5 by up to 30%. Also, for unusual geometries or large projects for which wind-induced damage of exposed geomembranes may have large financial consequences, wind tunnel tests of reduced-scale models or numerical simulation may be warranted.

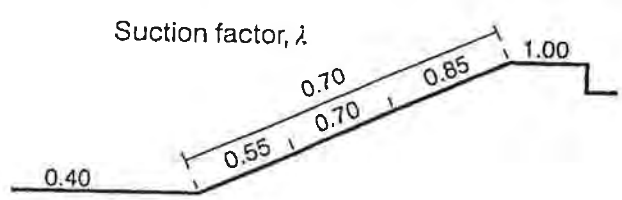

Figure 5. Recommended values of the suction factor for design of any slope based on the critical leeward slope.

Attachment B 2/6

GTC 11/11/05

Table 1. Typical density, thickness and mass per unit area for geomembranes, and relationship between mass per unit area and minimum uplift wind velocity.

Type of geomembrane	Geomembrane density ρ_{GM} (kg/m³)	Geomembrane thickness t_{GM} (mm)	Geomembrane mass per unit area μ_{GM} (4) (kg/m²)	Minimum uplift wind velocity V_{upmin} (5) (km/h)
PVC (1)	1250 (2)	0.5 1.0	0.63 1.25	11.1 15.7
* HDPE (1)	940	1.0 1.5 2.0 2.5	0.94 1.41 1.88 2.35	13.6 16.7 19.2 21.5
CSPE-R (1)	(3)	0.75 0.90 1.15	0.9 1.15 1.5	13.3 15.0 17.2
EIA-R (1)	(3)	0.75 1.0	1.0 1.3	14.0 16.0
Bituminous	(3)	3 5	3.5 6	26.2 34.3

Notes: (1) PVC = polyvinyl chloride; HDPE = high density polyethylene; CSPE-R = chlorosulfonated polyethylene-reinforced (commercially known as Hypalon); and EIA-R = ethylene interpolymer alloy-reinforced (commercially known as XR5). (2) PVC geomembranes have densities ranging typically from 1200 to 1300 kg/m³. An average value has been used in this table. (3) These geomembranes consist of several plies of different materials with different densities. (4) The relationship between density, thickness and mass per unit area is expressed by Equation 16. (5) Calculated using Equation 27 which is applicable to a geomembrane located at sea level and subjected to a suction equal to the reference pressure variation. Values tabulated in the last column can be found in Figure 6 on the curve for $z = 0$.

$$\mu_{GM} \geq \mu_{GMreq} = 0.0659\lambda V^2 e^{-(1.252 \times 10^{-4})z} \text{ with } \mu_{GMreq}(\text{kg/m}^2),\ V(\text{m/s}) \text{ and } z(\text{m}) \quad (20)$$

$$\mu_{GM} \geq \mu_{GMreq} = 0.005085\lambda V^2 e^{-(1.252 \times 10^{-4})z} \text{ with } \mu_{GMreq}(\text{kg/m}^2),\ V(\text{km/h}) \text{ and } z(\text{m}) \quad (21)$$

Figure 6 gives the relationship between the geomembrane mass per unit area, μ_{GM}, and the wind velocity, V, as a function of the altitude above sea level, z, for the case $\lambda = 1$, corresponding to the case where the geomembrane is subjected to a suction equal to the reference pressure variation ($S = \Delta p_R$). Figure 6 shows that typical polymeric geomembranes, with masses per unit area ranging between 0.5 and 2 kg/m², can resist uplift at sea level by winds with velocities ranging between 10 and 20 km/h, whereas bituminous geomembranes, with masses per unit area ranging between 3.5 and 6 kg/m², can resist uplift at sea level by winds with velocities ranging between 25 and 35 km/h.

Example 1. A 1.5 mm thick HDPE geomembrane is located at the bottom of a reservoir. The altitude of the reservoir is 450 m. Would this geomembrane be uplifted by a wind with a velocity of 30 km/h?

Attachment B 3/6

3.2.2 *Mechanical Behavior of the Geomembrane*

The problem is assumed to be two-dimensional. Therefore, the geomembrane is assumed to be characterized by its tension-strain curve measured in a tensile test that simulates plane-strain conditions. A wide-width tensile test provides a satisfactory approximation of this case. If only results of a uniaxial tensile test are available, the tensile characteristics under plane-strain conditions can be derived from the tensile characteristics under uniaxial conditions as indicated by Soderman and Giroud (1995).

Essential characteristics of geomembranes for use in design are the allowable tension, T_{all}, and strain, ε_{all}. Typical tension-strain curves are shown in Figure 8:

- If the geomembrane tension-strain curve has a peak (Curve 1), the allowable tension and strain correspond to the values of T and ε at the peak (as shown in Figure 8) or before the peak if a margin of safety is required.
- If the geomembrane tension-strain curve has a plateau (Curve 2), the allowable tension and strain correspond to the values of T and ε at the beginning of the plateau (as shown in Figure 8) or before if a margin of safety is required.
- If the geomembrane tension-strain curve has neither peak nor plateau (Curve 3), the allowable tension and strain correspond to the values of T and ε at the end of the curve, i.e. at break (as shown in Figure 8), or before if a margin of safety is required.

In all three cases, values of T_{all} and ε_{all} that are less than the values given above can be selected for any appropriate reasons (i.e. to meet regulatory requirements, to limit deformations, etc.).

* In some cases, the geomembrane tension-strain curve, or a portion of it, is assumed to be linear. Then, the following relationship exists:

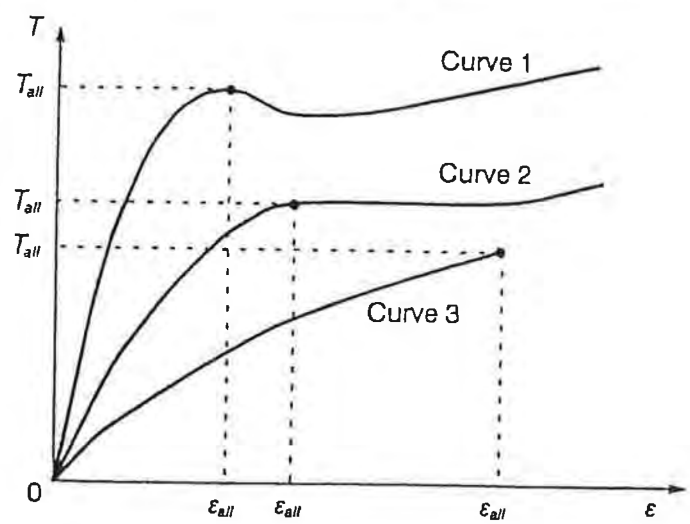

Figure 8. Typical tension-strain curves of geomembranes.

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*

$$T = J\varepsilon \tag{34}$$

where: T = geomembrane tension; J = geomembrane tensile stiffness; and ε = geomembrane strain. The case of geomembranes with a linear tension-strain curve will be further discussed in Section 3.5.

It is important to note that geomembranes that are not reinforced with a fabric, for example PVC and PE geomembranes, have tensile characteristics that are highly dependent on temperature. Extensive data on the influence of temperature on the tensile characteristics of HDPE geomembranes are provided by Giroud (1994). The influence of temperature will be further discussed in Section 3.6.

3.2.3 *Suction Due to Wind*

In the subsequent analysis, the suction applied by the wind is assumed to be uniform over the entire length L. In reality, the suction due to the wind is not uniformly distributed as shown in Figure 4. Therefore, the design engineer using the method presented in this paper must exercise judgment in selecting the value of the length L and the value of the ratio λ defined by Equation 13.

In accordance with the discussions presented in Sections 2.3 and 2.4, the suction that effectively uplifts the geomembrane is:

$$S_e = S - \mu_{GM}\, g \tag{35}$$

where S_e is the "effective suction".

Combining Equations 2, 13 and 35 gives:

$$S_e = \lambda \varrho V^2/2 - \mu_{GM}\, g \tag{36}$$

Combining Equations 3 and 36 gives:

$$S_e = \lambda \varrho_o (V^2/2) e^{-\varrho_o g z/p_o} - \mu_{GM}\, g \tag{37}$$

Using the values of ϱ_o and p_o given in Section 2.1 and g = 9.81 m/s^2, Equation 37 gives:

- At sea level:

$$S_e = 0.6465 \lambda V^2 - 9.81 \mu_{GM} \tag{38}$$

with S_e(Pa), V(m/s), μ_{GM}(kg/m^2)

$$S_e = 0.050 \lambda V^2 - 9.81 \mu_{GM} \tag{39}$$

with S_e(Pa), V(km/h), μ_{GM}(kg/m^2)

Attachment B 5/6

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Table 4. Relationship between the strain of the geomembrane uplifted by the wind and the normalized tensile stiffness of the geomembrane for the case where the geomembrane has a linear tension-strain curve (Equation 57).

ε (%)	$\frac{J}{S_e L}$	ε (%)	$\frac{J}{S_e L}$	ε (%)	$\frac{J}{S_e L}$	ε (%)	$\frac{J}{S_e L}$
0	∞	3.6	31.347	7.2	11.607	10.8	6.607
0.1	6463.688	3.7	30.124	7.3	11.384	10.9	6.525
0.2	2288.342	3.8	28.981	7.4	11.168	11.0	6.443
0.3	1247.294	3.9	27.910	7.5	10.959	11.1	6.365
0.4	811.232	4.0	26.905	7.6	10.757	11.2	6.291
0.5	581.251	4.1	25.960	7.7	10.561	11.3	6.212
0.6	442.767	4.2	25.071	7.8	10.372	11.4	6.138
0.7	351.834	4.3	24.233	7.9	10.189	11.5	6.065
0.8	288.358	4.4	23.442	8.0	10.010	11.6	5.994
0.9	241.983	4.5	22.694	8.1	9.839	11.7	5.925
1.0	206.885	4.6	21.987	8.2	9.671	11.8	5.857
1.1	179.565	4.7	21.316	8.3	9.508	11.9	5.790
1.2	157.804	4.8	20.680	8.4	9.351	12.0	5.724
1.3	140.137	4.9	20.076	8.5	9.198	12.1	5.660
1.4	125.562	5.0	19.502	8.6	9.049	12.2	5.598
1.5	113.368	5.1	18.956	8.7	8.905	12.3	5.537
1.6	103.044	5.2	18.435	8.8	8.765	12.4	5.477
1.7	94.212	5.3	17.939	8.9	8.628	12.5	5.418
1.8	86.586	5.4	17.465	9.0	8.495	12.6	5.359
1.9	79.947	5.5	17.013	9.1	8.365	12.7	5.302
2.0	74.125	5.6	16.580	9.2	8.240	12.8	5.247
2.1	68.983	5.7	16.167	9.3	8.118	12.9	5.192
2.2	64.421	5.8	15.771	9.4	7.998	13.0	5.138
2.3	60.345	5.9	15.392	9.5	7.882	13.1	5.086
2.4	56.688	6.0	15.027	9.6	7.769	13.2	5.035
2.5	53.391	6.1	14.678	9.7	7.658	13.3	4.984
2.6	50.407	6.2	14.342	9.8	7.551	13.4	4.934
2.7	47.696	6.3	14.020	9.9	7.446	13.5	4.885
2.8	45.223	6.4	13.710	10.0	7.344	13.6	4.837
2.9	42.960	6.5	13.412	10.1	7.243	13.7	4.790
3.0	40.885	6.6	13.126	10.2	7.146	13.8	4.743
3.1	38.973	6.7	12.849	10.3	7.051	13.9	4.698
3.2	37.209	6.8	12.582	10.4	6.958	14.0	4.653
3.3	35.577	6.9	12.325	10.5	6.867	14.1	4.609
3.4	34.064	7.0	12.078	10.6	6.779	14.2	4.566
3.5	32.657	7.1	11.838	10.7	6.692	14.3	4.524

Attachment B 6/6

GTC
11/11/05

The weather in the Blanding area is typified by warm summers and cold winters. The mean annual temperature in Blanding is about 50°F (10°C). January is usually the coldest month and July is usually the warmest month.

Winds are usually light to moderate in the area during all seasons, although occasional stronger winds may occur in the late winter and spring. The predominant winds are from the north through north-east (approximately 30 percent of the time) and from the south through south-west (about 25 percent of the time). Winds are generally less than 15 mph, with wind speeds faster than 25 mph occurring less than one percent of the time. The National Weather Service Station in Blanding, Utah is located about 6.25 miles (10km) north of the Mill. Data from the station is considered representative of the local weather conditions (1978 ER, Section 2.7.2).

Further description of local and regional weather and climate data are given in the 1978 ER (Section 2.7) and in the FES (Section 2.1).

3.3.1.2 On Site

On-site meteorological monitoring at the Mill was initiated in early 1977 and continues today. The original purpose of the meteorological monitoring program was to document the regional atmospheric baseline and to provide data to assist in assessing the potential air quality and radiological impacts arising from the operation of the Mill.

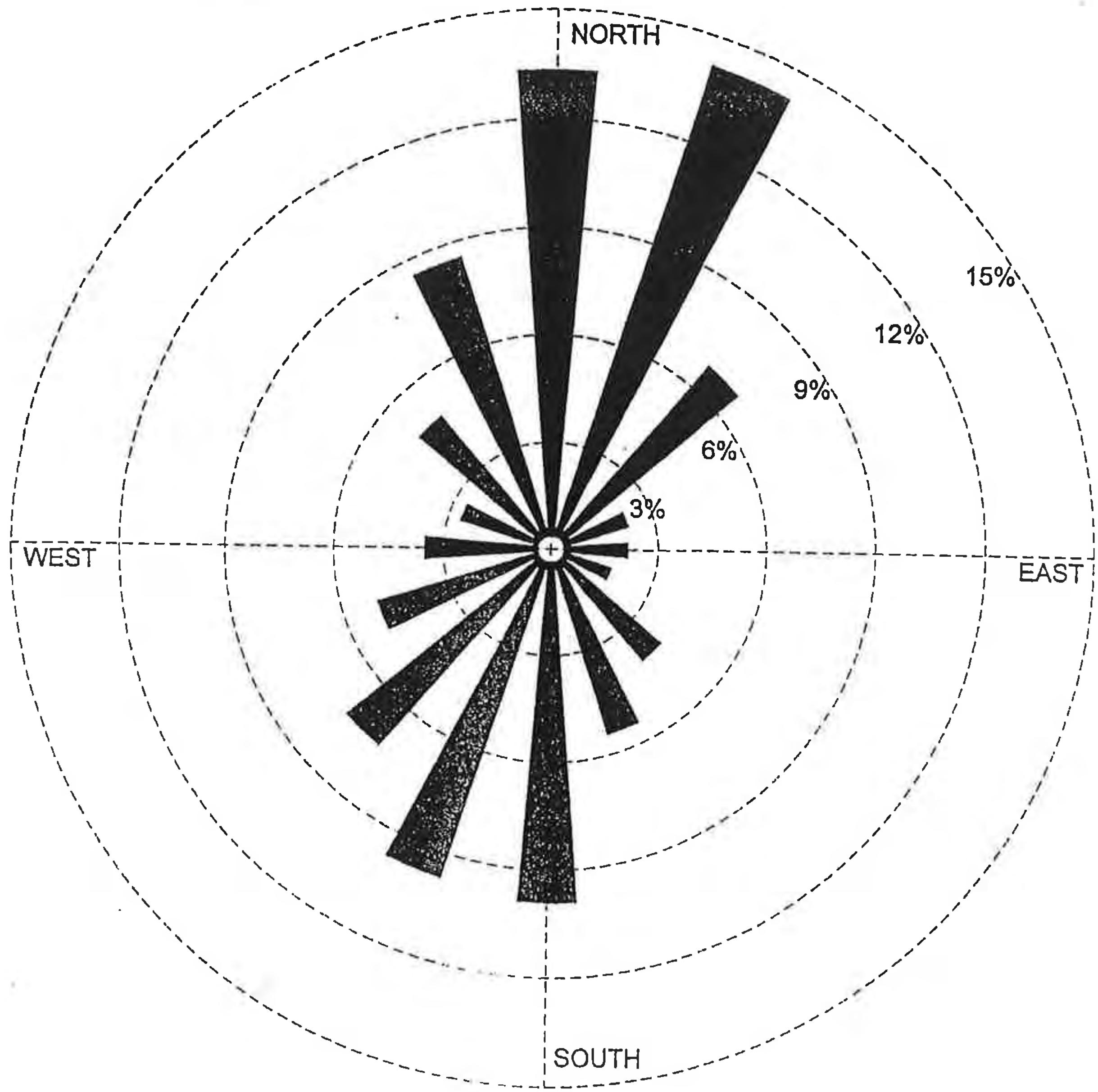
After the Mill construction was completed, the monitoring programs were modified to facilitate the assessment of Mill operations. The current meteorological monitoring program includes data collection for wind speed, wind direction, atmospheric stability according to the standard Pasquill scheme (via measurements of deviations in wind direction, referred to as sigma-theta), and precipitation as either rain or snow. The meteorological data are reported on a semi-annual basis. The details of these meteorological monitoring programs and the results are described in semi-annual reports prepared for IUSA and maintained at the Mill. Figure 3.3-1 shows windroses for the Mill site for January – December 2001.

3.3.2 Baseline Air Quality

3.3.2.1 FES Evaluation

At the time of the 1978 ER and FES, the Four Corners Air Quality Control Region which encompasses parts of Colorado, Arizona, New Mexico and Utah and within which the Mill site is located had a priority IA rating, signifying a violation of federal air standards, for particulate matter and sulfur dioxide due to emissions from fossil-fueled power plants located within the region (1978 ER, Sect. 2.7.4.2). This was an important consideration at the time since the original proposal was to use coal and oil as the source of process and building heat. Thus, much of the discussion of potential air quality effects of the Mill arose from discussions of the potential

Attachment C



January through December 2001

International Uranium (USA) Corporation			
Project	WHITE MESA MILL		
REVISIONS	County:		State: UT
Date / By	Location:		
	Figure 3.3-1 Wind Speed Direction (blowing from) For All Hours		
	Scale: AS SHOWN	Date: June 2003	figure 3.3-1.dwg
	Author: HRR		Drafted By: BM

High Density Polyethylene Drain Liner™

agru america

Product Data

Property	Test Method	Values			
Thickness (min. ave.), mil (mm)	ASTM D5994*	50 (1.25)	60 (1.5)	80 (2.0)	100 (2.5)
Thickness (lowest indiv.), mil (mm)	ASTM D5994*	50 (1.25)	54 (1.35)	72 (1.8)	90 (2.25)
*The thickness values may be changed due to project specifications (i.e., absolute minimum thickness)					
Drainage Stud Height (min. ave.), mil (mm)	ASTM D7466	130 (3.30)	130 (3.30)	130 (3.30)	130 (3.30)
Density, g/cc, minimum	ASTM D792, Method B	0.94	0.94	0.94	0.94
Tensile Properties (ave. both directions)	ASTM D6693, Type IV				
Strength @ Yield (min. ave.), lb/in width (N/mm)	2 in/minute	110 (19.3)	132 (23.1)	176 (30.8)	220 (38.5)
Elongation @ Yield (min. ave.), % (GL=1.3in)	5 specimens in each direction	13	13	13	13
Strength @ Break (min. ave.), lb/in width (N/mm)		110 (19.3)	132 (23.1)	176 (30.8)	220 (38.5)
Elongation @ Break (min. ave.), % (GL=2.0in)		300	300	300	300
Tear Resistance (min. ave.), lbs. (N)	ASTM D1004	38 (169)	40 (178)	53 (236)	64 (285)
Puncture Resistance (min. ave.), lbs. (N)	ASTM D4833	80 (355)	95 (422)	126 (560)	158 (703)
Carbon Black Content (range in %)	ASTM D4218	2 - 3	2 - 3	2 - 3	2 - 3
Carbon Black Dispersion (Category)	ASTM D5596	Only near spherical agglomerates for 10 views: 9 views in Cat. 1 or 2, and 1 view in Cat. 3			
Stress Crack Resistance (Single Point NCTL), hours	ASTM D5397, Appendix	300	300	300	300
Oxidative Induction Time, minutes	ASTM D3895, 200°C, 1 atm O_2	≥100	≥100	≥100	≥100
Melt Flow Index, g/10 minutes	ASTM D1238, 190°C, 2.16kg	≤1.0	≤1.0	≤1.0	≤1.0
Oven Aging with HP OIT, (% retained after 90 days)	ASTM D5721 ASTM D5885, 150°C, 500psi O_2	80	80	80	80
UV Resistance	GRI GM11	20hr. Cycle @ 75°C/4 hr. dark condensation @ 60°C			
with HP OIT, (% retained after 1600 hours)	ASTM D5885, 150°C, 500psi O_2	50	50	50	50

These product specifications meet or exceed GRI's GM13

Supply Information (Standard Roll Dimensions)

Thickness mil	Thickness mm	Width ft	Width m	Length ft	Length m	Area (approx.) ft²	Area (approx.) m²	Weight (average)* lbs	Weight (average)* kg
50	1.25	23	7	300	91.435	6,900	640.05	2,600	1,178.34
60	1.5	23	7	300	91.435	6,900	640.05	2,900	1,315.42
80	2.0	23	7	300	91.435	6,900	640.05	3,600	1,632.93
100	2.5	23	7	300	91.435	6,900	640.05	4,000	1,814.37

Notes:

All rolls are supplied with two slings. All rolls are wound on a 6 inch core. Special lengths are available on request. All roll lengths and widths have a tolerance of ±1%
**The weight values may change due to project specifications (i.e. absolute minimum thickness or special roll lengths) or shipping requirements (i.e. international containerized shipments).*

500 Garrison Road, Georgetown, South Carolina 29440 843-546-0600 800-373-2478 Fax: 843-527-2738
email: salesmkg@agruamerica.com www.agruamerica.com

ATTACHMENT D

GTC
11/11/05

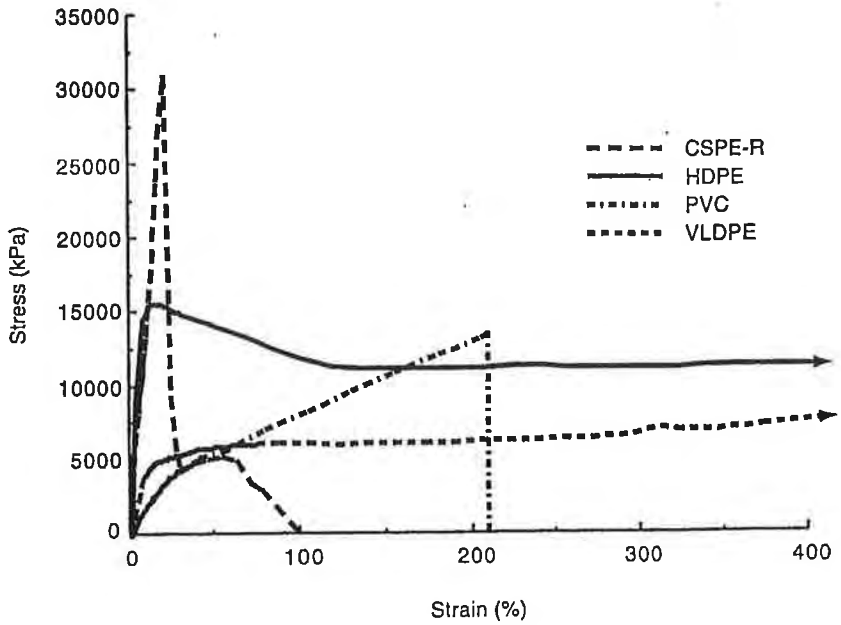


Figure 5.3 Tensile test results on 200 mm wide-width specimens of commonly used geomembranes using ASTM D-4885 test method.

formation beneath a geomembrane is such a case. This type of behavior could well be anticipated for a geomembrane used in a landfill cover placed over differentially subsiding solid-waste material. The situation can be modeled by placing the geomembrane in an empty container, as shown in Figure 5.4. An appropriate seal is made with the cover section and water is introduced above the geomembrane. Pressure is mobilized until the failure of the test specimen occurs. Beginning with Stefan [6], a number of variations of this test have been made. It is currently formalized as ASTM D5716.

TABLE 5.5b TENSILE BEHAVIOR PROPERTIES OF HDPE, VLDPE, PVC, AND CSPE-R

		✱ Wide-Width Tension Tests (Figure 5.3)			
Test Property	Unit	HDPE	VLDPE	PVC	CSPE-R
Maximum stress and	(kPa)	15,900	7,600	13,800	31,000
corresponding strain	(%)	15	400+	210	23
✱ Modulus	(MPa)	450	69	20	300
Ultimate stress and	(kPa)	11,000	7,600	13,800	2,800
corresponding strain	(%)	400+	400+	210	79

Nom. thicknesses are: HDPE 1.5 mm, VLDPE 1.0 mm, PVC 0.75 mm, CSPE-R 0.91 mm.
Abbreviations: + = did not fail

Attachment E

Source: *Koerner, R.M. (1998). "Designing with Geosynthetics," 4th Edition. Prentice-Hall: Upper Saddle River, NJ.*

Geosyntec consultants

COMPUTATION COVER SHEET

Client:	**EF**	Project:	**White Mesa Mill – Cells 5A and 5B**	Project/ Proposal No.:	**SC0634**
				Task No.	**02**

Title of Computations **PIPE STRENGTH CALCULATIONS**

Computations by:	Signature		12/18/12
	Printed Name	Rebecca Flynn, P.E.	Date
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		12/20/12
	Printed Name	Keaton Botelho, P.E.	Date
	Title	Project Engineer	
Computations Checked by:	Signature		12/20/12
	Printed Name	Keaton Botelho, P.E.	Date
	Title	Project Engineer	
Computations backchecked by: (originator)	Signature		12/18/12
	Printed Name	Rebecca Flynn, P.E.	Date
	Title	Project Engineer	
Approved by: (pm or designate)	Signature		12/13/12
	Printed Name	Gregory Corcoran, P.E.	Date
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:		Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	WMM – Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

PIPE STRENGTH CALCULATIONS
WHITE MESA MILL
BLANDING, UTAH

OBJECTIVE

The project involves placement of a triple liner system for the bases of Cells 5A and 5B at the White Mesa Mill in Blanding, Utah. The proposed liner system is shown in Attachment A. A 4-in diameter schedule 40 Poly Vinyl Chloride (PVC) pipe will be buried under a maximum of 43 ft of tailing deposits plus 9 feet of cover soil for a total of 52 feet of overburden. This calculation will evaluate if the pipe will remain structurally intact with the maximum load placed above the buried pipe.

SUMMARY OF ANALYSIS

The maximum possible load on the buried pipe is evaluated to be 45.1 pounds per square inch (psi). Assuming a maximum allowable ring deflection of 7.5 percent, a schedule 40 PVC pipe diameter of 4-in will remain structurally intact.

SITE CONDITIONS

The construction components pertinent to this analysis are, from top to bottom:

- Maximum of 43 ft of silt-like deposits with assumed maximum wet unit weight of 125 pounds per cubic foot (pcf) and 9 feet of cover soil with a maximum unit weight of 125 pcf;
- 60-mil smooth HDPE Geomembrane;
- 4-in diameter schedule 40 PVC pipe, embedded in coarse aggregate for the primary leak detection system (LDS);
- 300-mil geonet;
- 60-mil smooth HDPE Geomembrane;
- 4-in diameter schedule 40 PVC pipe, embedded in coarse aggregate for the secondary leak detection system (LDS); and
- 60-mil Drain Liner® HDPE Geomembrane.

Written by:	R. Flynn	Date:		Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	WMM – Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

A cross-section of the site conditions is presented as Attachment A.

ANALYSIS

In the analysis herein, the allowable ring deflection and the factor of safety values against pipe wall crushing and buckling will be evaluated.

Ring Deflection

Ring deflection is the change in the vertical diameter of the pipe as the pipe/bedding aggregate system deforms under the external vertical pressure. Ring deflection can be evaluated using Spangler's Modified Iowa Formula, as follows:

$$\frac{\Delta}{D} = \frac{D_L KP + KW'}{\left[\frac{2E}{3(DR-1)^3}\right] + 0.061E'}$$

(Attachment. B, 6/8)

where:

Δ Pipe deflection or change in diameter, in.

D Pipe diameter, in.

P Prism soil load, psi

K Bedding constant

W′ Live load, psi

DR Standard dimension ratio (SDR)

E Modulus of elasticity of pipe, psi

E′ Modulus of soil reaction, psi

D_L Deflection lag factor

Evaluate Variables

Written by:	R. Flynn	Date:		Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	WMM – Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

Δ/D The allowable ring deflection for PVC pipe is 7.5 percent based on a factor of safety of 4 (Attachment C, 2/2)

P Prism soil load = 125 pcf × 52 ft = 6,500 psf = 45.1 psi

Effect of Perforations

The effects of the perforations in the pipe should be checked to ensure they will not significantly reduce the pipe strength. The frequency of perforations in the pipe will be 2 perforations per every 12 lineal inches of the pipe (Attachment A). The perforations are anticipated to be 0.25 inches in diameter. According to EPA, Manual SW-8, "Lining of Waste Impoundment and Disposal Facilities," the cumulative length of perforations (lp) in the pipe should be determined per foot of pipe (Attachment G). This value is determined by:

$$l_p = (\frac{length}{perforation}) \cdot (perforations) = \left(\frac{0.25\ in}{perforation}\right) \cdot (2\,perforations) = 0.50\ in$$

The total vertical stress (prism soil load) to be utilized for pipe design calculations should be adjusted according to the following equation:

$$P_T = \left(\frac{12in}{12in - l_p}\right) \cdot (P) = \left(\frac{12in}{12in - 0.50\ in}\right) \cdot (45.1psi) = 47.1psi = 6{,}777\ psf$$

K Bedding constant = 0.1 (typical value, Attachment B, 5/8)

W′ Live load = 0 (no live loads are expected for the site)

DR Standard dimension ratio = $\frac{D_o}{t}$ (Attachment B, 3/8)

where:

Written by:	R. Flynn	Date:		Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	WMM – Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

D_o Outside diameter of pipe = 4.500 in. (Attachment D, 2/2)

t Minimum pipe wall thickness = 0.237 in. (Attachment D, 2/2)

$$\text{so, DR} = \frac{4.500}{0.237} = 19.0$$

E Modulus of elasticity of pipe = 400,000 psi

(for Class 12454-B rigid PVC pipe; Attachment E, 2/2)

E′ Modulus of soil reaction = 3,000 psi

(for crushed rock, Attachment B, 5/8)

D_L = 1.0 (Attachment B, 5/8)

Solve for the deflection provides:

$$\frac{\Delta}{D} = \frac{D_L KP + KW'}{\left[\frac{2E}{3(DR-1)^3}\right] + 0.061E'}$$

$$= \frac{1.0(0.1)(47.1) + 0.1(0)}{\left[\frac{2(400{,}000)}{3(19.0-1)^3}\right] + 0.061(3{,}000)} = 2.1\%$$

Since the calculated ring deflection (2.1%) is lower than the maximum allowable ring deflection (7.5%), the schedule 40 PVC pipe with 4-in will be suitable for the anticipated loading conditions.

Written by:	R. Flynn	Date:		Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	WMM – Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

Wall Crushing

Wall crushing can occur when the stress in the pipe wall, due to external vertical pressure, exceeds the compressive strength of the pipe material. Wall crushing can be calculated using the following equation:

$$T = \frac{P_y D_o}{2}$$ (Attachment B, 8/8)

where:

T Wall thrust, lbs/in.

P_y Vertical pressure, psi

D_o Outside diameter of pipe = 4.500 in (Attachment D, 2/2)

and;

$$\sigma_c = \frac{T}{A}$$ (Attachment B, 8/8)

where:

σ_c Compressive stress = 9,600 psi (Attachment F, 1/1)

A Cross sectional area of the pipe wall per unit length

$$= \frac{\pi}{4}\left(4.500^2 - (4.500 - 2(0.237))^2\right) = 3.174\,\text{in}^2/12\,\text{in} = 0.265\,\text{in}^2/\text{in}$$

Combining Equations and solving for P_y provides:

$$P_y = \frac{2\sigma_c A}{D_o}$$

Substituting the variables into the above equation provides:

$$P_y = \frac{2(9{,}600)(0.265)}{4.500} = 1{,}129 \text{ psi}$$

Comparing the above estimated value to the maximum loading allowed under ring deflection criteria (47.1 psi) provides:

FS_{WC} = 1,129/47.1

= 23.9

This value is greater than the acceptable factor of safety of 2.

Wall Buckling

Wall buckling, a longitudinal wrinkling in the pipe wall, can occur when the external vertical pressure exceeds the critical buckling pressure of the pipe/bedding aggregate system. Wall buckling can be calculated using the following equation:

$$P_{cr} = \frac{2E}{(DR-1)^3}$$ (Attachment B, 7/8)

where:

P_{cr} Buckling pressure, psi

E Modulus of elasticity = 400,000 psi (Attachment E, 2/2)

Written by:	R. Flynn	Date:		Reviewed by:	G. Corcoran	Date:	12/13/12
Client: EF		Project:	WMM – Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

DR Standard dimension ratio $= \frac{D_o}{t} = \frac{4.500}{0.237} = 19.0$

Therefore,

$$P_{cr} = \frac{2(400{,}000)}{(19.0-1)^3} = 137\ \text{psi}$$

Comparing the above estimated value to the maximum loading allowed under ring deflection criteria (47.1 psi) provides:

FS_{WC} = 137/47.1

= 2.9

This value is greater than the acceptable factor of safety of 2.

SUMMARY AND CONCLUSIONS

Using the Modified Iowa Formula as outlined in the Uni-Bell Plastic Pipe Association Handbook on PVC Pipe, the maximum load on the buried pipe assumed to be 45.1 psi will only cause a ring deflection of 2.0 percent, which is below the acceptable ring deflection of 7.5 percent. Acceptable factor of safety values against wall crushing and wall buckling were also evaluated using methods outlined in Uni-Bell Plastic Pipe Association Handbook on PVC Pipe. Therefore, schedule 40 PVC pipe with 4-in diameter is suitable for this application.

REFERENCES

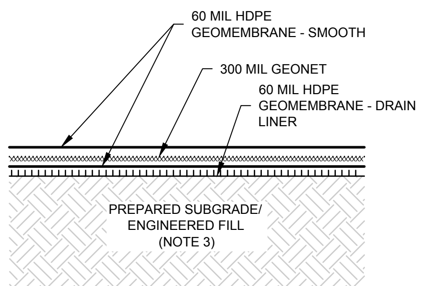
ASTM D 1784 (1993), "Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly (Vinyl Chloride) (CPVC) Compounds" ASTM Annual Method of Standards - Plastics

Written by:	R. Flynn	Date:		Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	WMM – Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

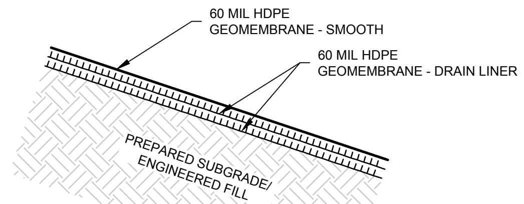
ASTM D 1785 (1996), "Standard Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120" ASTM Annual Method of Standards - Plastics

ASTM D 3034 (1997), "Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings" ASTM Annual Method of Standards - Plastics

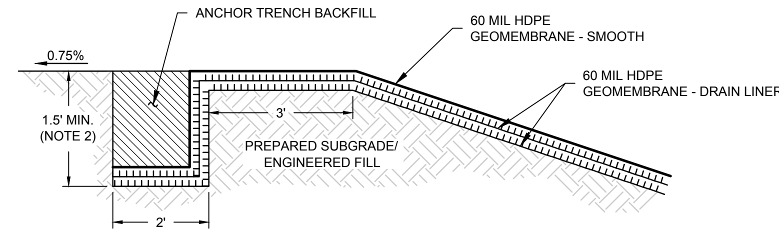
The Uni-Bell Plastic Pipe Association, "Handbook of PVC Pipe, Design and Construction," Dallas, Texas, 214-243-3902



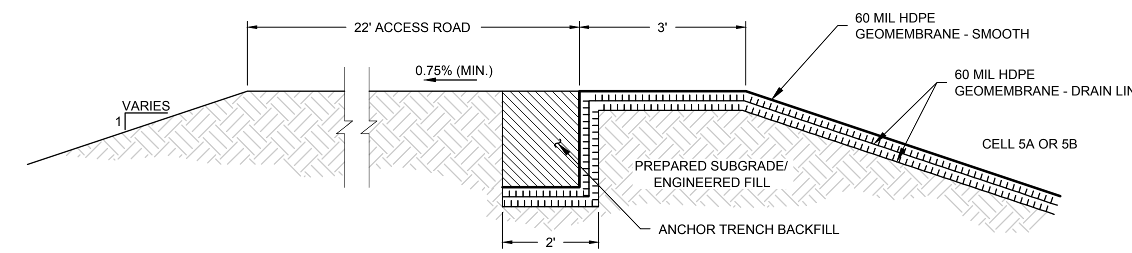
9 DETAIL
03A,03B,04A,04B BASE LINER SYSTEM
SCALE: 1" = 2'



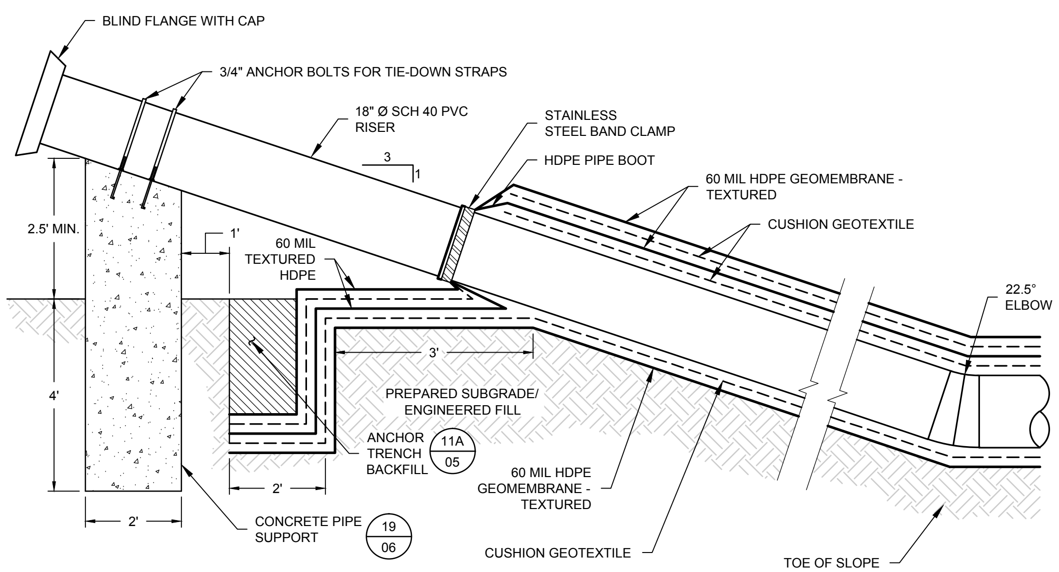
10 DETAIL
03A,03B,04A,04B SIDE SLOPE LINER SYSTEM
SCALE: 1" = 2'



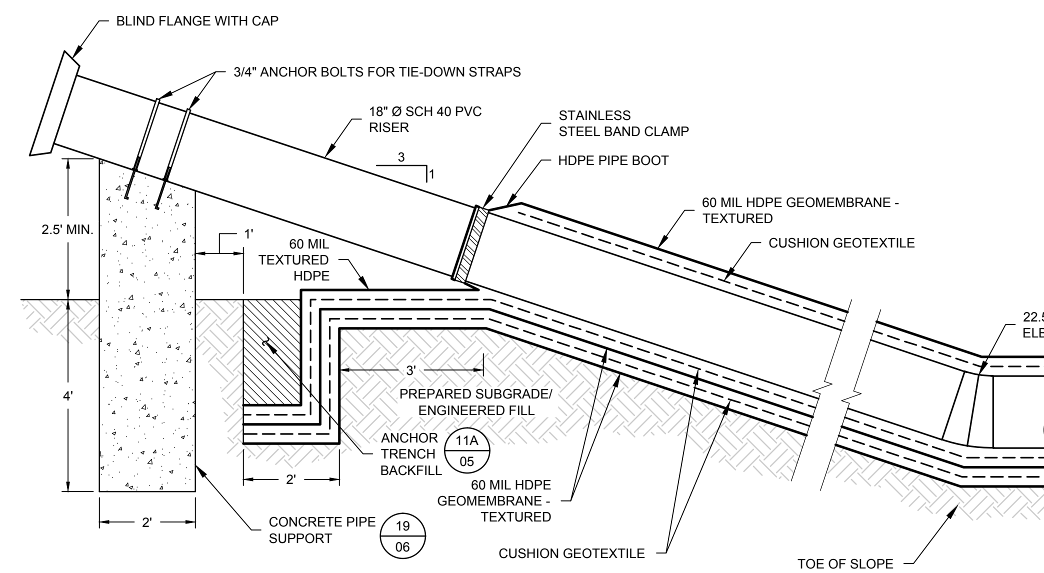
11A DETAIL
03A,03B,04A,04B,05,06,09 ANCHOR TRENCH
SCALE: 1" = 2'



11B DETAIL
03A,03B ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



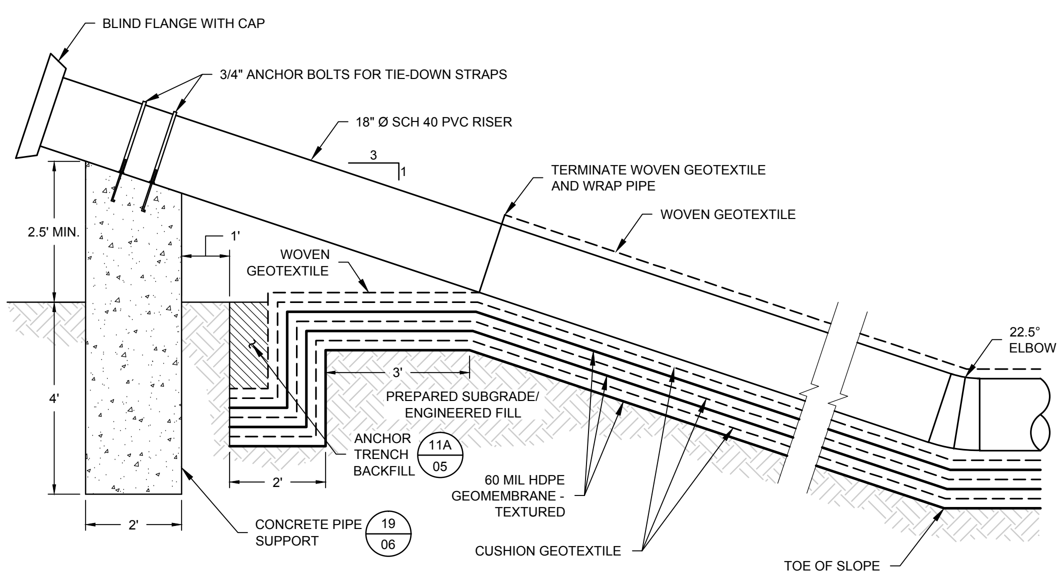
12 DETAIL
04A,04B SECONDARY LEAK DETECTION RISER PENETRATION
SCALE: 1" = 2'



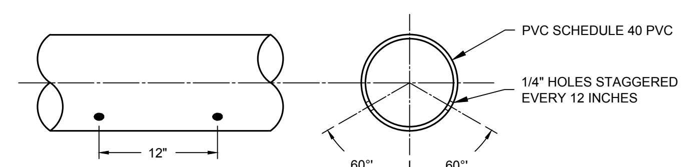
13 DETAIL
04A,04B PRIMARY LEAK DETECTION SYSTEM RISER PENETRATION
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. ANCHOR TRENCHES MAY BE CONSTRUCTED WITH A MAXIMUM DEPTH OF 3.5 FEET WITH UP TO 1 FOOT OF BACKFILL BETWEEN EACH GEOMEMBRANE IN BOTTOM OF ANCHOR TRENCH.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.



14 DETAIL
04A,04B SLIMES DRAIN RISER PENETRATION
SCALE: 1" = 2'



15 DETAIL
07,08 PERFORATED PIPE
SCALE: 1" = 1'

Attachment A

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS I

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	GTC	DATE:	JANUARY 2013
DRAWN BY:	MMC	PROJECT NO.:	SC0634
CHECKED BY:	RBF	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	
APPROVED BY:	GTC	05 OF 10	

(1in) (2in) (3in) (4in) SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634-05-07.dwg Last Edited by: MikeC on 12/21/2012 9:51 AM

The Uni-Bell PVC Pipe Association

Handbook of PVC Pipe

Design and Construction

Uni-Bell PVC Pipe Association

2655 Villa Creek Drive, Suite 155

Dallas, Texas 75234

$40.00

Attachment B, 1/8

2/8

TABLE 6.3 - Continued

Height of Cover (ft)	Soil Unit Weight (lb/ft³) 100	110	120	125	130
36	25.00	27.50	30.00	31.25	32.50
37	25.69	28.26	30.83	32.12	33.40
38	26.39	29.03	31.67	32.99	34.31
39	27.08	29.79	32.50	33.85	35.21
40	27.78	30.56	33.33	34.72	36.11
41	28.47	31.32	34.17	35.59	37.01
42	29.17	32.08	35.00	36.46	37.92
43	29.86	32.85	35.83	37.33	38.82
44	30.56	33.61	36.67	38.19	39.72
45	31.25	34.38	37.50	39.06	40.63
46	31.94	35.14	38.33	39.93	41.53
47	32.64	35.90	39.17	40.80	42.43
48	33.33	36.67	40.00	41.67	43.33
49	34.03	37.43	40.83	42.53	44.24
50	34.72	38.19	41.67	43.40	45.14

Tables 6.1, 6.2 and 6.3 assume a typical range for H and w. The table limits do not imply application limits.

Live Loads: Underground PVC pipe may also be subjected to live loads from different sources such as highways and railways. Live loads have little effect on pipe performance except at shallow burial depths.

Several methods exist for calculating these live loads. The design approach presented here is taken from the American Water Works Association standard for fiberglass pipe (AWWA C950).

Based on the Boussinesq formula for a point load at the surface of a semi-infinite elastic soil:

$$W_L = \frac{C_L P(1 + I_f)}{12}$$ *

Where: W_L = live-load on pipe, in pounds per inch

C_L = live-load coefficient, per foot of effective length

P = wheel load, in pounds

I_f = impact factor, dimensionless ($I_f = 0.766 - 0.133H$; $0 \le I_f \le 0.50$) * $1+I_f$ = 1.5 max

Note: ...ndard AASHTO H20 ...

Tables 6.4 and 6.5 give the live load coefficient C_L for a single wheel load and for two passing trucks, respectively. The design appr taken in these tables conservatively represents a wheel load as a point l Analytical expressions for C_L are given below the tables in terms of the diameter or radius and the height of cover.

TABLE 6.4

LIVE-LOAD COEFFICIENTS FOR SINGLE-WHEEL LOA

Pipe Diameter in.	Height of Cover Over Pipe H -- ft 2	4	6	8	10	12	14	16	
	Live-Load Coefficient C_L								
8	0.056	0.020	0.010	0.006	0.004	0.003	0.002	0.001	0.
10	0.069	0.025	0.012	0.007	0.004	0.003	0.002	0.002	0.
12	0.081	0.029	0.014	0.008	0.005	0.004	0.003	0.002	0.
14	0.091	0.034	0.016	0.009	0.006	0.004	0.003	0.002	0.
16	0.103	0.038	0.018	0.010	0.007	0.005	0.004	0.003	0.
18	0.115	0.042	0.020	0.012	0.008	0.005	0.004	0.003	0.
20	0.124	0.046	0.022	0.013	0.008	0.006	0.004	0.003	0.
24	0.141	0.055	0.026	0.015	0.010	0.007	0.005	0.004	0.
30	0.167	0.066	0.032	0.019	0.012	0.007	0.006	0.005	0.
36	0.183	0.076	0.038	0.022	0.015	0.010	0.008	0.006	0.
42	0.196	0.085	0.044	0.026	0.017	0.012	0.009	0.007	0.
48	0.205	0.094	0.049	0.029	0.019	0.014	0.010	0.008	0.

NOTE 1: An effective length of 3.0 ft of pipe is assumed.
NOTE 2:

$$C_L = \frac{1}{3} - \frac{2}{3\pi}\text{ARCSIN}\left[H\sqrt{\frac{R^2 + H^2 + 1.5^2}{(R^2 + H^2)(H^2 + 1.5^2)}}\right] + \frac{RH\left[\left(\frac{1}{R^2 + H^2} + \frac{1}{H^2 + 1.5^2}\right)\right]}{\pi\sqrt{R^2 + H^2 + 1.5^2}}$$

WHERE: H = earth cover, in feet; R = pipe radius, in feet; ARCSIN must be in radians.

As mentioned previously, the influence of live loads on the performa of PVC pipe is only significant in shallow depths, usually 4 feet (1.2 and less for highway loads. This is graphically demonstrated by the gr in Figure 6.7. Both show the total load calculated on a pipe exposed to loads and earth loads for highway and for railway traffic

:xible pipe may be defined as a conduit that will deflect at least two without any sign of structural distress such as injurious cracking. nduit to behave as a flexible pipe when buried, it is required that the nore yielding than the embedment soil surrounding it.

:xible pipe derives its soil load carrying capacity from its flexibility. oil load, the pipe tends to deflect, thereby developing passive soil at the sides of the pipe. At the same time, the ring deflection re- e pipe of the major portion of the vertical soil load which is then y the surrounding soil through the mechanism of an arching action pipe. (See Chapter VI.)

effective strength of the pipe-soil system is remarkably high. For , tests at Utah State University indicate that a rigid pipe with a three- ring strength of 3300 lb/ft (48.15 kN/m) buried in Class C bedding with a soil load of 5000 lb/ft (72.95 kN/m). However, under the soil conditions and loading, PVC sewer pipe with a minimum pipe of 46 psi deflects only 5 percent. This deflection is far below that ould cause damage to the PVC pipe wall. Thus, in this example, the e has failed but the flexible pipe has performed successfully.

ourse, in flat plate or three-edge loading, the rigid pipe will support ore than the flexible pipe. This anomaly tends to mislead many e flexible pipe users because they relate low flat plate supporting for flexible pipe to the in-soil load capacity. Flat plate or three-edge is an appropriate measure of load bearing strength for rigid pipes or flexible pipes.

Stiffness: The inherent strength of flexible pipe is called pipe which is measured, according to ASTM D 2412 Standard Test for External Loading Properties of Plastic Pipe by Parallel-Plate , at an arbitrary datum of 5 percent deflection. Pipe stiffness is de-

EQUATION 7.1

$$PS = F/\Delta Y = \frac{EI}{0.149r^3} = \frac{6.71EI}{r^3}$$

l wall pipes Equation 7.1 can be rewritten as:

$$PS = F/\Delta Y = \frac{6.71Et^3}{12r^3} = 0.559E\left[\frac{t}{r}\right]^3$$

Where:
- PS = Pipe Stiffness, lbf/in/in. or psi
- F = Force, lbs./Lin.
- ΔY = Vertical deflection, in.
- E = Modulus of elasticity, psi
- I = Moment of inertia of the wall cross-section per unit length of pipe, in^4/Lin. = in^3
- r = Mean radius of pipe, in.
- t = wall thickness, in.

For solid wall PVC pipe with outside diameter controlled dimensions (rather than I.D.) Equation 7.2 can be further simplified:

EQUATION 7.3

$$PS = 4.47\frac{E}{(DR - 1)^3}$$

Where: $DR = \frac{D_o}{t}$

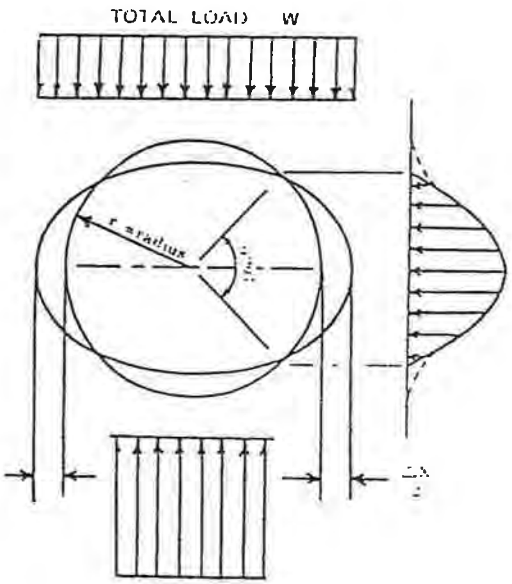
The resulting PS values for various dimension ratios and E values of PVC pipe are as shown in Table 7.1.

In addition to altering the "I" value by changing the DR, alternative shapes can be employed. It is this option of more efficient shapes that has resulted in a variety of profile wall gravity PVC pipe products for sanitary and drain applications. Users are afforded the economy of a higher stiffness than a DR product of the same raw material quantity and strength.

Equation 7.1 shows that the pipe stiffness increases as the moment of inertia of the wall cross section increases. For a solid wall pipe the moment of inertia is equal to $\frac{t^3}{12}$ in^4/Lin., with the center of gravity being at the mid-point of the pipe wall.

ATTACHMENT B, 3/8

SIS OF SPANGLER'S DERIVATION OF THE IOWA 'RMULA FOR DEFLECTION OF BURIED PIPES



(EQUATION 7.6)

$$\Delta X = \frac{D_L K W_c r^3}{EI + 0.061er^4}$$

THE IOWA FORMULA

e	=	$2h/\Delta X$
2r	=	D = Mean Pipe diameter
K	=	Bedding constant
D_L	=	Deflection lag factor
EI	=	Stiffness factor (related to pipe stiffness)

EQUATION 7.9

$$\Delta X = D_L \frac{K W_c r^3}{EI + 0.061er^4}$$

e:

D_L	=	Deflection lag factor
K	=	Bedding constant
W_c	=	Marston's load per unit length of pipe, lb/Lin.
r	=	Mean radius of the pipe, in.
E	=	Modulus of elasticity of the pipe material, psi
I	=	Moment of inertia of the pipe wall per unit length, $in^4/Lin = in^3$
e	=	Modulus of passive resistance of the side fill, $lb/in^2/in.$
ΔX	=	Horizontal deflection or change in diameter, in.

n 7.9 can be used to predict deflections of buried pipe if the three onstants **K**, **D_L** and e are known. The bedding constant, K, ac-

commodates the response of the buried flexible pipe to the opposite and equal reaction to the load force derived from the bedding under the pipe. The bedding constant varies with the width and angle of the bedding achieved in the installation. The bedding angle is shown in Figure 7.4. Table 7.2 contains a list of bedding factors, **K**, dependent upon the bedding angle. These were determined theoretically by Spangler and published in 1941. As a general rule, a value of **K** = 0.1 is assumed.

FIGURE 7.4
BEDDING ANGLE

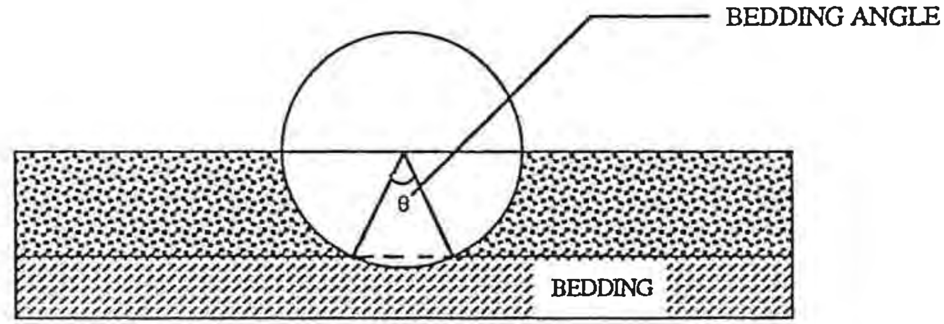


TABLE 7.2
VALUES OF BEDDING CONSTANT, K

BEDDING ANGLE (DEGREES)	K
0	0.110
30	0.108
45	0.105
60	0.102
90	0.096
120	0.090
180	0.083

In 1955, Reynold K. Watkins, a graduate student of Spangler, was investigating the modulus of passive resistance through model studies and examined the Iowa Formula dimensionally. The analysis determined that **e** could not possibly be a true property of the soil in that its dimensions are not those of a true modulus. As a result of Watkins' effort, another soil parameter was defined. This was the modulus of soil reaction, E' = er.

ATTACHMENT B. 4/8

EQUATION 7.10

$$\Delta X = D_L \frac{KW_c r^3}{EI + 0.061E'r^3}$$

other observations from Watkins' work are of particular note. little point in evaluating E' by a model test and then using the to predict ring deflection; the model gives ring deflection directly. ection may not be the only performance limit.

research efforts have attempted to measure E' without success. useful method has involved the measure of deflections for a pipe hich other conditions were known followed by back-calculation the Modified Iowa Formula to determine the correct value of E'. ires assumptions regarding the load, bedding factor and deflection to be used and has led to a variation in reported values of E'. attempt to acquire information on values of E' was conducted by C. Howard of the United States Bureau of Reclamation. Howard both laboratory and field data from many sources. Using infor- om over 100 laboratory and field tests, he compiled a table of aver- lues for various soil types and densities (see Table 7.3). He was o this by assuming values of E', K and W_c and then using the Iowa Formula to calculate a theoretical value of deflection. This l deflection was then compared with actual measurements. By as- e E' values of Table 7.3, a bedding constant K = 0.1 and deflec- actor D_L = 1.0, Howard was able to correlate the theoretical and results to within ± 2 percent deflection when he used the prism

This means that if theoretical deflections using Table 7.3 were ately 5 percent, measured deflection would range between 3 and 7 Although the vast majority of data from this study was taken from teel and reinforced plastic mortar pipe with diameters greater than , it does provide some useful information to guide designers of all ipe including PVC pipe since it helps to give an understanding of ied Iowa Deflection Formula.

AVERAGE VALUES OF MODULUS OF SOIL REACTION, E'
(For Initial Flexible Pipe Deflection)

Soil type-pipe bedding material (Unified Classification System[a]) (1)	E' for Degree of Compaction of Bedding, in pounds per square inch: Dumped (2)	Slight, <85% Proctor, <40% relative density (3)	Moderate, 85%-95% Proctor, 40%-70% relative density (4)	High, >95% Proctor, >70% relative density (5)
Fine-grained Soils (LL > 50)[b] Soils with medium to high plasticity CH, MH, CH-MH	No data available; consult a competent soils engineer; Otherwise use E' = 0			
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with less than 25% coarse-grained particles	50	200	400	1,000
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with more than 25% coarse-grained particles Coarse-grained Soils with Fines GM, GC, SM, SC[c] contains more than 12% fines	100	400	1,000	2,000
Coarse-grained Soils with Little or no Fines GW, GP, SW, SP[c] contains less than 12% fines	200	1,000	2,000	3,000
Crushed Rock	1,000	3,000	3,000	3,000
Accuracy in Terms of Percentage Deflection[d]	±2	±2	±1	±0.5

[a]ASTM Designation D 2487, USBR Designation E-3.

[b]LL = Liquid limit.

[c]Or any borderline soil beginning with one of these symbols (i.e. GM-GC, GC-SC).

[d]For ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Note: Values applicable only for fills less than 50 ft (15 m). Table does not include any safety factor. For use in predicting initial deflections only, appropriate Deflection Lag Factor must be applied for long-term deflections. If bedding falls on the borderline between two compaction categories, select lower E' value or average the two values. Percentage Proctor based on laboratory maximum dry density from test standards using about 12,500 ft-lb/cu ft (598,000 J/m³) (ASTM D 698, AASHTO T-99, USBR Designation E-11). 1 psi = 6.9 kPa.

SOURCE: "Soil Reaction for Buried Flexible Pipe" by Amster K. Howard, U.S. Bureau of Reclamation, Denver, Colorado. Reprinted with permission from American Society of Civil Engineers.

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TABLE 7.4

CALCULATED DEFLECTIONS OF BURIED AWWA C900 PVC PIPE
Deflection (Percent) for Highway H20 and Railway E80 Loads

of Cover →	2'		4'		6'		8'		10'		12'		14'		16'		18'		20'	
Load →	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80	H20	E80
E' Value	DR 14																			
50	0.58	2.26	0.49	1.75	0.51	1.66	0.59	1.43	0.67	1.28	0.80	1.25	0.94	1.27	1.07	1.35	1.21	1.49	1.34	1.51
200	0.54	2.10	0.45	1.63	0.48	1.55	0.55	1.34	0.62	1.19	0.75	1.16	0.87	1.19	1.00	1.26	1.12	1.33	1.25	1.40
400	0.50	1.93	0.42	1.49	0.44	1.42	0.50	1.22	0.57	1.09	0.69	1.07	0.80	1.09	0.91	1.15	1.03	1.22	1.14	1.29
1000	0.40	1.54	0.34	1.19	0.35	1.13	0.40	0.98	0.46	0.87	0.55	0.85	0.64	0.87	0.73	0.92	0.82	0.97	0.91	1.03
2000	0.30	1.15	0.25	0.89	0.26	0.85	0.30	0.73	0.34	0.66	0.41	0.64	0.48	0.65	0.55	0.69	0.62	0.73	0.68	0.77
E' Value	DR 18																			
50	1.26	4.89	1.07	3.79	1.11	3.60	1.28	3.10	1.45	2.79	2.09	2.71	2.04	2.76	2.33	2.93	2.62	3.10	2.91	3.27
200	1.09	4.22	0.92	3.28	0.97	3.11	1.12	0.69	1.25	2.40	1.51	2.34	1.76	2.38	2.01	2.53	2.26	2.67	2.51	2.82
400	0.92	3.58	0.78	2.77	0.82	2.63	0.93	2.27	1.06	2.03	1.28	1.98	1.48	2.01	1.69	2.14	1.91	2.26	2.12	2.38
1000	0.63	2.44	0.53	1.89	0.56	1.79	0.63	1.55	0.72	1.38	0.87	1.35	1.01	1.37	1.16	1.46	1.30	1.54	1.45	1.63
2000	0.41	1.59	0.35	1.23	0.36	1.17	0.42	1.01	0.47	0.91	0.57	0.88	0.66	0.90	0.76	0.95	0.85	1.01	0.95	1.06
E' Value	DR 25																			
50	3.24	12.56	2.73	9.73	2.86	9.23	3.29	7.96	3.73	7.15	4.48	6.97	5.22	7.09	5.97	7.52	6.71	7.96	7.46	8.39
200	2.30	8.91	1.94	6.96	2.05	6.60	2.34	5.71	2.66	5.10	3.21	4.97	3.71	5.03	4.23	5.34	4.76	5.65	5.29	5.95
400	1.65	6.47	1.41	4.97	1.47	4.75	1.68	4.10	1.91	3.66	2.30	3.57	2.67	3.63	3.05	3.85	3.43	4.07	3.82	4.29
1000	0.90	3.51	0.76	2.71	0.80	2.58	0.91	2.23	1.04	1.99	1.25	1.94	1.45	1.97	1.66	2.09	1.87	2.21	2.08	2.34
2000	0.51	1.99	0.43	1.54	0.45	1.46	0.52	1.26	0.59	1.13	0.71	1.10	0.83	1.12	0.94	1.19	1.06	1.26	1.18	1.33

(EQUATION 7.12)

Deflection Calculated by:

$$\frac{\Delta Y}{D} = \frac{D_L KP + KW'}{[2E/(3(DR - 1)^3)] + 0.061E'}$$

Where:

- P = Prism Load, psi
- K = Bedding constant, 0.1
- W' = Live load, psi
- DR = Dimension ratio
- E = 400,000 psi
- E' = Modulus of soil reaction, psi
- D_L = Deflection lag factor, 1.0

NOTE: Calculation based on soil weight (w) = 120 lb/ft³

Deflection Lag and Creep: The length of time that a buried flex
pipe will continue to deflect after the maximum imposed load is realize
limited and is a function of soil density in the pipe zone. As soil densit
the sides of the pipe increases, the time during which the pipe will conti
to deflect decreases, and the total deflection in response to load decrease
In fact, after the trench load reaches a maximum, the pipe-soil sys
continues to deflect only as long as the soil around the pipe is in the proc
of consolidation. Once the embedment soil has reached the density requ
to support the load, the pipe will not continue to deflect.

The full load on any buried pipe is not reached immediately after ins
lation unless the final backfill is compacted to a high density. For a p
with good flexibility, the long-term load will not exceed the prism lo
The increase in load with time is the largest contribution to increasing
flection. Therefore, for design, the prism load should be used, thus ef
tively compensating for the increased trench consolidation load with t
and resulting increased deflection. When deflection calculations are ba
on prism loads, the deflection lag factor, DL, should be 1.0.

Creep is normally associated with the pipe material and is define
continuing deformation with time when the material is subjected to a c
stant load. Most plastics exhibit creep. As temperature increases, the cr
rate under a given load increases. Also, as stress increases, the creep
for a given temperature increases. As PVC creeps, it also relaxes with ti
Stress relaxation is defined as the decrease in stress, with time, in a mate
held in constant deformation.

Figure 7.5 shows stress relaxation curves for PVC pipe samples hel
a constant deflection condition. It is evident that PVC pipe does re
stresses with time. The highest stress in a buried PVC non-pressure pip
encountered at the equilibrium deflection condition. The behavior dem
strated in Figure 7.5 results in a decrease in the actual stress in the pip
that deflection.

Figure 7.6 shows long-term data for PVC pipe buried in a soil b
Long-term deflection tests were run at Utah State University by imposi
given soil load which was held constant throughout the duration of the
PVC pipe material creep properties have little influence on deflection
but soil properties such as density exert great influence.

of up to 18 kip axle. Under light to medium aircraft loads of up to 00 pounds gross weight, a minimum burial depth of 2 feet is recommended.

is recommended that special attention be given to the selection, placeand compaction of backfill material with shallow burial flexible pipe, s PVC pipe underneath rigid pavement to prevent injurious cracking road surface.

reverse curvature performance limit for flexible steel pipe was estabshortly after publication of the Iowa Formula. It was determined that ated steel pipe would begin to reverse curvature at a deflection of 20 percent. Design at that time called for a limit of 5 percent deflecus providing a structural safety factor of 4.0. From this early design eration, an arbitrary design value of 5.0 percent deflection was se-

ried PVC sewer pipe (ASTM D 3034, DR 35), when deflecting in re- to external loading, may develop recognizable reversal of curvature flection of 30 percent. This level of deflection has been commonly ated as a conservative performance limit for PVC sewer pipe. Reat Utah State University has demonstrated that the load carrying caof PVC sewer pipe continues to increase even when deflections insubstantially beyond the point of reversal of curvature. With considof this performance characteristic of PVC sewer pipe, engineers lly consider the 7.5 percent deflection limit recommended by ASTM (Appendixes) to provide a very conservative factor of safety against al failure.

igitudinal bending of a pipeline is usually indicative of less than saty installation conditions. Unlike "rigid pipes," PVC pipe will not n flexure but will bend. Usually such bending does not significantly a pipeline's performance. Only short radius bends can be considered nance limiting for PVC pipe. (See Chapter VIII - Special Design itions - Longitudinal Bending.)

: *buckling* phenomenon may govern design of flexible pipes under ons of internal vacuum, sub-aqueous installations or loose soil f the external load exceeds the compressive strength of the pipe ma- For a circular ring subjected to a uniform external pressure or internal , the critical buckling pressure (P_{cr}) is defined by Timoshenko as:

*

$$P_{cr} = \frac{3EI}{r^3} = 0.447\ PS$$

Where:
- r = Mean pipe radius, in.
- I = Pipe wall moment of inertia (in^4/in)
- PS = Pipe stiffness
- E = Modulus of elasticity, psi

With the moment of inertia (I) defined as $t^3/12$ for solid wall pipes, Equation 7.13 becomes:

EQUATION 7.14

$$P_{cr} = \frac{2E}{\left[\frac{D_o - t}{t}\right]^3} = \frac{2E}{(DR - 1)^3}$$

Where:
- E = Modulus of elasticity, psi
- DR = Dimension ratio
- D_o = Outside pipe diameter, in.
- t = Pipe wall thickness, in.

For long tubes such as pipelines under combined stress, E is replaced by $E/(1 - v^2)$ and the critical buckling pressure is:

EQUATION 7.15

$$P_{cr} = \frac{3EI}{(1 - v^2)r^3} = \frac{0.447\ PS}{(1 - v^2)}$$

or for solid wall pipes

EQUATION 7.16

$$P_{cr} = \frac{2E}{(1 - v^2)(DR - 1)^3} = \frac{2E}{(1 - v^2)}\left[\frac{t}{D_o - t}\right]^3$$

ATTACHMENT B 7/5

·d in this installation.

$$= \frac{2E}{(1-v^2)(DR-1)^3} = \frac{2(400,000)}{[1 - (0.38)^2]\ (18-1)^3} = 190.3 \text{ psi}$$

:

DR 35 PVC sewer pipe with a 400,000 psi modulus of elasticity ıfined in a saturated soil providing E' = 800 psi, what height (H) of ırated soil which weighs 120 lbs/ft^3 (w) would cause buckling? eight will be limited so deflection does not exceed 7.5 percent.

$$P_{cr} = \frac{2(400,000)}{[1 - (0.38)^2]\ (35 - 1)^3} = 23.8 \text{ psi}$$

$$P_b = 1.15 \sqrt{23.8\ (800)} = 158.7 \text{ psi} = 22,850 \text{ psf}$$

$$H = P/w = 22,850/120 = 190 \text{ feet}$$

deflection to 7.5 percent:

$$\Delta = \frac{KP_e}{.149\ PS + .061E'} \times 100$$

$$P_e = \frac{\Delta(.149\ PS + .061E')}{K}$$

$$= \frac{0.075\ [.149(46) + .061(800)]}{0.11}$$

$$P_e = 37.9 \text{ psi} = 5,464 \text{ psf}$$

$$H \text{ (to limit deflection)} = 5,464/120 = 45.5 \text{ ft.}$$

:imum cover is limited by the allowable deflection not by buckling. 'efore, the safety factor for the critical failure mode by buckling of 'VC pipe is ample.

:arch has established that flexible steel pipe walls can buckle at de- : considerably less than 20 percent if the load is large and the soil ling the pipe is extremely compacted. Based on these observations, the design of buried flexible pipes. This theory assumed that the backfill was highly compacted, that deflection would be negligible and that the performance limit was *wall crushing*. The design concept is expressed by:

EQUATION 7.21

$$T = P_y \times \frac{D_o}{2}$$

Where: P_y = Vertical soil pressure, psi
D_o = Outside diameter, in.
T = Wall Thrust, pounds/in.

EQUATION 7.22

$$\sigma_c = \frac{T}{A}$$

Where: σ_c = Compressive stress, psi
A = Area of the pipe wall, in.^{2}/in.

Example: A profile wall PVC pipe (D_o = 19.15 in., A = 2.503 in.^{2}/ft.) is concrete cradled. At what vertical soil pressure or depth of cover could one expect failure by ring compression? (w = 120 lbs./ft.^{3})

$$\sigma_c = \frac{T}{A} \qquad P_y = wH$$

Conservatively assume σ_c = hydrostatic design basis or hoop tensile = 4000 psi.

$$P_y = \frac{\sigma_c 2A}{D_o} = \frac{4000(2)(2.503/12)}{19.15}$$

$$P_y = 87.1 \text{ psi} = wH$$

$$H = \frac{P_y}{w} = \frac{87.1 \text{ psi}}{120 \text{ lbs/ft.}^3} \times 144 \text{ in}^2/\text{ft}^2$$

ATTACHMENT B 8/8

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Designation: D 3034 – 97

Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings[1]

This standard is issued under the fixed designation D 3034; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers requirements and test methods for materials, dimensions, workmanship, flattening resistance, impact resistance, pipe stiffness, extrusion quality, joining systems and a form of marking for type PSM poly(vinyl chloride) (PVC) sewer pipe and fittings.

1.2 Pipe and fittings produced to this specification should be installed in accordance with Practice D 2321.

1.3 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following precautionary caveat pertains only to the test methods portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D1600 Terminology for Abbreviated Terms Relating to Plastics[2,3]

D1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[3]

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D2152 Test Method for Degree of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion[3]

D2321 Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications[3]

D2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading[3]

D2444 Test Method for Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)[3]

D2564 Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems[3]

D2749 Symbols for Dimensions of Plastic Pipe Fittings[3]

D2855 Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings[3]

D3212 Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

2.2 *Federal Standard:*[4]

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *Military Standard:*[4]

MIL-STD-129 Marking for Shipment and Storage

3. Terminology

3.1 *Definitions*— Definitions are in accordance with Terminology F 412, and abbreviations are in accordance with Terminology D 1600, unless otherwise specified. The abbreviation of poly(vinyl chloride) plastics is PVC.

3.1.1 The term PSM is not an abbreviation but rather an arbitrary designation for a product having certain dimensions.

4. Significance and Use

4.1 The requirements of this specification are intended to provide pipe and fittings suitable for non-pressure drainage of sewage and surface water.

NOTE 1—Industrial waste disposal lines should be installed only with the specific approval of the cognizant code authority since chemicals not commonly found in drains and sewers and temperatures in excess of 60°C (140°F) may be encountered.

5. Materials

5.1 *Basic Materials*—The pipe shall be made of PVC plastic having a cell classification of 12454-B or 12454-C or 12364-C or 13364-B (with minimum tensile modulus of

[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.62 on Sewer.

Current edition approved Dec. 10, 1996 and May 10, 1997. Published November 1997. Originally published as D 3034 – 72. Last previous edition D 3034 – 96.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

ATTACHMENT C, 1/2

TABLE X1.1 Base Inside Diameters and 7½ % Deflection Mandrel Dimension

Nominal Size, in.	SDR-41			SDR-35			SDR-26			SDR 23.5		
	Average Inside Diameter	Base Inside Diameter[A]	7½ % Deflection Mandrel	Average Inside Diameter	Base Inside Diameter[A]	7½ % Deflection Mandrel	Average Inside Diameter	Base Inside Diameter[A]	7½ % Deflection Mandrel	Average Inside Diameter	Base Inside Diameter[A]	7½ % Deflection Mandrel
						in.						
6	5.951	5.800	5.37	5.893	5.742	5.31	5.764	5.612	5.19	5.713	5.562	5.14
8	7.966	7.740	7.16	7.891	7.665	7.09	7.715	7.488	6.93	...	...	...
9	8.952	8.691	8.04	...	...	...	...	...	...	...	...	...
10	9.958	9.657	8.93	9.864	9.563	8.84	9.644	9.342	8.64	...	...	...
12	11.854	11.478	10.62	11.737	11.361	10.51	11.480	11.102	10.27	...	...	...
15	14.505	14.029	12.98	14.374	13.898	12.86	14.053	13.575	12.56	...	...	...
						mm						
6	151.16	147.32	136.3	149.68	145.85	134.9	146.41	142.54	131.8	145.11	141.27	130.6
8	202.34	196.60	181.8	200.43	194.69	180.1	195.96	190.20	175.9	...	...	...
9	227.38	220.75	204.2	...	...	...	...	...	...	...	...	...
10	252.93	245.29	226.9	250.54	242.90	224.7	244.96	237.29	219.5	...	...	...
12	301.09	291.54	269.7	298.12	288.57	266.9	291.59	281.99	260.9	...	...	...
15	368.43	356.34	329.6	365.10	353.01	326.5	356.95	344.80	318.9	...	...	...

[A] Base inside diameter is a minimum pipe inside diameter derived by subtracting a statistical tolerance package from the pipe's average inside diameter. The tolerance package is defined as the square root of the sum of squared standard manufacturing tolerances.

$$\text{Average inside diameter} = \text{average outside diameter} - 2(1.06)t$$

$$\text{Tolerance package} = \sqrt{A^2 + 2B^2 + C^2}$$

where:

t = minimum wall thickness (Table 1),
A = outside diameter tolerance (Table 1),
B = excess wall thickness tolerance = $0.06t$, and
C = out-of-roundness tolerance.

The values for C were derived statistically from field measurement data and are given as follows for various sizes of pipe:

Nominal Size, in.	Value for C	
	in.	mm
6	0.150	3.81
8	0.225	5.72
9	0.260	6.60
10	0.300	7.62
12	0.375	9.52
15	0.475	12.06

X2. RECOMMENDED LIMIT FOR INSTALLED DEFLECTION[5]

X2.1 Design engineers, public agencies, and others who have the responsibility to establish specifications for maximum allowable limits for deflection of installed PVC sewer pipe have requested direction relative to such a limit.

X2.2 PVC sewer piping made to this specification and installed in accordance with Practice D 2321 can be expected to perform satisfactorily provided that the internal diameter of the barrel is not reduced by more than 7½ % of its base inside diameter when measured not less than 30 days following completion of installation.

[5] Supporting data can be obtained from ASTM Headquarters. Request RR:F-17-1009.

ATTACHMENT C, 2/2

Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120[1]

This standard is issued under the fixed designation D 1785; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers poly(vinyl chloride) (PVC) pipe made in Schedule 40, 80, and 120 sizes and pressure-rated for water (see Appendix). Included are criteria for classifying PVC plastic pipe materials and PVC plastic pipe, a system of nomenclature for PVC plastic pipe, and requirements and test methods for materials, workmanship, dimensions, sustained pressure, burst pressure, flattening, and extrusion quality. Methods of marking are also given.

1.2 The text of this specification references notes, footnotes, and appendixes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 The following safety hazards caveat pertains only to the test methods portion, Section 8, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific precautionary statement is given in Note 7.

NOTE 1—CPVC plastic pipes, Schedules 40 and 80, which were formerly included in this specification, are now covered by Specification F 441.

NOTE 2—The sustained and burst pressure test requirements, and the pressure ratings in the Appendix, are calculated from stress values obtained from tests made on pipe 4 in. (100 mm) and smaller. However, tests conducted on pipe as large as 24-in. (600-mm) diameter have shown these stress values to be valid for larger diameter PVC pipe.

NOTE 3—PVC pipe made to this specification is often belled for use as line pipe. For details of the solvent cement bell, see Specification D 2672 and for details of belled elastomeric joints, see Specifications D 3139 and D 3212.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[3]

D 1599 Test Method for Short-Time Hydraulic Failure Pressure of Plastic Pipe, Tubing, and Fittings[3]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1784 Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[2]

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]

D 2152 Test Method for Degree of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion[3]

D 2672 Specification for Joints for IPS PVC Pipe Using Solvent Cement[3]

D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials[3]

D 3139 Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals[3]

D 3212 Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals[3]

F 412 Terminology Relating to Plastic Piping Systems[3]

F 441 Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80[3]

2.2 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage[4]

2.4 *NSF Standards:*

Standard No. 14 for Plastic Piping Components and Related Materials[5]

Standard No. 61 for Drinking Water System Components—Health Effects[5]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Terminology F 412 and abbreviations are in accordance with Terminology D 1600, unless otherwise specified. The abbreviation for poly(vinyl chloride) plastic is PVC.

3.2 *Descriptions of Terms Specific to This Standard:*

3.2.1 *hydrostatic design stress*—the estimated maximum

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[1] This specification is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.25 on Vinyl Based Pipe.

Current edition approved Dec. 10, 1996. Published November 1997. Originally published as D 1785 – 60. Last previous edition D 1785 – 96a$^{\epsilon 1}$.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.04.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

[5] Available from the National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106.

ATTACHMENT D 1/2

TABLE 1 Outside Diameters and Tolerances for PVC Plastic Pipe Schedules 40, 80, and 120, in. (mm)

Nominal Pipe Size	Outside Diameter	Tolerances		
		Average	Maximum Out-of-Roundness (maximum minus minimum diameter)	
			Schedule 40 sizes 3½ in. and over; Schedule 80 sizes 8 in. and over	Schedule 40 sizes 3 in. and less; Schedule 80 sizes 6 in. and less; Schedule 120 sizes all
⅛	0.405 (10.29)	±0.004 (±0.10)	...	0.016 (0.41)
¼	0.540 (13.72)	±0.004 (±0.10)	...	0.016 (0.41)
⅜	0.675 (17.14)	±0.004 (±0.10)	...	0.016 (0.41)
½	0.840 (21.34)	±0.004 (±0.10)	...	0.016 (0.41)
¾	1.050 (26.67)	±0.004 (±0.10)	...	0.020 (0.51)
1	1.315 (33.40)	±0.005 (±0.13)	...	0.020 (0.51)
1¼	1.660 (42.16)	±0.005 (±0.13)	...	0.024 (0.61)
1½	1.900 (48.26)	±0.006 (±0.15)	...	0.024 (0.61)
2	2.375 (60.32)	±0.006 (±0.15)	...	0.024 (0.61)
2½	2.875 (73.02)	±0.007 (±0.18)	...	0.030 (0.76)
3	3.500 (88.90)	±0.008 (±0.20)	...	0.030 (0.76)
3½	4.000 (101.60)	±0.008 (±0.20)	0.100 (2.54)	0.030 (0.76)
4	4.500 (114.30)	±0.009 (±0.23)	0.100 (2.54)	0.030 (0.76)
5	5.563 (141.30)	±0.010 (±0.25)	0.100 (2.54)	0.060 (1.52)
6	6.625 (168.28)	±0.011 (±0.28)	0.100 (2.54)	0.070 (1.78)
8	8.625 (219.08)	±0.015 (±0.38)	0.150 (3.81)	0.090 (2.29)
10	10.750 (273.05)	±0.015 (±0.38)	0.150 (3.81)	0.100 (2.54)
12	12.750 (323.85)	±0.015 (±0.38)	0.150 (3.81)	0.120 (3.05)
14	14.000 (355.60)	±0.015 (±0.38)	0.200 (5.08)	...
16	16.000 (406.40)	±0.019 (±0.48)	0.320 (8.13)	...
18	18.000 (457.20)	±0.019 (±0.48)	0.360 (9.14)	...
20	20.000 (508.00)	±0.023 (±0.58)	0.400 (10.2)	...
24	24.000 (609.60)	±0.031 (±0.79)	0.480 (12.2)	...

TABLE 2 Wall Thicknesses and Tolerances for PVC Plastic Pipe, Schedules 40, 80, and 120,[A,B] in. (mm)

Nominal Pipe Size	Wall Thickness[A]					
	Schedule 40		Schedule 80		Schedule 120	
	Minimum	Tolerance	Minimum	Tolerance	Minimum	Tolerance
⅛	0.068 (1.73)	+0.020 (+0.51)	0.095 (2.41)	+0.020 (+0.51)	...	...
¼	0.088 (2.24)	+0.020 (+0.51)	0.119 (3.02)	+0.020 (+0.51)	...	...
⅜	0.091 (2.31)	+0.020 (+0.51)	0.126 (3.20)	+0.020 (+0.51)	...	...
½	0.109 (2.77)	+0.020 (+0.51)	0.147 (3.73)	+0.020 (+0.51)	0.170 (4.32)	+0.020 (+0.51)
¾	0.113 (2.87)	+0.020 (+0.51)	0.154 (3.91)	+0.020 (+0.51)	0.170 (4.32)	+0.020 (+0.51)
1	0.133 (3.38)	+0.020 (+0.51)	0.179 (4.55)	+0.021 (+0.53)	0.200 (5.08)	+0.024 (+0.61)
1¼	0.140 (3.56)	+0.020 (+0.51)	0.191 (4.85)	+0.023 (+0.58)	0.215 (5.46)	+0.026 (+0.66)
1½	0.145 (3.68)	+0.020 (+0.51)	0.200 (5.08)	+0.024 (+0.61)	0.225 (5.72)	+0.027 (+0.68)
2	0.154 (3.91)	+0.020 (+0.51)	0.218 (5.54)	+0.026 (+0.66)	0.250 (6.35)	+0.030 (+0.76)
2½	0.203 (5.16)	+0.024 (+0.61)	0.276 (7.01)	+0.033 (+0.84)	0.300 (7.62)	+0.036 (+0.91)
3	0.216 (5.49)	+0.026 (+0.66)	0.300 (7.62)	+0.036 (+0.91)	0.350 (8.89)	+0.042 (+1.07)
3½	0.226 (5.74)	+0.027 (+0.68)	0.318 (8.08)	+0.038 (+0.96)	0.350 (8.89)	+0.042 (+1.07)
4	0.237 (6.02)	+0.028 (+0.71)	0.337 (8.56)	+0.040 (+1.02)	0.437 (11.10)	+0.052 (+1.32)
5	0.258 (6.55)	+0.031 (+0.79)	0.375 (9.52)	+0.045 (+1.14)	0.500 (12.70)	+0.060 (+1.52)
6	0.280 (7.11)	+0.034 (+0.86)	0.432 (10.97)	+0.052 (+1.32)	0.562 (14.27)	+0.067 (+1.70)
8	0.322 (8.18)	+0.039 (+0.99)	0.500 (12.70)	+0.060 (+1.52)	0.718 (18.24)	+0.086 (+2.18)
10	0.365 (9.27)	+0.044 (+1.12)	0.593 (15.06)	+0.071 (+1.80)	0.843 (21.41)	+0.101 (+2.56)
12	0.406 (10.31)	+0.049 (+1.24)	0.687 (17.45)	+0.082 (+2.08)	1.000 (25.40)	+0.120 (+3.05)
14	0.437 (11.10)	+0.053 (+1.35)	0.750 (19.05)	+0.090 (+2.29)	...	...
16	0.500 (12.70)	+0.060 (+1.52)	0.843 (21.41)	+0.101 (+2.57)	...	...
18	0.562 (14.27)	+0.067 (+1.70)	0.937 (23.80)	+0.112 (+2.84)	...	...
20	0.593 (15.06)	+0.071 (+1.80)	1.031 (26.19)	+0.124 (+3.15)	...	...
24	0.687 (17.45)	+0.082 (+2.08)	1.218 (30.94)	+0.146 (+3.71)	...	...

[A] The minimum is the lowest wall thickness of the pipe at any cross section. The maximum permitted wall thickness, at any cross section, is the minimum wall thickness plus the stated tolerance. All tolerances are on the plus side of the minimum requirement.

[B] These dimensions conform to nominal IPS dimensions, with the exception that Schedule 120 wall thickness for pipe sizes ½ to 3½ in. (12.5 to 87.5 mm), inclusive, are special PVC plastic pipe sizes.

ATTACHMENT D, 2/2

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Designation: D 1784 – 92

An American National Stan

Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[1]

This standard is issued under the fixed designation D 1784; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification covers rigid PVC and CPVC compounds intended for general purpose use in extruded or molded form, including piping applications involving special chemical and acid resistance or heat resistance, composed of poly(vinyl chloride), chlorinated poly(vinyl chloride), or vinyl chloride copolymers containing at least 80 % vinyl chloride, and the necessary compounding ingredients. The compounding ingredients may consist of lubricants, stabilizers, non-poly(vinyl chloride) resin modifiers, pigments and inorganic fillers.

NOTE 1—Selection of specific compounds for particular end uses or applications requires consideration of other characteristics such as thermal properties, optical properties, weather resistance, etc. Specific requirements and test methods for these properties shall be by mutual agreement between the purchaser and the seller.

1.2 Rigid PVC compounds intended for pipe, fittings and other piping appurtenances are covered in Specifications D 3915 and D 4396.

1.3 Rigid PVC compounds intended for building product applications are covered in Specification D 4216.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 The following safety hazards caveat pertains only to the test methods portion, Section 11, of this specification: *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 2—This specification is similar in content (but not technically equivalent) to ISO 1163-1:1985 and ISO 1163-2:1980.[2]

2. Referenced Documents

2.1 *ASTM Standards:*

D 256 Test Methods for Impact Resistance of Plastics and Electrical Insulating Materials[3]

D 471 Test Method for Rubber Property—Effect Liquids[4]

D 543 Test Method for Resistance of Plastics to Chemic Reagents[3]

D 618 Practice for Conditioning Plastics and Electric Insulating Materials for Testing[3]

D 635 Test Method for Rate of Burning and/or Extent a Time of Burning of Self-Supporting Plastics in a Ho zontal Position[3]

D 638 Test Method for Tensile Properties of Plastics[3]

D 648 Test Method for Deflection Temperature of Plasti Under Flexural Load[3]

D 790 Test Methods for Flexural Properties of Unrei forced and Reinforced Plastics and Electrical Insulatir Materials[3]

D 883 Terminology Relating to Plastics[3]

D 1600 Terminology for Abbreviated Terms Relating t Plastics[3]

D 1898 Practice for Sampling of Plastics[5]

D 1921 Test Methods for Particle Size (Sieve Analysis) c Plastic Materials[5]

D 3892 Practice for Packaging/Packing of Plastics[5]

D 3915 Specification for Poly(Vinyl Chloride) (PVC) an Related Plastic Pipe and Fitting Compounds for Pre sure Applications[7]

D 4216 Specification for Rigid Poly(Vinyl Chloride) (PVC and Related Plastic Building Products Compounds[7]

D 4396 Specification for Rigid Poly(Vinyl Chloride) (PVC and Related Plastic Compounds for Non-Pressure Pip ing Products[7]

D 5260 Classification for Chemical Resistance of Poly (Vinyl Chloride) (PVC) Homopolymer and Copolyme Compounds and Chlorinated Poly(Vinyl Chloride (CPVC) Compounds[6]

3. Terminology

3.1 *Definitions*—Definitions are in accordance with Defi nitions D 883 and abbreviations with Terminology D 160 unless otherwise indicated.

4. Classification

4.1 Means for selecting and identifying rigid PVC com

[1] This specification is under the jurisdiction of ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.15 on Thermoplastic Materials.

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[2] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 09.01.

[5] *Annual Book of ASTM Standards*, Vol 08.02.

[6] *Annual Book of ASTM Standards*, Vol 08.03.

[7] *Annual Book of ASTM Standards*, Vol 08.04.

ATTACHMENT E . 1/2

TABLE 1 Class Requirements for Rigid Poly(Vinyl Chloride) Compounds

NOTE—The minimum property value will determine the cell number although the maximum expected value may fall within a higher cell

Designation Order No.	Property and Unit	Cell Limits 0	1	2	3	4	5	6	7	8
1	Base resin	unspecified	poly(vinyl chloride) homopolymer	chlorinated poly(vinyl chloride)	vinyl copolymer					
2	Impact strength (Izod) min: J/m of notch	unspecified	<34.7	34.7	80.1	266.9	533.8	800.7		
	ft·lb/in. of notch		<0.65	0.65	1.5	5.0	10.0	15.0		
3	Tensile strength, min: MPa	unspecified	<34.5	34.5	41.4	48.3	55.2			
	psi		<5 000	5 000	6 000	7 000	8 000			
4	Modulus of elasticity in tension, min: MPa	unspecified	<1930	1930	2206	2482	2758	3034		
	psi		<280 000	280 000	320 000	360 000	400 000	440 000		
5	Deflection temperature under load, min, 1.82 MPa (264 psi): °C	unspecified	<55	55	60	70	80	90	100	110
	°F		<131	131	140	158	176	194	212	230
	Flammability	A	A	A	A	A	A	A	A	A

A All compounds covered by this specification when tested in accordance with Method D 635 shall yield the following results: average extent of burning of <25 mm; average time of burning of <10 s.

pounds are provided in Tables 1 and 2. The properties enumerated in Table 1 and the tests defined are expected to provide identification of the compounds selected. They are not necessarily suitable for direct application in design because of differences in shape of part, size, loading, environmental conditions, etc.

4.2 Classes are designated by the cell number for each property in the order in which they are listed in Table 1 including a suffix letter specifying the requirements for chemical resistance, as shown in Table 2.

NOTE 3—The chemical resistance requirements in Table 2 are included to provide identification of the compounds selected. They are not necessarily suitable for rating of application chemical resistance.

NOTE 4—The manner in which selected materials are identified by this classification system is illustrated by a Class 12454-B rigid PVC compound having the following requirements (see Tables 1 and 2):

Class 1 2 4 5 4 B

Identification:
- Poly(vinyl chloride) homopolymer — 1
- *Property and Minimum Value:*
- Impact strength (Izod) (34.7 J/m (0.65 ft·lbf/in.)) — 2
- Tensile stength (48.3 MPa (7000 psi)) — 4
- Modulus of elasticity in tension (2758 MPa (400 000 psi)) — 5
- Deflection temperature under load (70°C (158°F)) — 4
- Chemical resistance (meets the requirements of Suffix B in Table 2) — B

NOTE 5—The cell-type format provides the means for identification and close characterization and specification of material properties, alone or in combination, for a broad range of materials. This type format, however, is subject to possible misapplication since unobtainable property combinations can be selected if the user is not familiar with commercially available materials. The manufacturer should be consulted.

4.3 Type and grade number designations have been widely used to define the minimum physical properties and chemical resistance requirements of certain commercial classes of rigid PVC compounds. Table X1.1 in the Appendix lists these type and grade numbers and the corresponding class numbers selected from Table 1 and 2. The classes for previous types and grades of poly(vinyl chloride vinyl acetate) compounds are listed in Table X2.1 in the Appendix.

4.4 Product application chemical resistance when specified shall be classified according to the Classification Section of Classification D 5260.

5. Ordering Information

5.1 The purchase order, or inquiry for these materials, shall state the specification number and identify the class selected, for example, D 1784, Class 12454-B.

5.2 Further definition, as may be required for the fol-

TABLE 2 Suffix Designation for Chemical Resistance

Solution	A	B	C	D
H_2SO_4 (93 %)—14 days immersion at 55 ± 2°C:				
Change in weight:				
Increase, max, %	1.0A	5.0A	25.0	NAB
Decrease, max, %	0.1A	0.1A	0.1	NA
Change in flexural yield strength:				
Increase, max, %	5.0A	5.0A	5.0	NA
Decrease, max, %	5.0A	25.0A	50.0	NA
H_2SO_4 (80 %—30 days immersion at 60 ± 2°C:				
Change in weight:				
Increase, max, %	NA	NA	5.0	15.0
Decrease, max, %	NA	NA	5.0	0.1
Change in flexural yield strength:				
Increase, max, %	NA	NA	15.0	25.0
Decrease, max, %	NA	NA	15.0	25.0
ASTM Oil No. 3—30 days immersion at 23°C:				
Change in weight:				
Increase, max, %	0.5	1.0	1.0	10.0
Decrease, max, %	0.5	1.0	1.0	0.1

A Specimens washed in running water and dried by an air blast or other mechanical means shall show no sweating within 2 h after removal from the acid bath.

B NA = not applicable.

ATTACHMENT E, 2/2

Physical Properties of Harvel Rigid PVC & CPVC Pipe

Properties	ASTM Test Method	PVC 1120 (Normal Impact)	PVC 2110 (Hi Impact)	Harvel CPVC 4120
Mechanical				
Specific Gravity, g/cm³	D792	1.40 ± .02	1.37 ± .02	1.55 ± .02
Tensile Strength at 73° F psi	D638	7,450	6,400	8,000
Modulus Elasticity In Tension, psi at 73° F	D638	420,000	385,000	360,000
Compressive Strength, psi at 73° F	D695	9,600	8,600	9,000
Flexural Strength at 73° F psi	D790	14,450	11,850	15,100
Izod Impact, ft. lb./in. notch at 73° F	D256	.75	10.9	1.5
Hardness Durometer D	D2240	82 ± 3	78 ± 3	–
Hardness Rockwell R	D785	110 - 120	–	119
Thermal				
Coefficient of Thermal Conductivity $\frac{(Cal.)\,(cm)}{(cm^2)\,(sec.)\,(^\circ C)} \times 10^{-4}$	C177	3.5	4.5	0.96
Coefficient of Linear Expansion	D696			
x 10^{-5} cm/cm °C		5.2	9.9	6.2
x 10^{-5} in/in °F		2.9	5.5	3.4
Heat Distortion Temperature, °F at 264 psi	D648	170	145	217
Specific Heat, Cal./°C/gm	D2766	0.25	0.25	–
Upper Service Temp. Limit °F		140	140	200
Flammability				
Average Time of Burning (sec.)	D635	<5	<5	<5
Average Extent of Burning (mm)		<10	<15	<10
Flame Spread Index	E162	<10	–	<10
Flame Spread	E84	10-25	–	4-18
Flash Ignition		730°F	–	900°F
Smoke Developed*		600-1000	–	9-169
Flammability (.062")	UL-94	V-O	–	V-O, 5VB, 5VA
Softening Starts, approx. °F		250	–	295
Material Become Viscous, °F		350	–	395
Material Carbonizes, °F		425	–	450
Limiting Oxygen Index (LOI)				60
Electrical				
Dielectric Strength, volts/mil	D149	1,413	1,085	1,250
Dielectric Constant	D150			
60 cps at 30°C		3.70	3.90	–
1000 cps at 30°C		3.62	3.31	–
Power Factor %	D150			
60 cps at 30°C		1.25	2.85	–
1000 cps at 30°C		2.62	3.97	–
Volume Resistivity at 95°C, ohms/cm/10^{12}		1.2	2.4	–
Harvel Rigid Pipe is non-electrolytic.				
Other Properties				
Water Absorption, % Increase– 24hrs. at 25°C	D570	0.05	0.10	0.03
Light Transmission	E308	Opaque	Opaque	–
Light Stability		Excellent	Excellent	–
Effect of Sunlight		Slight Darkening	Slight Darkening	–
Color (Standard)		Dark Grey	Light Grey	Medium Grey
Material Cell Classification				
ASTM D1784		12454-B	16334-D	23447-B
ASTM D3915		12452-4	14341-1	23444-4

ASTM D1784 and D3915 refer to similar compounds. The major difference is that the alphabetical sixth place designation refers to corrosion resistance under ASTM D1784, and the sixth place designation under D3915 refers to the hydrostatic design stress. In addition, D3915 also places upper limits for values in the second through the fifth place designations.

*Tests performed on pipe sizes 3/4" - 4" with a single pipe exposed each test. Some of the CPVC pipes were water filled and these resulted in the lower smoke development values.

NOTE: Harvel CPVC pipe is extruded from Corzan™ CPVC compounds manufactured by BF Goodrich Specialty Polymers and Chemicals Division.

HARVEL PLASTICS MANUFACTURER DOCUMENTATION

ATTACHMENT F, 1/1

be small compared to the pressure due to the fill, the vertical pressure on the top of the pipe can be assumed to be equal to the unit weight of the refuse fill multiplied by the distance from top of fill to top of pipe, thus:

$$\sigma_v = (\omega_f)(H_f).$$

V.2.2.3 Perforated Pipe

Perforations will reduce the effective length of pipe available to carry loads and resist deflection. The effect of perforations can be taken into account by using an increased load per nominal unit length of the pipe. If l_p equals the cumulative length in inches of perforations per foot of pipe, the increased vertical stress to be used equals:

$$(\sigma_v)\text{design} = \frac{12}{12-l_p} \times (\sigma_v)\text{actual}$$

REFERENCE: EPA, MANUAL SW-8 "LINING OF WASTE IMPOUNDMENT AND DISPOSAL FACILITIES". SEPTEMBER 1980

Attachment G 1/1

Geosyntec consultants

COMPUTATION COVER SHEET

Client:	**Energy Fuels**	Project:	**White Mesa Mill – Cells 5A and 5B**	Project/ Proposal No.:	**SC0634**
				Task No.	**02**

Title of Computations **PUNCTURE EVALUATION**

Computations by:	Signature	[signature]	12/18/12 Date
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature	[signature]	12/20/12 Date
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations Checked by:	Signature	[signature]	12/20/12 Date
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations backchecked by: (originator)	Signature	[signature]	12/18/12 Date
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature	[signature]	12/18/12 Date
	Printed Name	Gregory Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/10/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

PUNCTURE EVALUATION
WHITE MESA MILL
BLANDING, UTAH

OBJECTIVE

The project involves placement of a triple liner system for the base of Cells 5A and 5B at the White Mesa Mill in Blanding, Utah. The proposed liner system is shown in Attachment A. The objective of this calculation is to evaluate the maximum particle sizes of soil/aggregate materials adjacent to the geomembrane that will not puncture or damage the geomembrane.

SUMMARY OF ANALYSIS

The analyses suggest that the following maximum particle sizes and geotextile mass per unit areas will be required:

Component of Liner	Maximum Particle Size (in)	Maximum Protrusion Height (in)	*Cushion Material*
Slimes drain system over geomembrane	1	N/A	16 oz/yd^2
Leak detection system (LDS) over geomembrane	1	N/A	16 oz/yd^2
Geomembrane over prepared subgrade	N/A	0.7	N/A

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client: EF		Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

SITE CONDITIONS

The proposed triple liner system will be comprised of the following components on the side slopes, from top to bottom:

- primary 60-mil smooth HDPE geomembrane;
- secondary 60-mil HDPE Drain Liner® geomembrane;
- tertiary 60-mil HDPE Drain Liner® geomembrane; and
- prepared subgrade.

On the cell bottom the proposed triple liner system with be comprised of the following components, from top to bottom:

- primary 60-mil smooth HDPE geomembrane;
- 300-mil geonet
- secondary 60-mil smooth HDPE geomembrane;
- tertiary 60-mil HDPE Drain Liner® geomembrane; and
- prepared subgrade.

The slimes drain header pipe will be placed on top of the primary geomembrane with cushion geotextile and drainage aggregate placed above (Attachment A). Two Leak Detection Systems (LDS) will be installed (1) between the primary geomembrane and the secondary geomembrane and (2) between the secondary geomembrane and tertiary geomembrane (Attachment A). The LDS will consist of a PVC pipe surrounded by aggregate and wrapped in a 16 oz/yd^2 geotextile. The tertiary geomembrane will be installed over prepared subgrade.

The tailings deposits are anticipated to be similar to silt with an average maximum wet unit weight of 125 pounds per cubic foot (pcf) (See slope stability calculation for this value). For conservatism, we have assumed that a maximum of 43 ft of tailing deposits plus 9 feet of cover soil may be present. Therefore, the design overburden pressure is 52 ft × 125 pcf = 6,500 pounds per square foot (psf) or 311 kilopascals (kPa).

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

APPROACH

LDS Trenches

The geomembranes will be under- and/or over-lain by a nonwoven cushion geotextile to protect against puncture from the underlying and/or overlying LDS gravel. The approach by Koerner (1997) was used to evaluate the required properties of the cushion geotextile. According to this approach, the important parameters that affect the puncture protection of geomembranes are: overlying pressure, mass per area of the geotextile, and the particle size and shape of the material overlying the geotextile. For the analysis herein, the overlying pressure and the mass per unit area of the geotextile are given and the maximum particle size is evaluated for the geotextile.

Subgrade and Geomembrane

The tertiary geomembrane will be installed directly on the prepared subgrade. Evaluation of the maximum allowable particle size for the soil materials located directly against these geomembranes is calculated using the methods presented in Giroud et al. (1995). According to the analysis by Giroud et al. (1995), a relationship can be made between the failure strength of a geomembrane in a laboratory probe test and the failure pressure of a geomembrane in the field when loaded by a water pressure. Attachment C presents portions of the Giroud et al. (1995) paper for use herein.

ANALYSES

LDS Trenches and Slimes Drain Header Pipe

Narejo et al. (1996, Attachment B) present the following equation for evaluating geotextile puncture protection of 60 mil (1.5 mm) HDPE geomembrane:

$$H^2 = \frac{450M_A}{P_{allow}} \qquad \text{(Attachment B)}$$

where:

H = cone height (mm), which corresponds to predicted effective protrusion height, which equals one-half maximum stone size.

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/10/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

M_A = mass per unit area geotextile (g/m^2)

= 16 oz/yd^2 = 542 g/m^2 (slimes drain and LDS)

P_{allow} = maximum long term allowable pressure

where: $P_{allow} = P'_{allow}(MF_S \times MF_{PC} \times MF_A)(FS_{CR} \times FS_{CBD})$ (Attachment B)

where: MF_S, MF_{PC}, MF_A = modification factors (discussed below)

FS_{CR}, FS_{CBD} = partial factor of safety values (discussed below)

P'_{allow} = allowable pressure on geomembrane

$= (FS)(P_{actual\,field\,pressure})$ (Attachment B)

where: FS = global factor of safety, 3.0 (Attachment B)

$P_{actual\ field\ pressure}$ = 311 kPa

P'_{allow} = (311)(3) = 933 kPa

MF_S = shape factor: (Attachment B)

1.0 (assume angular particles)

MF_{PC} = protrusion configuration: (Attachment B)

1.0 (assume isolated protrusions)

MF_A = soil arching: (Attachment B)

1.0 (assume none)

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

FS_{CR} = partial factor of safety for creep: (Attachment B)
for H>12 mm, $FS_{CR} = 1.3$

FS_{CBD} = partial factor of safety for chemical and biological degradation: (Attachment B)
1.5 (based on aggressive environment for polypropylene geotextiles in LDS and slimes drain)

Solving for P_{allow} provides:

$$P_{allow} = (933)\,(1.0 \times 1.0 \times 1.0)\,(1.3 \times 1.5)$$

$$P_{allow} = 1{,}820 \text{ kPa}$$

Solving for H, the predicted effective protrusion height, provides:

$$H^2 = \frac{450 M_A}{P_{allow}}$$

$$H_{cushion} = \left(\frac{450(542)}{1820}\right)^{1/2} = 11.6 \text{ mm} = 0.5 \text{ in}$$

The predicted effective protrusion height equals one half the maximum stone size. Therefore, the maximum stone size for the gravel to be placed around the slimes drain and in the LDS is 2 × 0.5 inches, or 1.0 inches. We recommend the maximum particle size for construction be 1 inch for the slimes drain and LDS.

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/10/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

Subgrade and Geomembrane

Giroud's equation (Giroud et al. 1995) is used to calculate the maximum subgrade protrusion height. The relationship is as follows (Attachment C)

$$\frac{\lambda \times d_{s,round} \times P_p}{t_{GMs}} = \frac{F_p \times Z_{\varepsilon Peak}}{d_p \times t_{GMp}}$$

where: λ = term that characterizes the stone arrangement
= 0.87 for densely packed stones (Attachment C)

$d_{s,\,round}$ = the stone size **[to be solved]**

P_p = field pressure, kPa
= 311 kPa

$Z_{\varepsilon Peak}$ = 0.749, function of ε defined by
$\varepsilon = \frac{\sin^{-1} Z_\varepsilon}{Z_\varepsilon} - 1$; ε=strain at yield, 13% (Attachment D)

$t_{GM,s}$ = t_{GMp} = thickness of the geomembrane in the application and the probe test, respectively
= 1.5 mm (60 mil)

F_p = 95 lb = 422 N, puncture resistance as reported for 60-mil HDPE geomembrane (Attachment D)

F_p' = $\frac{F_p}{\sum FS}$ where $\sum FS = FS_{cr} \times FS_{id} \times FS_{cd} \times FS_{bd}$
Factor of Safety for Creep, FS_{cr} = 1.5

Factor of Safety for Installation Damage, FS_{id} = 2.0

Factor of Safety for Chemical Degradation, FS_{cd} = 2.0

Factor of Safety for Biological Degradation, FS_{bd} = 1.0

F_p' = $\frac{422\ N}{1.5 \times 2 \times 2 \times 1}$ = 70 N

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/10/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

d_p = diameter of probe
= 8 mm used in laboratory puncture test according to ASTM D 4833

Therefore, solving Giroud's equation from above:

$$d_{s,round} = \frac{F_p \times Z_{\varepsilon Peak} \times t_{GMS}}{d_p \times \lambda \times P_p}$$

$$d_{s,round} = \frac{70\ N \times 0.749 \times 1.5mm}{8mm \times 0.87 \times 311kPa}$$

$d_{s,round}$ = 36 mm = 1.40 in.

Therefore, the maximum particle size of the subgrade should be 1.4 in. A maximum protrusion size of 0.7 in. will be specified for the subgrade.

NOTE TO TECHNICAL SPECIFICATIONS

For practical construction and CQA purposes, the calculated maximum particle sizes and protrusion heights of the soil components of the liner are rounded down to a convenient magnitude. The subgrade will be rolled and compacted; therefore, the maximum protrusion height (instead of maximum particle size) is required for the technical specifications. The specifications should reflect the following information:

Soil Component of Liner	Maximum Protrusion Height (in.)	Maximum Particle Size (in.)
Drainage aggregate	N/A	1
Prepared subgrade	0.7	N/A

Written by:	R. Flynn	Date:	11/7/12	Reviewed by:	G. Corcoran	Date:	12/8/12
Client:	EF	Project:	Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

REFERENCES

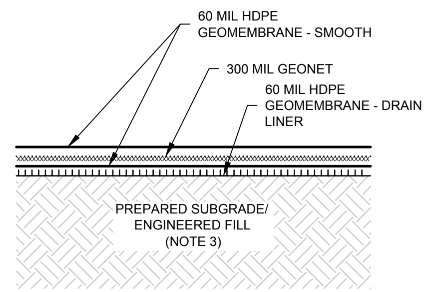
Agru Product Data: High Density Polyethylene Drain Liner

Giroud, J.P., Badu-Tweneboah, K., and Soderman, K.L. (1995) "Theoretical Analysis of Geomembrane Puncture," Geosynthetics International, Vol. 2, No. 6, pp.1019-1048

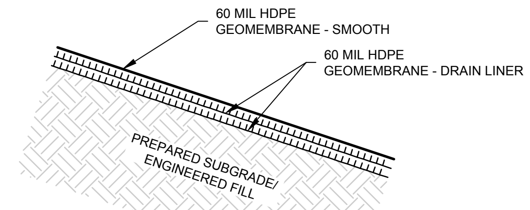
Koerner, R.M., Wilson-Fahmy, R.F. and Narejo, D. (1996) "Puncture Protection of Geomembranes Part III: Examples", Geosynthetics International, Vol. 3, No. 5, pp. 655-675.

Narejo, D., Koerner, R.M. and Wilson-Fahmy, R.F. (1996) "Puncture Protection of Geomembranes Part II: Experimental", Geosynthetics International, Vol. 3, No. 5, pp. 629-653.

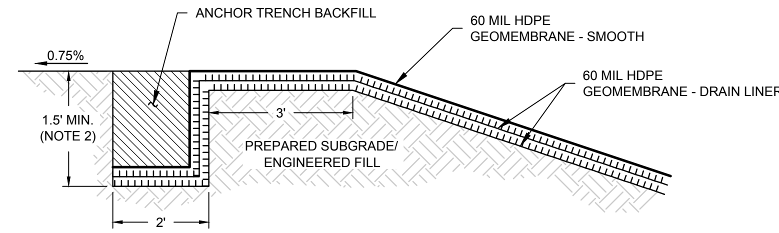
Wilson-Fahmy, R.F., Narejo, D., and Koerner, R.M. (1996) "Puncture Protection of Geomembranes Part I, Theory", Geosynthetics International, Vol. 3, No. 5, pp. 605-628.



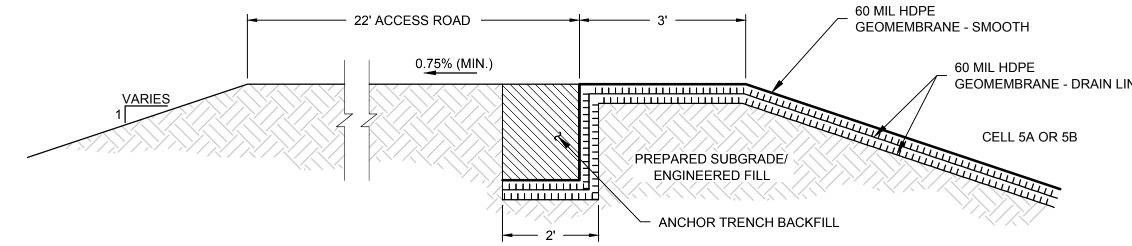
9 DETAIL
03A,03B,04A,04B BASE LINER SYSTEM
SCALE: 1" = 2'



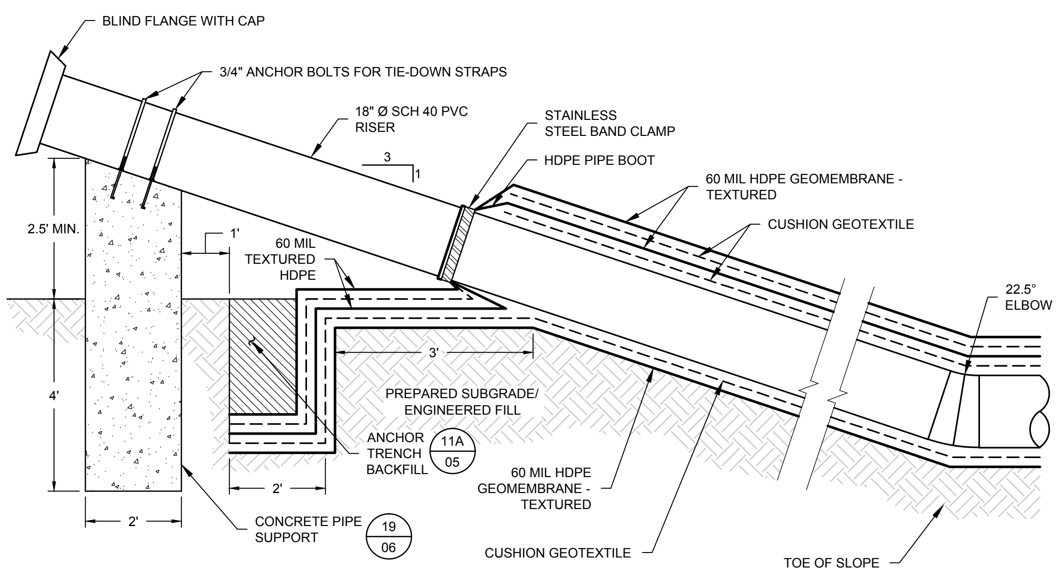
10 DETAIL
03A,03B,04A,04B SIDE SLOPE LINER SYSTEM
SCALE: 1" = 2'



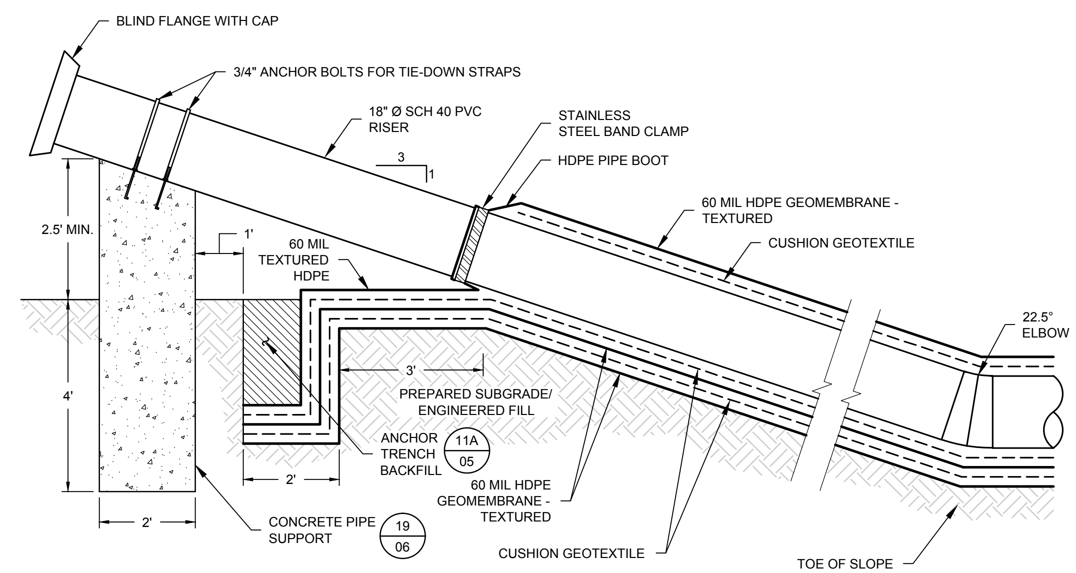
11A DETAIL
03A,03B,04A,04B,05,06,09 ANCHOR TRENCH
SCALE: 1" = 2'



11B DETAIL
03A,03B ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



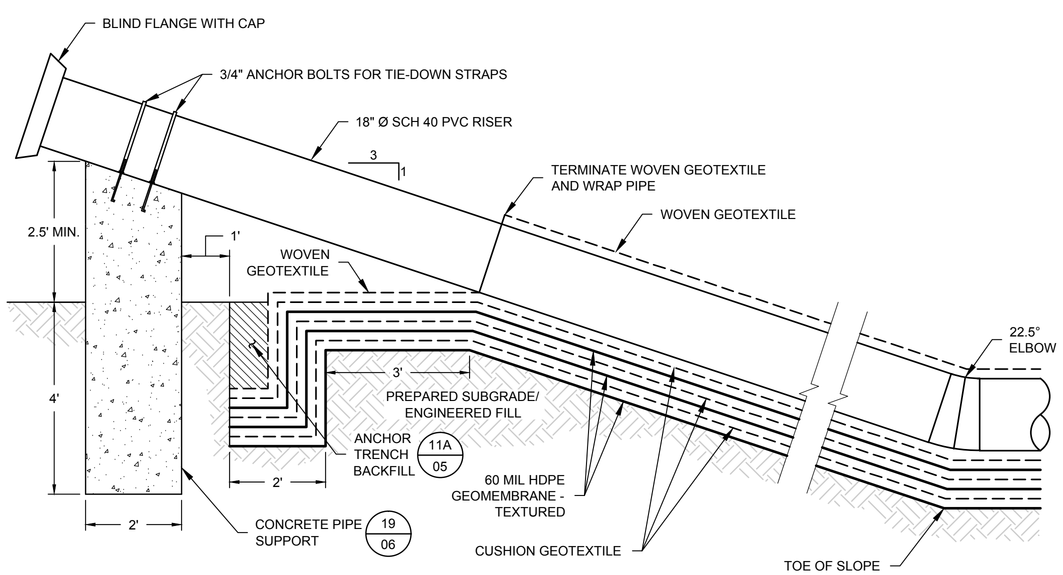
12 DETAIL
04A,04B SECONDARY LEAK DETECTION RISER PENETRATION
SCALE: 1" = 2'



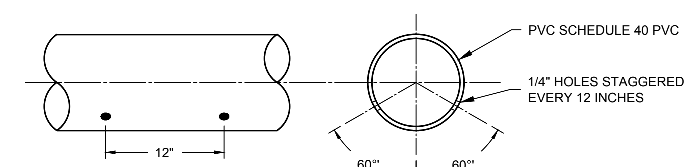
13 DETAIL
04A,04B PRIMARY LEAK DETECTION SYSTEM RISER PENETRATION
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY.
2. ANCHOR TRENCHES MAY BE CONSTRUCTED WITH A MAXIMUM DEPTH OF 3.5 FEET WITH UP TO 1 FOOT OF BACKFILL BETWEEN EACH GEOMEMBRANE IN BOTTOM OF ANCHOR TRENCH.
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS. ALL LOOSE (BLASTED OR RIPPED) SOIL AND ROCK SHALL BE REMOVED TO EXPOSE COMPETENT SOIL / ROCK PRIOR TO PLACING ENGINEERING FILL.



14 DETAIL
04A,04B SLIMES DRAIN RISER PENETRATION
SCALE: 1" = 2'



15 DETAIL
07,08 PERFORATED PIPE
SCALE: 1" = 1'

Attachment A (1/2)

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc.

TITLE: LINER SYSTEM DETAILS I

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

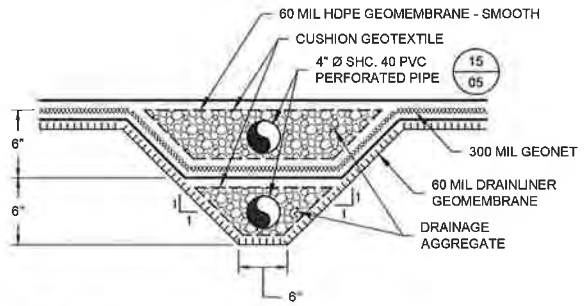
DATE

DESIGN BY:	GTC	DATE:	JANUARY 2013
DRAWN BY:	MMC	PROJECT NO.:	SC0634
CHECKED BY:	RBF	FILE:	SC0634-05-07
REVIEWED BY:	GTC	DRAWING NO.:	05 OF 10
APPROVED BY:	GTC		

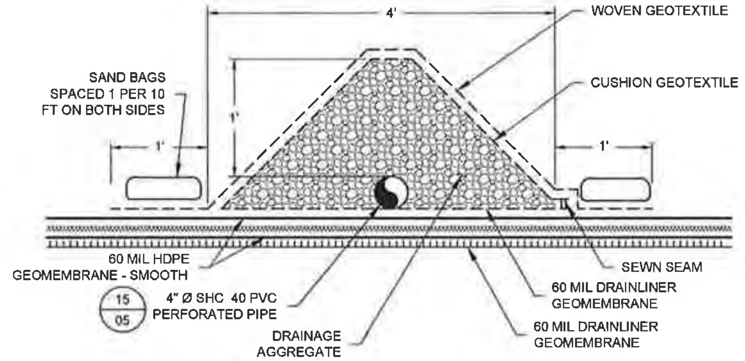
PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

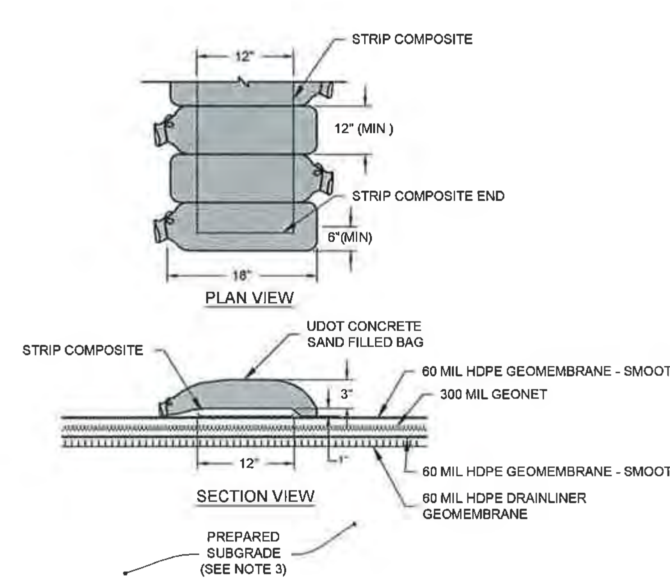
P:\PRJ\SDCadd\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634-05-07.dwg Last Edited by: MikeC on 12/21/2012 9:51 AM



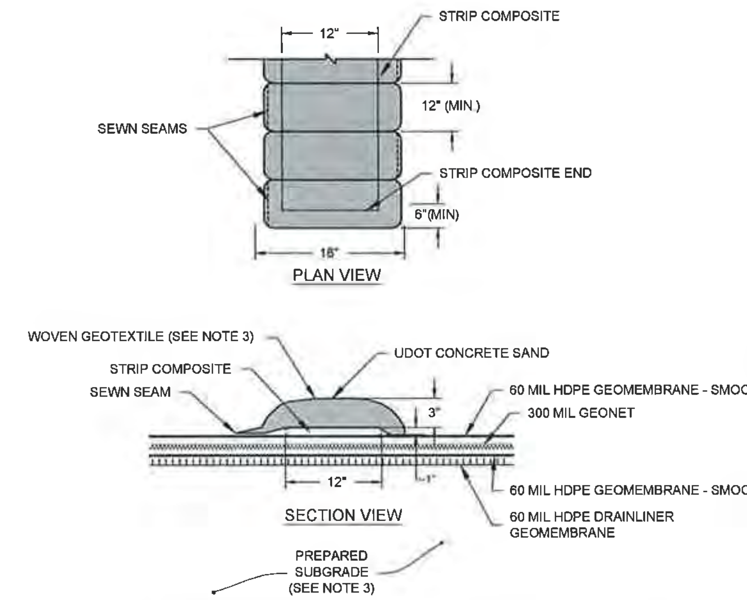
16 DETAIL
04A,04B LEAK DETECTION SYSTEM TRENCHES
SCALE: 1" = 1'



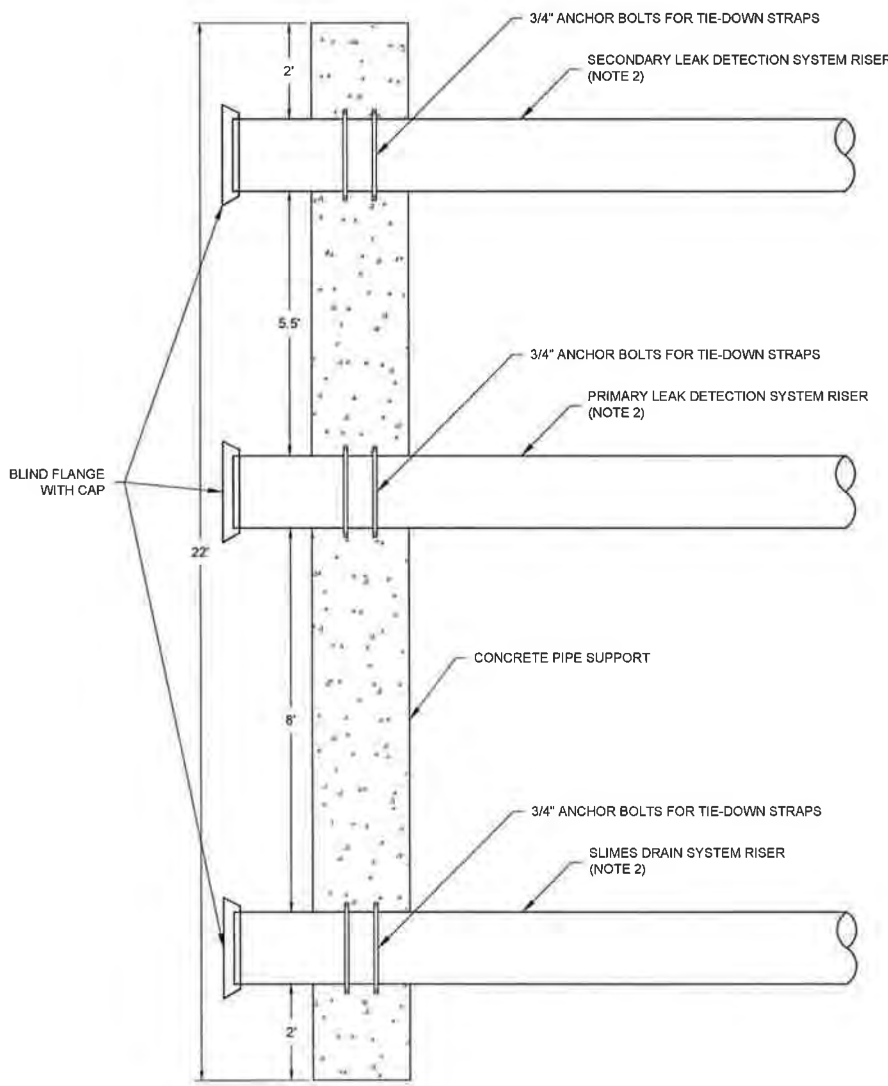
17 DETAIL
04A,04B SLIMES DRAIN HEADER
SCALE: 1" = 1'



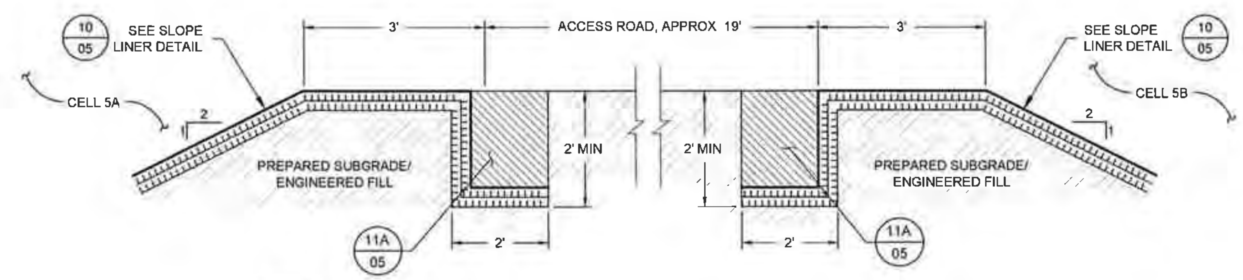
18A DETAIL
04A,04B SLIMES DRAIN LATERAL - OPTION 1
SCALE: 1" = 1'



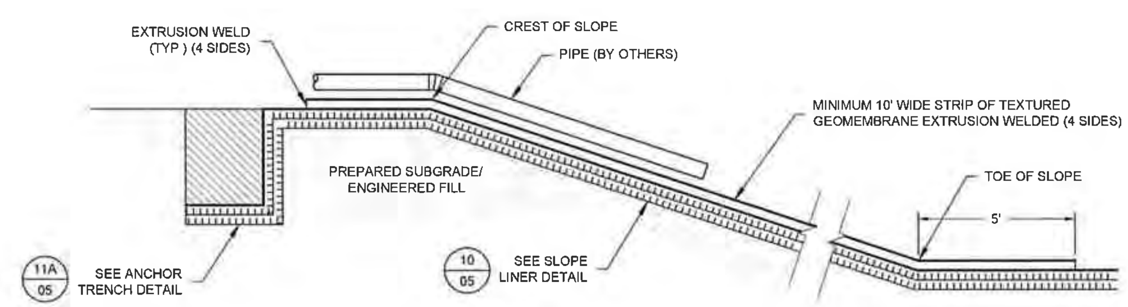
18B DETAIL
04A,04B SLIMES DRAIN LATERAL - OPTION 2
SCALE: 1" = 1'



19 DETAIL
03A,03B,04A,04B CONCRETE PIPE SUPPORT
SCALE: 1" = 2'



20 DETAIL
03A,03B,04A,04B CELL 5A - CELL 5B ACCESS ROAD & ANCHOR TRENCH
SCALE: 1" = 2'



21 DETAIL
03A,03B,04A,04B SPLASH PAD DETAIL
SCALE: 1" = 2'

NOTES:

1. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY
2. EXPOSED PVC PIPE SHALL BE PAINTED TO MINIMIZE DAMAGE DUE TO UV
3. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF FILL OVERLYING SANDSTONE IN ACCORDANCE WITH SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATION

ATTACHMENT A (2/2)

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858 674 6559

Energy Fuels Resources (USA) Inc

TITLE: LINER SYSTEM DETAILS II

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED

SIGNATURE

DATE

DESIGN BY	GTC	DATE	JANUARY 2013
DRAWN BY	MMC	PROJECT NO.	SC0834
CHECKED BY	RBF	FILE	SC0634-05-07
REVIEWED BY	GTC	DRAWING NO.	
APPROVED BY	GTC	06 OF 12	

(3in) (2in) (1in)
(1in) (2in) (3in) (4in)
SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

SIMPLIFIED DESIGN CHARTS FOR GEOMEMBRANE CUSHIONS

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ABSTRACT

Recent and ongoing research indicates that use of a properly selected nonwoven, needle-punched geotextile cushion adjacent to (above and/or below) a geomembrane can effectively protect it from construction and operational damage. The current practice selects an appropriate geotextile cushion using the Geosynthetic Research Institute (GRI) method (Koerner, et. al. 1996). This method was used to develop simplified design charts allowing quick, conservative selection of an appropriate geotextile cushion. Charts are provided for typical applications including solid waste landfills and liquid impoundments with varying load, subgrade and cover/subgrade soil conditions. In addition, a brief discussion of the design procedure is provided with completed numerical examples.

INTRODUCTION

Most solid and hazardous waste landfills, lagoons and reservoirs built today incorporate geomembranes to contain liquids. Although these low permeability liners have demonstrated excellent performance, they are susceptible to damage when drainage stone or alternate drainage media (such as shredded tires, crushed glass, etc.) are placed over them (Figure 1). In addition, geomembranes are prone to damage from isolated protrusions present in the subgrade onto which they are deployed.

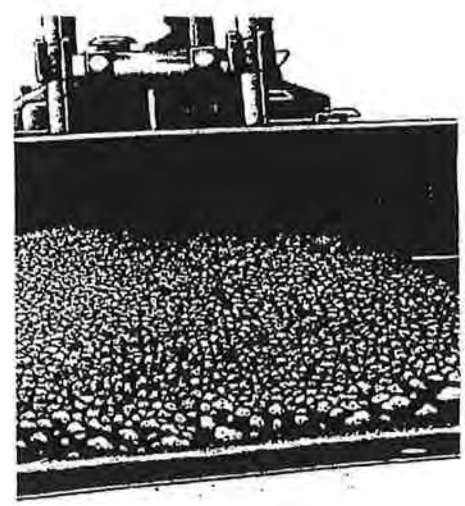

Figure 1. Stone Placement over a Geomembrane

Figure 2 illustrates the typical components of modern landfill liner system and Figure 3 represents a typical liquid impoundment liner system. Of these components, the geomembrane is the most prone to

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damage. Protecting the geomembrane from tearing or puncturing during construction and operation is critical. Recent and ongoing research indicates that deployment of a properly selected nonwoven, needle-punched geotextile cushion adjacent to (above and/or below) a geomembrane provides effective protection against damage.

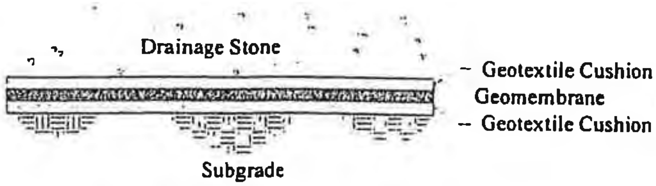

Figure 2. Typical Municipal Landfill Liner System

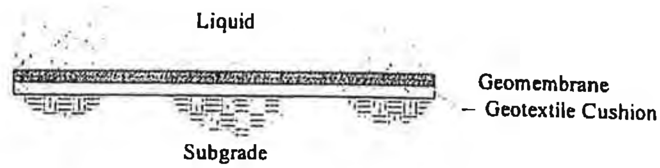

Figure 3. Typical Liquid Impoundment Liner System

STATE OF GEOMEMBRANE CUSHION DESIGN PRACTICE

State of geomembrane cushion design practice suggests using the generalized procedure developed by Koerner, et. al (1996) at the Geosynthetic Research Institute (GRI). The GRI method couples theoretical (Wilson-Fahmy, et. al., 1996) and empirical (Narejo, et. al., 1996) puncture protection analysis through use of a global factor of safety. The method directly applies to 1.5 mm (60 mil), smooth, high density polyethylene (HDPE) geomembranes protected by virgin polymer, nonwoven, needle-punched geotextiles. However, early work by Hullings and Koerner (1991) and field research by Richardson and Johnson (1998) indicate that the method may be conservative for geomembranes manufactured from more flexible polymers. Koerner, et. al. (1996) also suggest that the GRI method may be extended to other types of cushion materials.

The governing equation (Equation 1) incorporates several simplifying assumptions. For extrapolation to field design, (at least partially) subjective modification/reduction factors are required. In addition, laboratory testing used to develop the model did not incorporate dynamic loading. Therefore, the GRI method is considered adequate in cases where uniform, normal, static loading controls the design (i.e. moderate to high waste fills and most liquid impoundments) and may be under-conservative in cases where construction (dynamic) loading controls (i.e. shallow waste fills, poor construction practices, etc.). Based on field evaluation of geosynthetic cushions under construction loading, Richardson (1996) recommends modification of the GRI method such that the minimum nonwoven geotextile cushion mass selected is 405 g/m^2 (12 oz/yd^2) for 2.5 cm (1 in) maximum gravel over smooth HDPE geomembranes. This recommendation was later extended to 1.3 cm (0.5 in) gravel through additional field testing (Richardson and Johnson, 1998). Reddy et. al. (1996) performed similar field evaluations and concluded that a lighter 270 g/m^2 (8 oz/yd^2) geotextile is capable of providing adequate protection against construction loading. Based on laboratory testing, Reddy and Saichek (1998) also concluded that a 270 g/m^2 (8 oz/yd^2) may provide acceptable long-term protection under specific conditions.

Although a comprehensive review of previous research is beyond the scope of this paper, the reader is encouraged to read and understand the referenced literature prior to application or modification of the GRI method. This methodology (that forms the basis for the simplified design charts presented later in this paper) is summarized in the following steps.

Step 1: Estimate the Allowable Pressure on the Geomembrane (in terms of M_A)

$$P'_{allow} = \left(450 \cdot \frac{M_A}{H^2}\right)\left(\frac{1}{MF_S \cdot MF_{PC} \cdot MF_A}\right)\left(\frac{1}{FS_{CR} \cdot FS_{CBD}}\right) \qquad \text{(Equation 1)}$$

Where:

P'_{allow} = Allowable pressure on geomembrane (kPa)
450 = Empirical constant ($kPa \cdot mm^2/(g/m^2)$)
M_A = Required mass per unit area of nonwoven, needle-punched geotextile (g/m^2)
H = Effective height of protrusion (mm)
MF_S = Modification factor for protrusion shape (dimensionless)
MF_{PC} = Modification factor for protrusion configuration (dimensionless)
MF_A = Modification factor for overburden arching effect (dimensionless)
FS_{CR} = Factor of safety for geotextile creep (dimensionless)
FS_{CBD} = Factor of safety for geotextile chemical/biological degradation (dimensionless)

Equation 1 should be solved in terms of M_A. The effective height of protrusion (H) represents the maximum height of any object in contact with the geomembrane extends relative to the overlying/underlying media. In cases where protection is sought from uniformly packed stones (such as landfill leachate collection/drainage media), H may be estimated as one-half the maximum particle diameter of the stones. However, when protection is sought from isolated protrusions (such as stones encountered in a hastily prepared subgrade), H may be estimated as the maximum particle diameter of the protrusions. In the later case, the value of H may be based on observed conditions, or specified by restricting the largest particle size allowed to remain on the prepared subgrade during geosynthetic deployment. Modification Factors for protrusion shape, protrusion configuration, and overburden arching effect may be selected based on guidelines presented by Narejo, et. al (1996):

Table 1. Recommended Modification Factor for Protrusion Shape
(Adapted from Narejo, et. al., 1996, page 647)

Protrusion Shape	Modification Factor, MF_S
Angular	1.00
Subrounded	0.50
Rounded	0.25

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Table 2. Recommended Modification Factor for Protrusion Configuration
(Adapted from Narejo, et. al., 1996, page 647)

Protrusion Configuration	Modification Factor, MF_{PC}
Isolated Protrusions	1.00
Uniformly Packed Surface	0.50

Table 3. Recommended Modification Factor for Overburden Arching Effect
(Adapted from Narejo, et. al., 1996, page 648)

Anticipated Arching Effect	Modification Factor, MF_A
None (i.e. Liquid Overburden)	1.00 ←
Moderate	0.50
Maximum	0.25

Through limited creep testing, Narejo, et. al. (1996) indicated that geotextile cushion creep is primarily a function of H and M_A. Since M_A is unknown at this point, Equation 1 may be solved by assuming a reasonable value for FS_{CR} based on the anticipated M_A required. Following completion of the required calculations, the assumed value of FS_{CR} must be checked for validity. Table 4 provides recommended FS_{CR} values in the form of unique linear equations for several commonly available nonwoven, needle-punched geotextiles. It is interesting to note that the recommended upper limit with respect to H, is in general agreement (probably by coincidence) with construction limits established by Richardson (1996) and Reddy and Saichek (1996). The equations for FS_{CR} and their range of validity were interpolated/extrapolated from available geotextile cushion creep test data (Narejo, et. al., 1996).

Table 4. Factor of Safety for Geotextile Creep
(Adapted from Narejo, et. al., 1996, page 644 - 648)

Nonwoven, Needle-punched Geotextile Mass per Unit Area	Factor of Safety, FS_{CR}
270 g/m^2 (N/R for H > 12 mm)	$\approx 0.0417 \cdot H + 1.25$ ←
405 g/m^2 (N/R for H > 19 mm)	$\approx 0.0292 \cdot H + 1.18$
540 g/m^2 (N/R for H > 25 mm)	$\approx 0.0166 \cdot H + 1.11$
675 g/m^2 (N/R for H > 29 mm)	$\approx 0.0139 \cdot H + 1.08$
745 g/m^2 (N/R for H > 31 mm)	$\approx 0.0129 \cdot H + 1.07$
810 g/m^2 (N/R for H > 32 mm)	$\approx 0.0119 \cdot H + 1.06$
945 g/m^2 (N/R for H > 35 mm)	$\approx 0.0100 \cdot H + 1.03$
1015 g/m^2 (N/R for H > 36 mm)	$\approx 0.0089 \cdot H + 1.02$
1080 g/m^2 (N/R for H > 38 mm)	$\approx 0.0080 \cdot H + 1.00$

NOTE: N/R = Not recommended

The factor of safety for chemical and biological degradation (FS_{CBD}) should be selected based on the aggressiveness of the anticipated chemical environment and the geotextile polymer composition. Table 5 provides general recommendations:

Table 5. Recommended Factor of Safety for Chemical and Biological Degradation (based on Koerner, 1994, page 151 and Synthetic Industries, 1997)

Chemical Environment	Factor of Safety for Chem/Bio Degradation, FS_{CBD}	
	Polyester (PET) Geotextiles	Polypropylene (PP) Geotextiles
Normal (i.e. 3 < pH < 10)	1.0	1.0
Aggressive (pH <3 or pH > 10)	1.5 – 2.0	1.0 – 1.5

Step 2: Estimate the Anticipated Pressure on the Geomembrane

$$P_{actual} = \gamma \cdot h \qquad \text{(Equation 2)}$$

Where:

γ = Unit weight of overburden material or liquid (kN/m^3)
h = Design height of overburden material or liquid depth (m)
P_{actual} = Estimated maximum pressure on geomembrane (kPa)

The parameters required to complete Equation 2 may be assumed or specified based on site specific considerations. The unit weight of typical municipal solid waste may be estimated to equal 12.56 kN/m^3 (80 lb/ft^3) in the absence of site specific data. Likewise, the unit weight of most liquids can be approximated by the unit weight of water, 9.81 kN/m^3 (62.4 lb/ft^3).

In some cases (i.e. shallow waste fills, poor construction practices, etc.), the dynamic forces associated with construction loading may exceed those associated with long-term static loading. The exact point at which this occurs is dependent on multiple variables and difficult (if not impossible) to estimate. Therefore, caution should be exercised in selection of a geotextile cushion having a mass per unit area less than 405 g/m^2 (12 oz/yd^2), the construction limit recommended by Richardson and Johnson (1998).

Step 3: Calculate the Required Mass per Unit Area of the Cushion Geotextile

$$P'_{allow} \geq FS_{g\,min} \cdot P_{actual} \qquad \text{(Equation 3)}$$

Where:

P'_{allow} = Allowable pressure on geomembrane in terms of M_A (Equation 1)
FS_{gmin} = Global Factor of Safety (dimensionless)

Equation 3 may be solved for M_A through substitution (Equation 1 and 2 results) and algebraic manipulation. The global factor of safety (FS_{gmin}) should be selected based on the protrusion configuration and H. Recommendations are provided in Table 6.

Table 6. Recommended Global Factor of Safety
(Adapted from Koerner, et. al., 1996, page 648)

Protrusion Configuration	Global Factor of Safety, FS_{gmin}
Isolated Protrusions	$= 0.22 \cdot H + 1.77$ (≥ 3.0)
Uniformly Packed Surface	3.0

Step 4: Select Appropriate Geotextile Cushion

Select a nonwoven, needle-punched geotextile having a minimum average roll value (MARV) M_A greater than or equal to that calculated in Step 3. It should be noted that the method presented herein is based on limited testing (Narejo, et. al, 1996) using virgin polymer, nonwoven, needle-punched geotextile and may not apply to all types of geotextiles and cushion materials.

Step 5: Check Assumed Value of FS_{CR} and Construction Limits

In Step 1, FS_{CR} was assumed to allow solution of Equation 1. Check Table 4 to ensure that the assumed value is valid for the geotextile selected in Step 4 (If not, revise FS_{CR} and repeat Steps 1 through 4).

In cases where solid material (i.e. rock, solid waste, etc.) will be placed on top of the geomembrane with heavy equipment, construction loading must be considered. Based on field experimentation, the minimum M_A geotextile should be between 270 g/m^2 (8 oz/yd^2) (Reddy, et. :., 1996) and 405 g/m^2 (12 oz/yd^2) (Richardson and Johnson, 1998) to prevent construction .amage. The reader should review and understand both documents prior to selecting a geotextile having M_A less than 405 g/m^2.

SIMPLIFIED GEOMEMBRANE CUSHION SELECTION CHARTS

A series of simplified design charts have been developed for the most common geomembrane cushioning applications based on the methodology presented. These charts allow the user to quickly and conservatively select an appropriate virgin polymer, nonwoven, needle-punched geotextile cushion. The applicability and assumptions associated with these charts are provided in the notes section of each figure. In addition, the reader is encouraged to review and understand the limitations of the GRI method (discussed in the referenced literature) prior to application the charts on the following pages. Figures 4 through 7 present charts for landfill applications while Figures 8 and 9 relate to liquid impoundment applications.

EXAMPLES

The following simple design examples illustrate application of the charts and GRI ethod to three common geomembrane cushion applications. Examples 1 and 2 illustrate lection of a geotextile cushion using Figures 4 through 9. Example 3 depicts selection of a geotextile cushion for conditions other than those represented by the charts.

Example 1: Municipal Landfill Liner Cushion

A municipal solid waste (MSW) landfill cell is to be constructed over a carefully prepared subgrade (no significant isolated protrusions). The leachate collection media (to be placed above the geomembrane) is angular crushed stone with a maximum diameter of 38 mm (1.5 in). The maximum design height of the cell is 80 m (262.5 ft). Select an appropriate geotextile to protect the geomembrane.

Solution 1:

Using the design charts in Figures 4 or 5 select a needle-punched, nonwoven, polypropylene geotextile having a MARV M_A of at least 540 g/m^2 (16 oz/yd^2).

Example 2: Liquid Impoundment Liner Cushion

A liquid impoundment is to be constructed over a subgrade containing isolated, angular stone protrusions. The impoundment is to be lined with a geomembrane underlain by a 540 'm^2 (16.0 oz/yd^2) needle-punched, nonwoven, polypropylene geotextile for protection against : subgrade stones. No stone or other solid material will be placed on the geomembrane. Therefore, construction loading is not a concern. It is anticipated that the maximum liquid depth will be 20 m (65.6 ft). For specification purposes, determine the largest stone which may safely remain on the subgrade without damaging the geomembrane.

Solution 2:

Based on the design charts in Figures 8 or 9, stones larger than 23 mm (0.9 in) in diameter might damage the geomembrane. Thus, the construction specification could be written to require removal of all protruding subgrade stones larger than approximately 25 mm (1 in).

Example 3: Industrial Landfill Liner Cushion

A portion of the cell described in Example 1 is to be used as a monofill for automobile shredder fluff (average unit weight equal to 10.2 kN/m^3 (65 lb/ft^3)). This portion of the cell is design to be filled to a height of 25 m (82 ft). In addition, a finer 25 mm (1 in) angular, crushed stone will be used for leachate collection media. Assuming all other liner components (except the cushion) remain unchanged, select an appropriate geotextile to protect the geomembrane.

Solution 3:

The design charts are not applicable to this problem since $\gamma \neq 12.6$ kN/m^3 (80 lb/ft^3). In dition, construction loading may control geotextile selection given the relatively shallow fill ight and low unit weight of waste. Consequently, the problem must be solved by equation.

A. Determine P'_{allow} in terms of M_A, where:

H	= ½ of maximum overlying particle diameter = 12.5 mm
MF_S	= 1.0 (Table 1 - angular stone)
MF_{PD}	= 0.5 (Table 2 - uniformly packed surface)
MF_A	= 0.75 (Table 3 - moderate arching of waste materials)
FS_{CR}	= 1.6 (assumed, corresponds to 270 g/m^2 - to be checked against Table 4)
FS_{CBD}	= 1.2 (Table 5 - polypropylene geotextile in waste application)

$$P'_{allow} = \left(450 \cdot \frac{M_A}{12.5^2}\right)\left(\frac{1}{1.0 \cdot 0.5 \cdot 0.75}\right)\left(\frac{1}{1.6 \cdot 1.2}\right) = 4.0 \cdot M_A$$

B. Determine anticipated pressure on geomembrane, where:

γ	= 10.2 kN/m^3 (given)
h	= 25 m (given)

$$P_{actual} = 10.2 \cdot 25 = 255 \cdot \text{kPa} \quad \text{(Equation 2)}$$

C. Solve for minimum geotextile M_A through manipulation of Equation 3, where:

FS_{gmin}	= 3.0 (Table 6 – uniform packed stones, no isolated subgrade protrusions)
P'_{allow}	= 4.0· M_A (Equation 1)

$4.0 \cdot M_A \geq 3.0 \cdot 255$ (Equation 3) or: $M_A \geq \dfrac{3.0 \cdot 255}{4.0}$

Thus, $M_A \geq 191.3$ g/m^2 (5.7 oz/yd^2)

D. Check result against Creep limits established in Table 4 and Construction Limits:

From Table 4, the minimum acceptable M_A = 405 g/m^2 (12 oz/yd^2). Coincidentally, this agrees with the construction limits recommended by Richardson and Johnson (1998). Thus, select a nonwoven, needle-punched geotextile having a MARV M_A of at least 405 g/m^2. Although, FS_{CR} was selected based on a 270 g/m^2 (8 oz/yd^2) geotextile, the problem need not be reevaluated in this case since a 405 g/m^2 (12 oz/yd^2) geotextile is the minimum acceptable material based on creep limits (Table 4).

SUMMARY AND APPLICABILITY

The design charts and methodology provided herein are intended to provide a quick and nservative method to select an appropriate geomembrane cushion. Prior to applying the sign charts or method, the reader should review and understand the limitations and assumptions discussed in the referenced literature. In circumstances where site specific conditions deviate significantly from the research forming the basis for the charts and GRI method, it is recommended that a project specific testing program be conducted and evaluated by a qualified professional. Geosynthetic materials, testing parameters, etc. should be modeled after anticipated field conditions.

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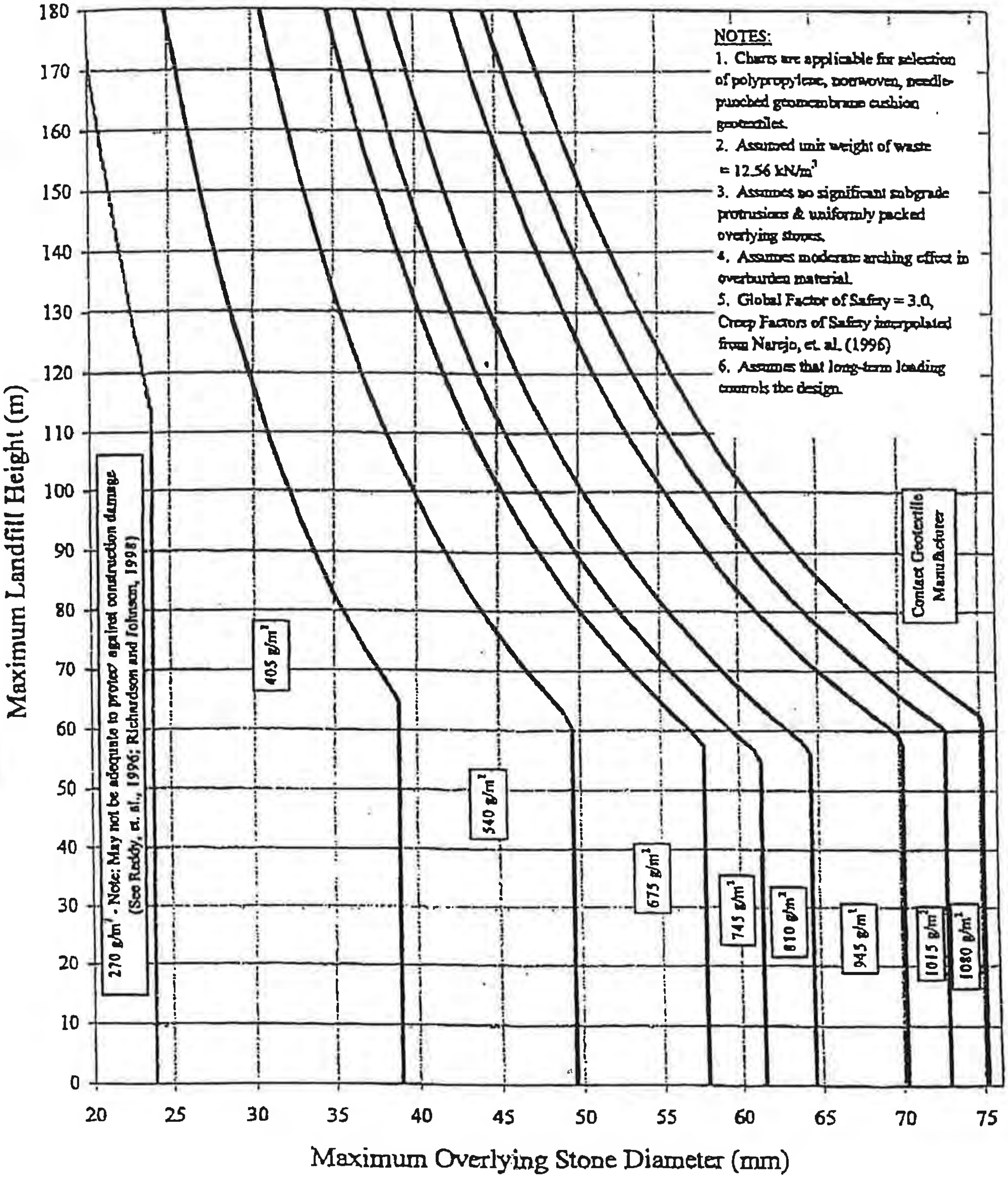

Figure 4. Geomembrane Cushion Selection Chart - Landfill Application, Rounded Overlying Stones (SI Units)

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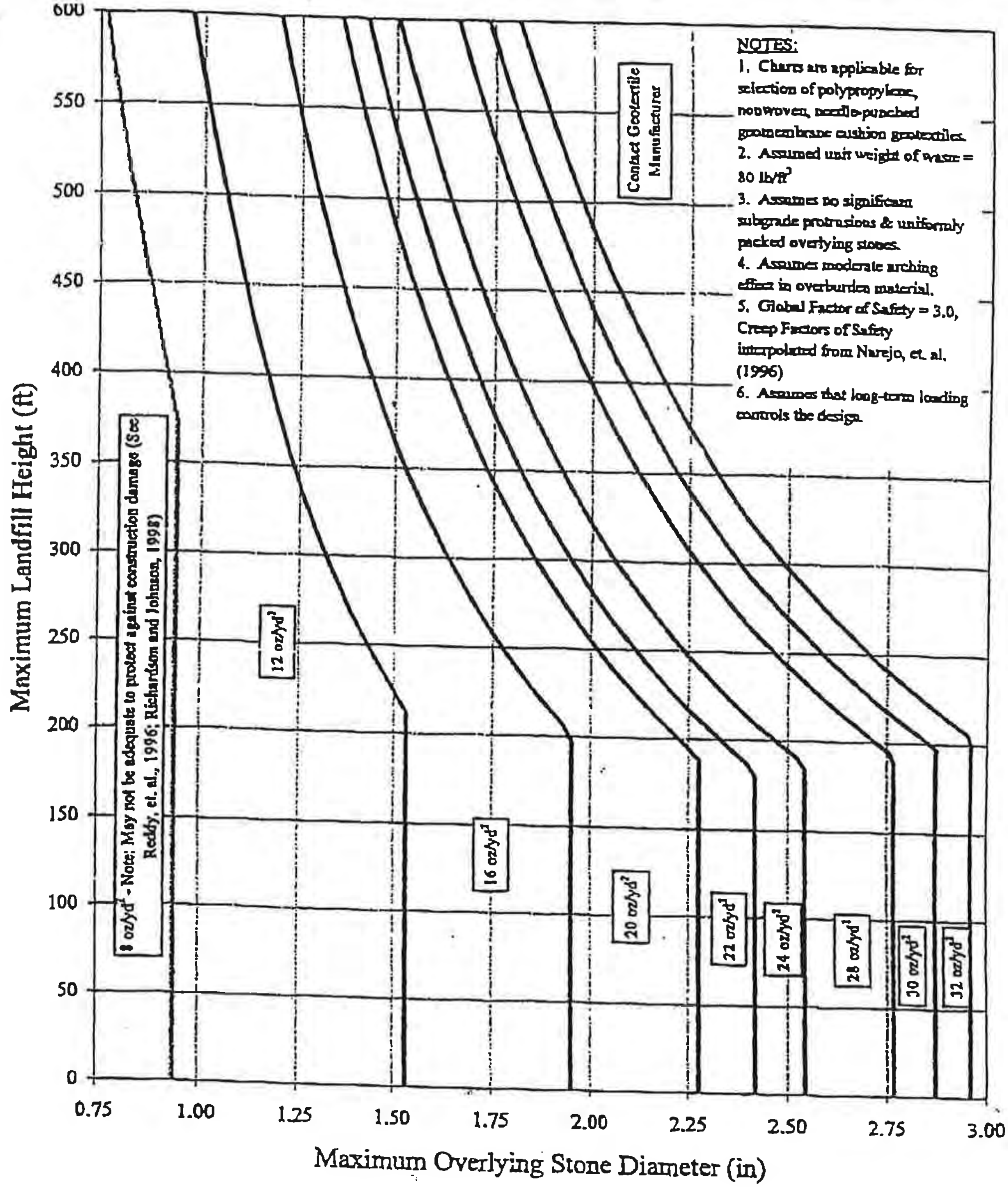

Figure 5. Geomembrane Cushion Selection Chart - Landfill Application, Rounded Overlying Stones (US Units)

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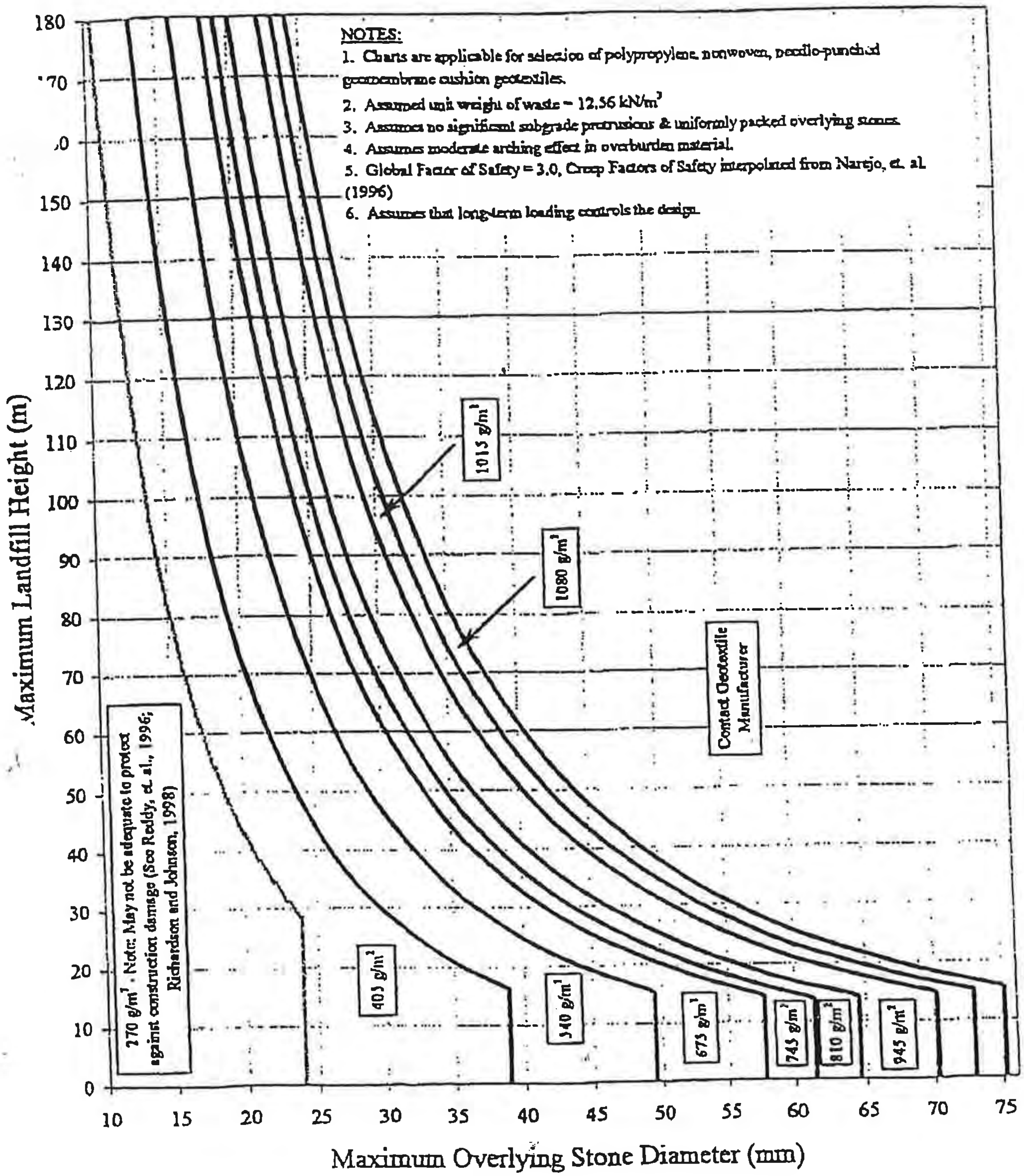

Figure 6. Geomembrane Cushion Selection Chart - Landfill Application, Angular Overlying Stones (SI Units)

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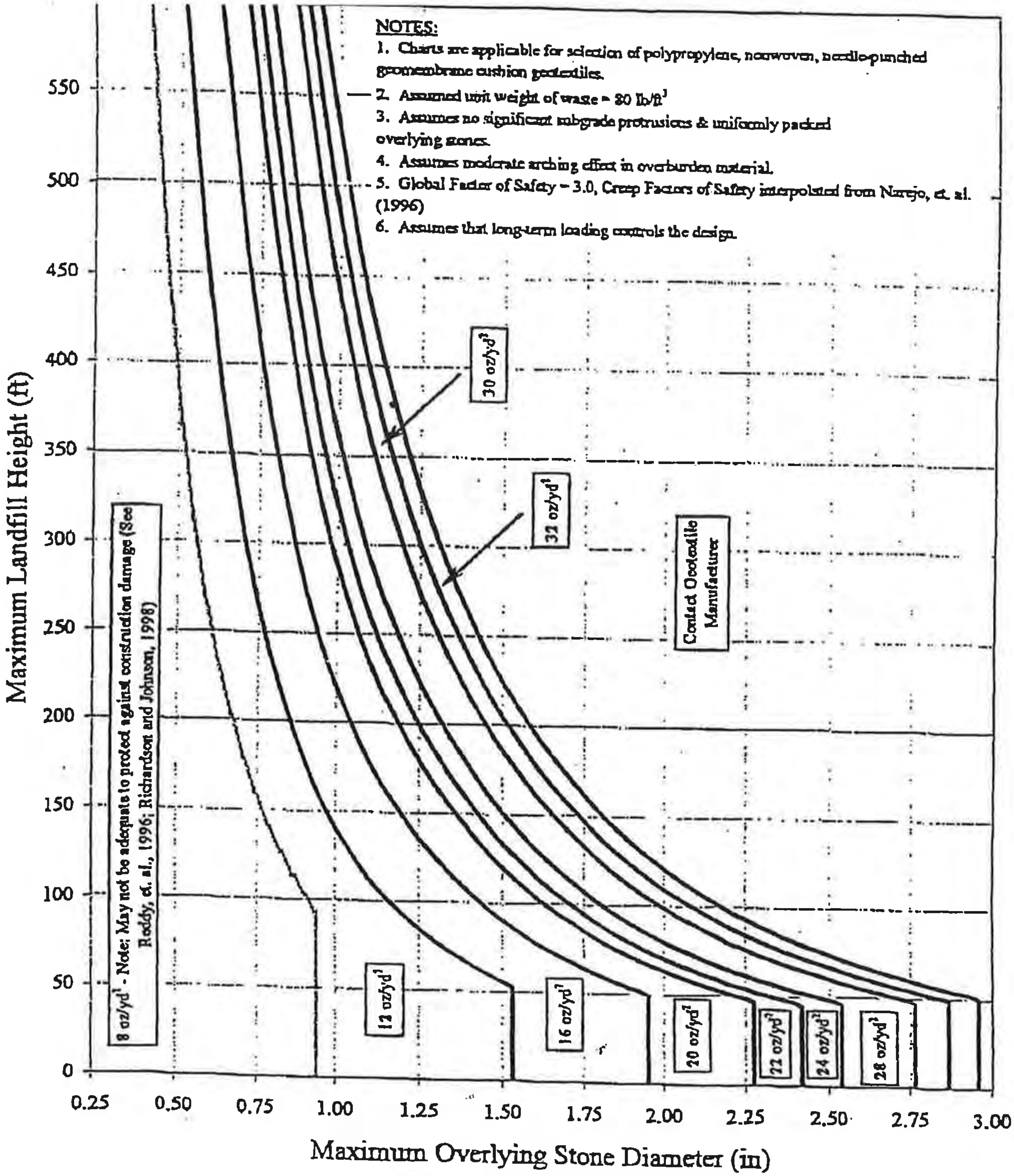

Figure 7. Geomembrane Cushion Selection Chart - Landfill Application, Angular Overlying Stones (US Units)

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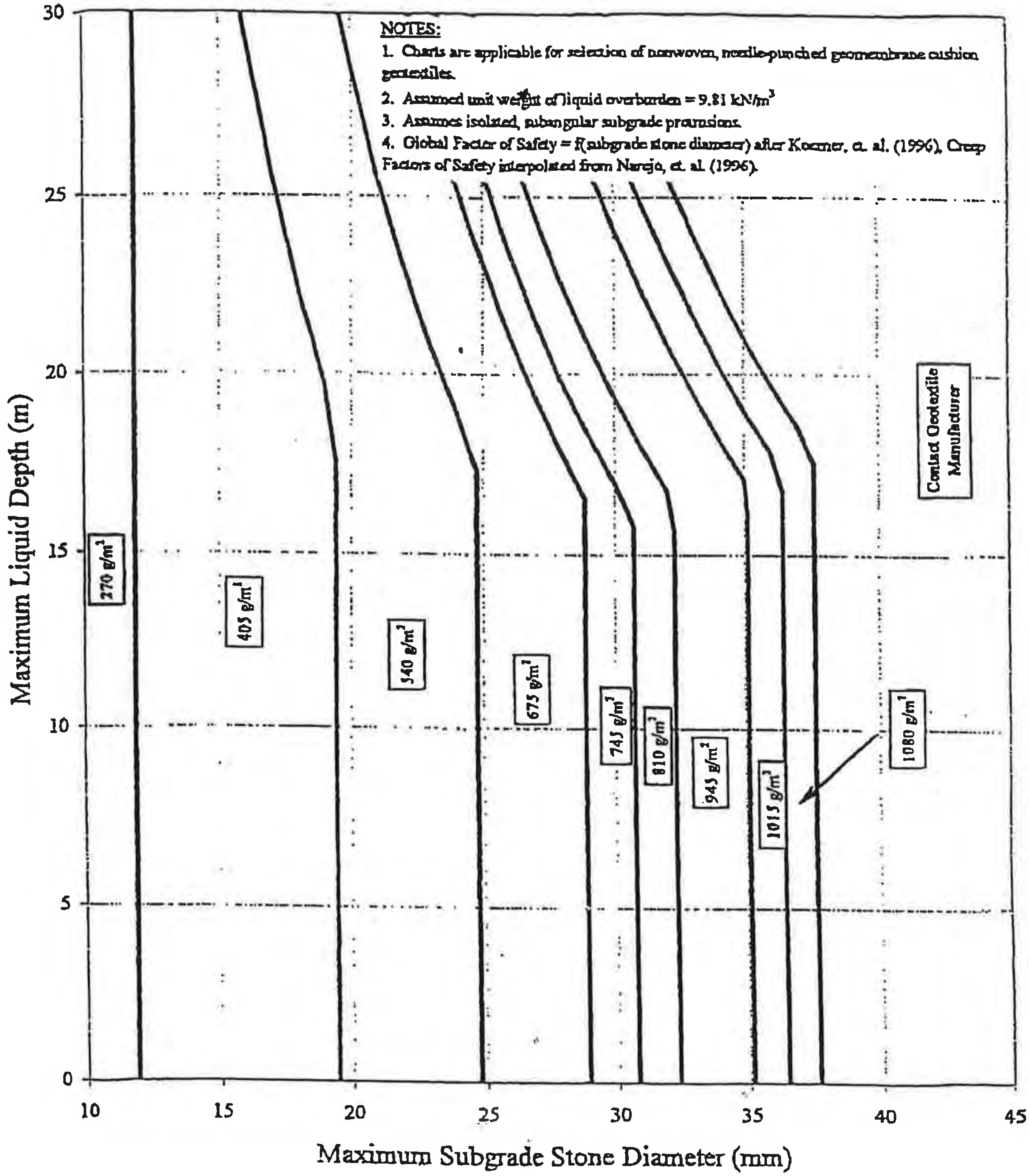

Figure 8. Geomembrane Cushion Selection Chart - Liquid Impoundment Application, Subangular Subgrade Stones (SI Units)

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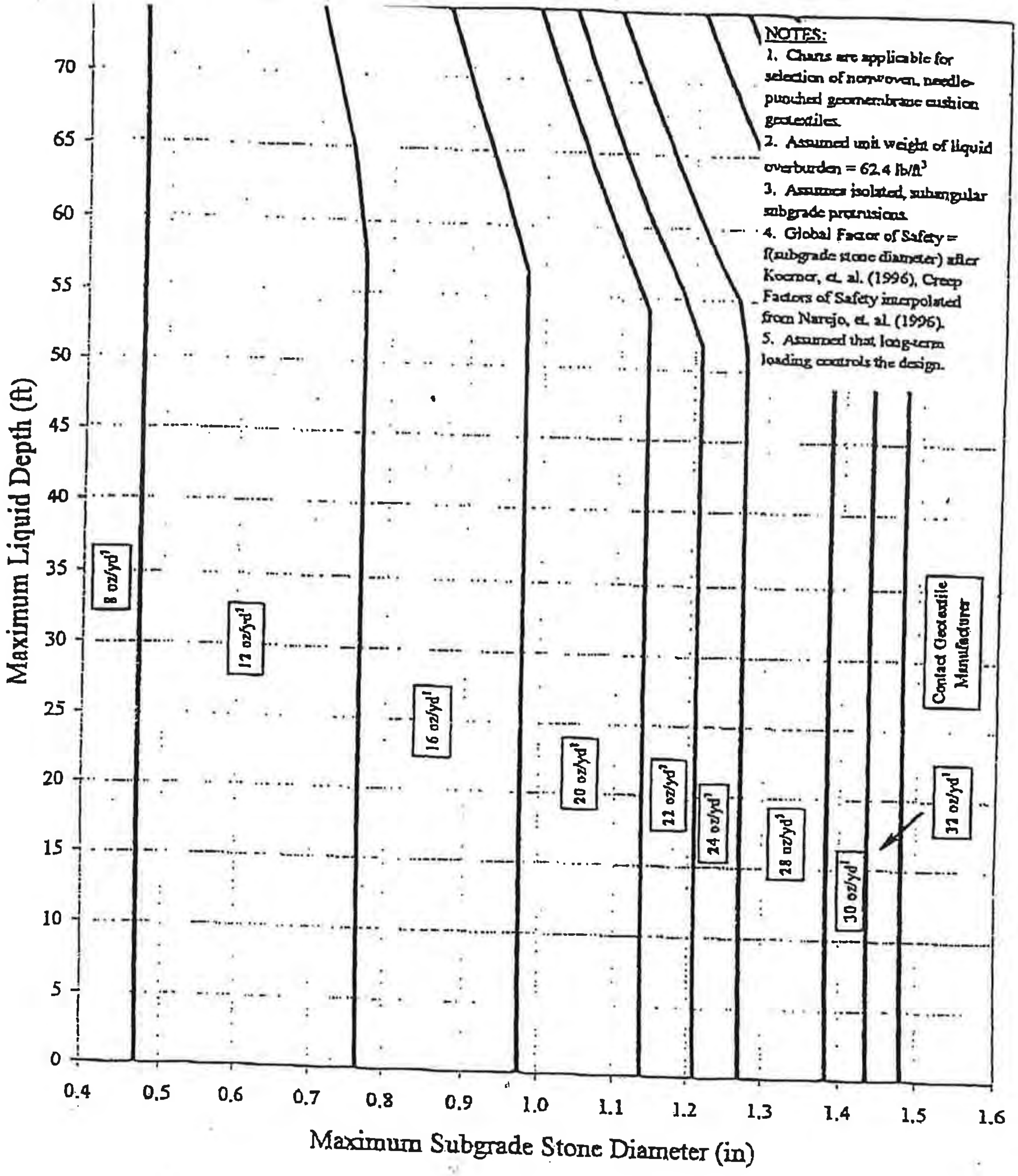


Figure 9. Geomembrane Cushion Selection Chart - Liquid Impoundment Application, Subangular Subgrade Stones (US Units)

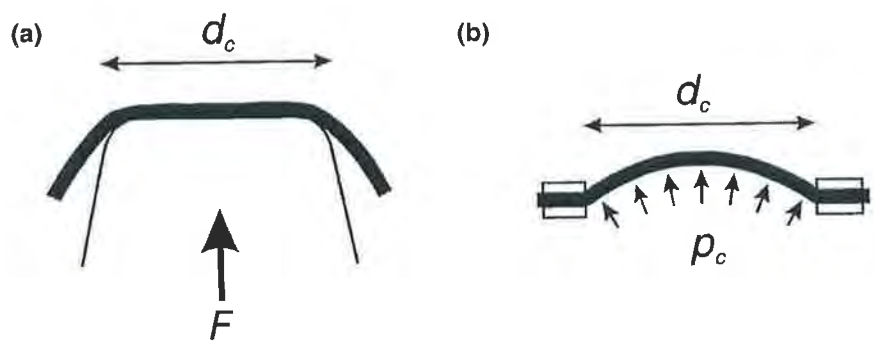


Figure 1. Geomembrane puncture: (a) contact between geomembrane and puncturing object; (b) analogy with the burst test.

where: ε = geomembrane strain; and Z_ε = function of ε implicitly defined by the following equation:

$$\varepsilon = \frac{\sin^{-1} Z_\varepsilon}{Z_\varepsilon} - 1 \tag{3}$$

Since Z_ε cannot be expressed explicitly, it is convenient to tabulate its values. The values of Z_ε presented in Table 1 were obtained by trial and error using Equation 3. It should be noted that the function Z_ε exists only in the range $0 \leq \varepsilon \leq 57\%$.

Eliminating p_c between Equations 1 and 2 gives:

$$F = \pi d_c T Z_\varepsilon \tag{4}$$

The geomembrane tension, T, is expressed as follows:

$$T = \sigma t_{GM} \tag{5}$$

where: σ = tensile stress in the geomembrane; and t_{GM} = thickness of the geomembrane.

Combining Equations 4 and 5 gives:

$$F = \pi\, d_c \sigma\, t_{GM}\, Z_\varepsilon \tag{6}$$

Geomembrane failure in the puncture mode occurs when the stress, σ, and the strain, ε, in the geomembrane reach their values at the peak of the stress-strain curve, σ_{peak} and ε_{peak}, respectively. These peak values are the stress and strain at yield (σ_Y and ε_Y) for geomembranes that yield or the stress and strain at break (σ_b and ε_b) for geomembranes that do not yield. Therefore:

Attachment C (1/5)

Table 1. Function Z_ε .

ε (%)	Z_ε (-)	ε (%)	Z_ε (-)	ε (%)	Z_ε (-)
0	0.000	2.6	0.381	12	0.728
0.2	0.109	2.8	0.395	13	0.749
0.3	0.134	3	0.408	14	0.768
0.4	0.154	3.2	0.420	15	0.785
0.5	0.172	3.4	0.432	16	0.801
0.6	0.188	3.6	0.443	17	0.816
0.8	0.217	3.8	0.454	18	0.830
1	0.242	4	0.465	19	0.844
1.2	0.264	5	0.513	20	0.856
1.4	0.284	6	0.555	25	0.905
1.6	0.303	7	0.591	30	0.940
1.8	0.321	8	0.624	35	0.964
2	0.337	9	0.654	40	0.980
2.2	0.353	10	0.681	50	0.997
2.4	0.367	11	0.705	57	1.00

Note: The values of Z_ε were calculated using Equation 3.

$$F_P = \pi\, d_c\, \sigma_{peak}\, t_{GM}\, Z_{\varepsilon\, peak} \tag{7}$$

where: F_p = geomembrane puncture resistance measured in a probe test; and $Z_{\varepsilon peak}$ = value of Z_ε for $\varepsilon = \varepsilon_{peak}$.

Equation 7 is the general relationship between the puncture resistance F_P and the following parameters: the diameter of the contact area, d_c , between the puncturing object and the geomembrane; and the geomembrane characteristics, σ_{peak} , ε_{peak} , and t_{GM} . This relationship is used in subsequent sections to develop specific relationships for various practical cases. The use of Equation 7 is limited to values of the geomembrane strain at peak, ε_{peak} , not greater than 57%, which is the limit of validity of the function Z_ε . This limits the applicability of the method to geomembranes that rupture or yield at a strain not greater than 57%, such as high density polyethylene (HDPE) geomembranes that yield at a strain on the order of 10 to 15%, and geomembranes reinforced with a woven fabric, such as chlorosulfonated polyethylene (CSPE) geomembranes, that typically break at approximately 20% strain.

It should be noted that Equation 7 generally applies to homogeneous geomembranes, which are characterized by the parameters σ_{peak} , ε_{peak} , and t_{GM} . In the case of geomembranes that are not homogeneous, i.e. geomembranes which comprise layers of different materials, such as reinforced geomembranes, it is not appropriate to use σ_{peak} and t_{GM} ; these geomembranes are characterized by the geomembrane tension at peak, T_{peak} , and by ε_{peak} . Using the relationship between tension and tensile stress expressed by

Attachment C (2/5)

10. However, the puncture force is not the same in the two cases because the contact diameter, d_{cs}, in the case of a stone, is not the same as the probe diameter, d_p. Eliminating σ_{peak} and ε_{peak} between Equations 9 and 10 gives:

$$\frac{F_{Ps}}{F_P} = \frac{d_{cs}\, t_{GMs}}{d_p\, t_{GMp}} \tag{11}$$

where: t_{GMs} = thickness of the geomembrane in contact with stones; and t_{GMp} = thickness of the geomembrane tested with a probe.

The next step of the analysis is the evaluation of the force applied to the geomembrane by a stone in contact with the geomembrane. It is assumed that one surface of the geomembrane is subjected to a pressure, p, applied by a liquid and the other surface of the geomembrane is in contact with a layer of stones of uniform size and identical shape (Figure 3). Such a layer is referred to as a "uniform stone layer" in this paper. The stone shapes are assumed to be three-dimensional, i.e. the stones are assumed to have similar dimensions in all directions; in other words, flat stones such as slates are not considered. Three-dimensional shapes are typical of rounded or crushed stones (but, in a given "uniform stone layer", all stones are assumed to have the same shape).

The force applied to the geomembrane by a given stone depends on the stone arrangement. In Figure 4, three-dimensional stones are schematically represented by circles in a plan view. The average surface area of geomembrane associated with one stone is expressed by the following equation if the stone arrangement is hexagonal (Figure 4a):

$$A_{avg} = \frac{\sqrt{3}}{2}\, d_s^2 \tag{12}$$

where d_s is the diameter of a stone. (The classical definition of the diameter of a stone is the diameter of a circular hole, or the side length of a square hole, through which, the stone would just pass.)

If the stone arrangement is square (Figure 4b), the average surface area of geomembrane associated with one stone is:

$$A_{avg} = d_s^2 \tag{13}$$

More generally, the average surface area of geomembrane associated with a stone can be expressed by the following equation:

$$A_{avg} = \lambda\, d_s^2 \tag{14}$$

where λ is a dimensionless term that is a function of the stone arrangement. The parameter λ is close to one in the case of a uniform stone layer:

- For a dense (hexagonal) arrangement, according to Equations 12 and 14:

Attachment C (3/5)

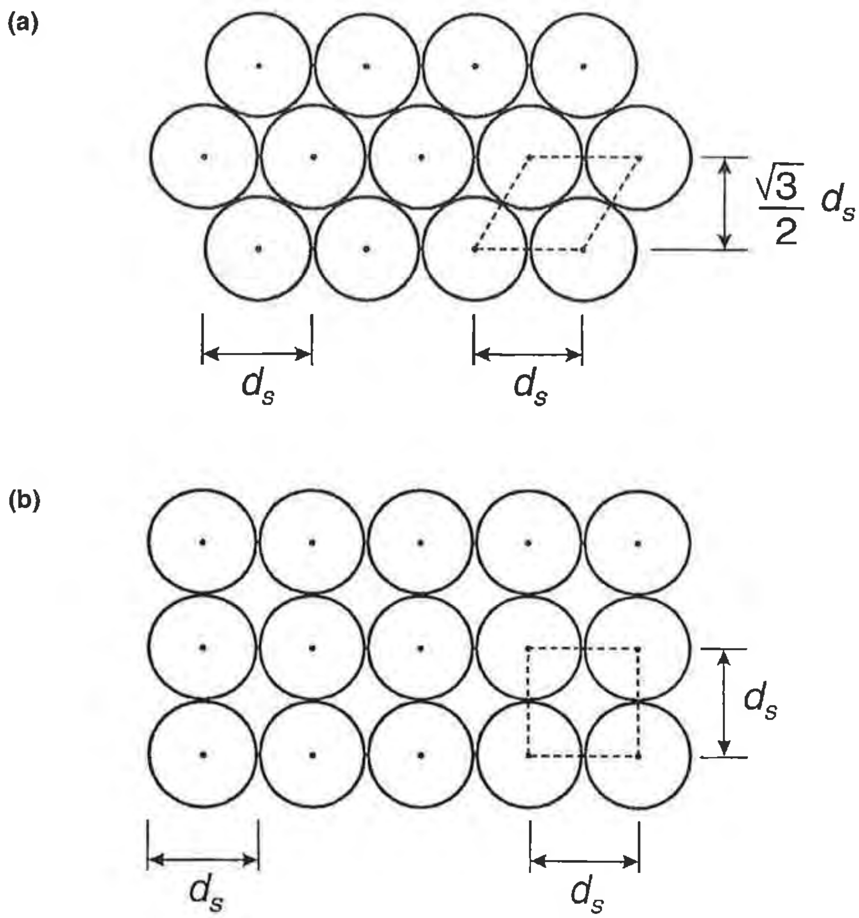


Figure 4. Arrangement of spherical particles: (a) hexagonal arrangement; (b) square arrangement.
(Note: The parallelogram in Figure 4a or the square in Figure 4b delineate the area associated with one particle.)

$$\lambda = \sqrt{3}/2 = 0.87 \quad (15)$$

*

- For a loose (square) arrangement, according to Equations 13 and 14:

$$\lambda = 1 \quad (16)$$

Attachment C (4|5)

hence:

$$d_{cround} = d_{sround} Z_\varepsilon \quad (26)$$

where Z_ε is the function of ε implicitly defined by Equation 3 and the numerical values of which are given in Table 1.

Combining Equations 21 and 26, with $d_s = d_{sround}$ and $d_{cs} = d_{cround}$, gives the following relationship when puncture occurs, i.e. when $\varepsilon = \varepsilon_{peak}$:

$$\frac{\lambda \, d_{sround} \, p_P}{t_{GMs}} = \frac{F_P \, Z_{\varepsilon \, peak}}{d_p \, t_{GMp}} \quad (27)$$

Like Equation 21, Equation 27 expresses a relationship between parameters related to the stones, on the left, and parameters related to the probe test, on the right. In addition, there is a factor related to the geomembrane on the right ($Z_{\varepsilon peak}$). Equation 21 is valid for any stone shape, whereas Equation 27 is valid for rounded stones and was developed assuming the rounded stones are spherical.

Example 2. The same case as for Example 1 is considered. To withstand a pressure of 830 kPa what should the maximum size of rounded stones be ?

Assuming that yield of a typical HDPE geomembrane occurs at a strain of 11%, Table 1, for $\varepsilon_{peak} = 11\%$, gives:

$$Z_{\varepsilon peak} = 0.705$$

Equation 27 can then be used as follows:

$$d_{sround} = \frac{1.5}{(\sqrt{3}/2)(830,000)} \frac{(290)(0.705)}{(6.35 \times 10^{-3})(1.0)} = 0.067 \text{ m} = 67 \text{ mm}$$

The stone size of 67 mm calculated in the case of rounded stones is significantly larger than the stone sizes of 17 to 24 mm obtained in Example 1 in the case of angular stones, which is consistent with the fact that a geomembrane has a larger contact area with a rounded stone than with an angular stone.

END OF EXAMPLE 2

In the case of rounded stones, it should be noted that failure in the puncture mode may not be the worst case. It is possible that the geomembrane is more likely to fail in the burst mode between the stones. Design engineers should always consider the possibility for the geomembrane to burst between stones when a geomembrane, subjected to a liquid pressure, rests on a layer of stones of approximately uniform size, and they should

Attachment C (5/5)

High Density Polyethylene Drain Liner™

Product Data

Property	Test Method	Values			
Thickness (min. ave.), mil (mm)	ASTM D5994*	50 (1.25)	60 (1.5)	80 (2.0)	100 (2.5)
Thickness (lowest indiv.), mil (mm)	ASTM D5994*	50 (1.25)	54 (1.35)	72 (1.8)	90 (2.25)
*The thickness values may be changed due to project specifications (i.e., absolute minimum thickness)					
Drainage Stud Height (min. ave.), mil (mm)	ASTM D7466	130 (3.30)	130 (3.30)	130 (3.30)	130 (3.30)
Density, g/cc, minimum	ASTM D792, Method B	0.94	0.94	0.94	0.94
Tensile Properties (ave. both directions)	ASTM D6693, Type IV				
Strength @ Yield (min. ave.), lb/in width (N/mm)	2 in/minute	110 (19.3)	132 (23.1)	176 (30.8)	220 (38.5)
Elongation @ Yield (min. ave.), % (GL=1.3in)	5 specimens in each direction	13	13	13	13
Strength @ Break (min. ave.), lb/in width (N/mm)		110 (19.3)	132 (23.1)	176 (30.8)	220 (38.5)
Elongation @ Break (min. ave.), % (GL=2.0in)		300	300	300	300
Tear Resistance (min. ave.), lbs. (N)	ASTM D1004	38 (169)	40 (178)	53 (236)	64 (285)
Puncture Resistance (min. ave.), lbs. (N)	ASTM D4833	80 (355)	95 (422)	126 (560)	158 (703)
Carbon Black Content (range in %)	ASTM D4218	2 - 3	2 - 3	2 - 3	2 - 3
Carbon Black Dispersion (Category)	ASTM D5596	Only near spherical agglomerates for 10 views: 9 views in Cat. 1 or 2, and 1 view in Cat. 3			
Stress Crack Resistance (Single Point NCTL), hours	ASTM D5397, Appendix	300	300	300	300
Oxidative Induction Time, minutes	ASTM D3895, 200°C, 1 atm O_2	≥100	≥100	≥100	≥100
Melt Flow Index, g/10 minutes	ASTM D1238, 190°C, 2.16kg	≤1.0	≤1.0	≤1.0	≤1.0
Oven Aging with HP OIT, (% retained after 90 days)	ASTM D5721 ASTM D5885, 150°C, 500psi O_2	80	80	80	80
UV Resistance	GRI GM11	20hr. Cycle @ 75°C/4 hr. dark condensation @ 60°C			
with HP OIT, (% retained after 1600 hours)	ASTM D5885, 150°C, 500psi O_2	50	50	50	50

These product specifications meet or exceed GRI's GM13

Supply Information (Standard Roll Dimensions)

Thickness mil	Thickness mm	Width ft	Width m	Length ft	Length m	Area (approx.) ft²	Area (approx.) m²	Weight (average)* lbs	Weight (average)* kg
50	1.25	23	7	300	91.435	6,900	640.05	2,600	1,178.34
60	1.5	23	7	300	91.435	6,900	640.05	2,900	1,315.42
80	2.0	23	7	300	91.435	6,900	640.05	3,600	1,632.93
100	2.5	23	7	300	91.435	6,900	640.05	4,000	1,814.37

Notes:

All rolls are supplied with two slings. All rolls are wound on a 6 inch core. Special lengths are available on request. All roll lengths and widths have a tolerance of ±1%
**The weight values may change due to project specifications (i.e. absolute minimum thickness or special roll lengths) or shipping requirements (i.e. international containerized shipments).*

500 Garrison Road, Georgetown, South Carolina 29440 843-546-0600 800-373-2478 Fax: 843-527-2738
email: salesmkg@agruamerica.com www.agruamerica.com

Attachment D (1/1)

Geosyntec consultants

COMPUTATION COVER SHEET

Client:	**Energy Fuels**	Project:	**White Mesa Mill – Cells 5A and 5B**	Project/ Proposal No.:	**SC0634**
				Task No.	**02**

Title of Computations **SEISMIC DEFORMATION ANALYSIS**

Computations by:	Signature		12/18/12 Date
	Printed Name	Jay L. Griffin	
	Title	Senior Staff Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		12/21/12 Date
	Printed Name	Steven M. Fitzwilliam, P.E.	
	Title	Associate Engineer	
Computations Checked by:	Signature		12/21/12 Date
	Printed Name	Steven M. Fitzwilliam, P.E.	
	Title	Associate Engineer	
Computations backchecked by: (originator)	Signature		12/18/12 Date
	Printed Name	Jay L. Griffin	
	Title	Senior Staff Engineer	
Approved by: (pm or designate)	Signature		12/12/12 Date
	Printed Name	Gregory Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes: ____________________

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Geosyntec consultants

Written by:	**J. Griffin**	Date:	**11/28/12**	Reviewed by:	**S. Fitzwilliam**	Date:	12/21/12
Client:	**Energy Fuels**	Project:	**White Mesa Mill– Cells 5A &5B**	Project/ Proposal No.:	**SC0634**	Task No.:	**02**

PERMANENT SEISMIC DEFORMATION ANALYSIS
CELLS 5A AND 5B
WHITE MESA MILL
BLANDING, UTAH

OBJECTIVE

The objective of this analysis is to evaluate the seismically induced permanent deformation of the embankments for Cells 5A and 5B at the White Mesa Mill Facility located in Blanding, Utah.

METHOD OF ANALYSIS

Seismic deformation is a function of average acceleration of the sliding mass and the yield acceleration. Geosyntec used the Makdisi and Seed (Attachment A) method to estimate permanent seismic deformations, based on yield accelerations determined from pseudo-static limit equilibrium analyses, design earthquake motions determined from documented sources, and the attached design charts (Makdisi and Seed, 1978).

Three cross-sections were selected for analysis and are shown in Figure 1. The first cross section, Section A-A', is a west-east cross section that models Cell 5A filled with tailings and Cell 5B empty. The section spans Cells 5A and 5B, with berm slopes inclined at approximately 2:1 (Horizontal:Vertical) and a base grade sloping toward the berm at approximately 1 percent. The second cross section, Section B-B', is a north-south cross section that models Cell 5A before filling and spans the berm separating the southern portion of existing Cell 4B and Cell 5A. Section B-B' was modeled with Cell 4B full of tailings and Cell 5A empty. Both sections were modeled without a liner on the empty cell in order to evaluate berm stability. The third cross section, Section C-C' is a north-south cross section that spans the embankment on the south side of Cell 5A. Section C-C' is modeled with Cell 5A filled with tailings. The embankment back slope is inclined at 3:1.

DESIGN CRITERION

In accordance with the current state of practice, acceptable seismically induced permanent deformations are less than 6 to 12 inches for waste mass configurations

Written by:	J. Griffin	Date:	11/28/12	Reviewed by:	S. Fitzwilliam	Date:	12/21/12
Client:	Energy Fuels	Project:	White Mesa Mill– Cells 5A &5B	Project/ Proposal No.:	SC0634	Task No.:	02

(Seed and Bonaparte, 1992). To evaluate seismically induced permanent deformations at Cells 5A and 5B, Geosyntec established a maximum seismically induced deformation of 6 inches as the design criterion.

The peak ground acceleration (PGA) at the site was previously evaluated in the Cell 4 Design Report (UMETCO, 1988) as referenced by MFG, Inc. in a letter to International Uranium Corporation (presently Energy Fuels) dated 27 November 2006 (Attachment C). The design report indicates that the maximum acceleration at the site is 0.10 g, representing a 2 percent probability of exceedance within 50 years (approximate return period of 2,500 years). The report states that this design acceleration is suitable for operational conditions at site.

DEFORMATION ANALYSES

Estimating the seismically induced deformations includes the following steps, summarized in Table 1:

1. Perform pseudostatic slope stability analyses to evaluate the yield acceleration (k_y) resulting in a factor of safety of 1.0 for the critical cross sections. The results of the pseudostatic slope stability evaluation for each cross section are provided in Table 1. These values were determined using the computer software SLOPE/W 2004 (Version 6.22) developed by Geo-Slope International Ltd. (2004).

2. Estimate k_{max} (the maximum average acceleration for a potential sliding mass extending to a specified depth y) using the upper bound for observed motions at earth dams reported by Harder (Harder, 1991), through the following two steps:

   a. Estimate value of acceleration at the top of the embankment, $\ddot{u}_{max}$ based on the Harder (1991) curve (included in Attachment D), the acceleration at the crest of the berm, $\ddot{u}_{max}$, is estimated to be 0.35 g;

   b. Calculate k_{max} as 0.35 times $\ddot{u}_{max}$ based on the Makdisi and Seed curve in Attachment A (Figure 7 in Makdisi and Seed, 1978).

Written by:	J. Griffin	Date:	11/28/12	Reviewed by:	S. Fitzwilliam	Date:	12/21/12
Client:	Energy Fuels	Project:	White Mesa Mill– Cells 5A &5B	Project/ Proposal No.:	SC0634	Task No.:	02

3. Calculate the ratio of k_y/k_{max} for each cross section and compute resulting deformations based on the Makdisi and Seed Simplified Method (see Figure 10 in Attachment A). Figure 10 displays an upper bound of 1.0 for k_y/k_{max}; therefore, if the ratio of k_y/k_{max} exceeds 1.0, seismically induced deformations are estimated to be minimal (less than 1 centimeter or 0.4 inches).

Table 1: Seismic Deformation Analyses Results

Cross Section	PGA (g)	k_y	$\ddot{u}_{max}$	k_{max}	k_y/k_{max}	δ (cm)
A-A’	0.1	0.65g	0.35g	0.12g	5.4	<1
B-B’	0.1	0.66g	0.35g	0.12g	5.5	<1
C-C’	0.1	0.51g	0.35g	0.12g	4.2	<1

RESULTS AND CONCLUSIONS

Results of the permanent deformation analysis indicate that the expected seismically induced permanent deformation is expected to be minimal, and significantly less than the design criterion of 6 inches.

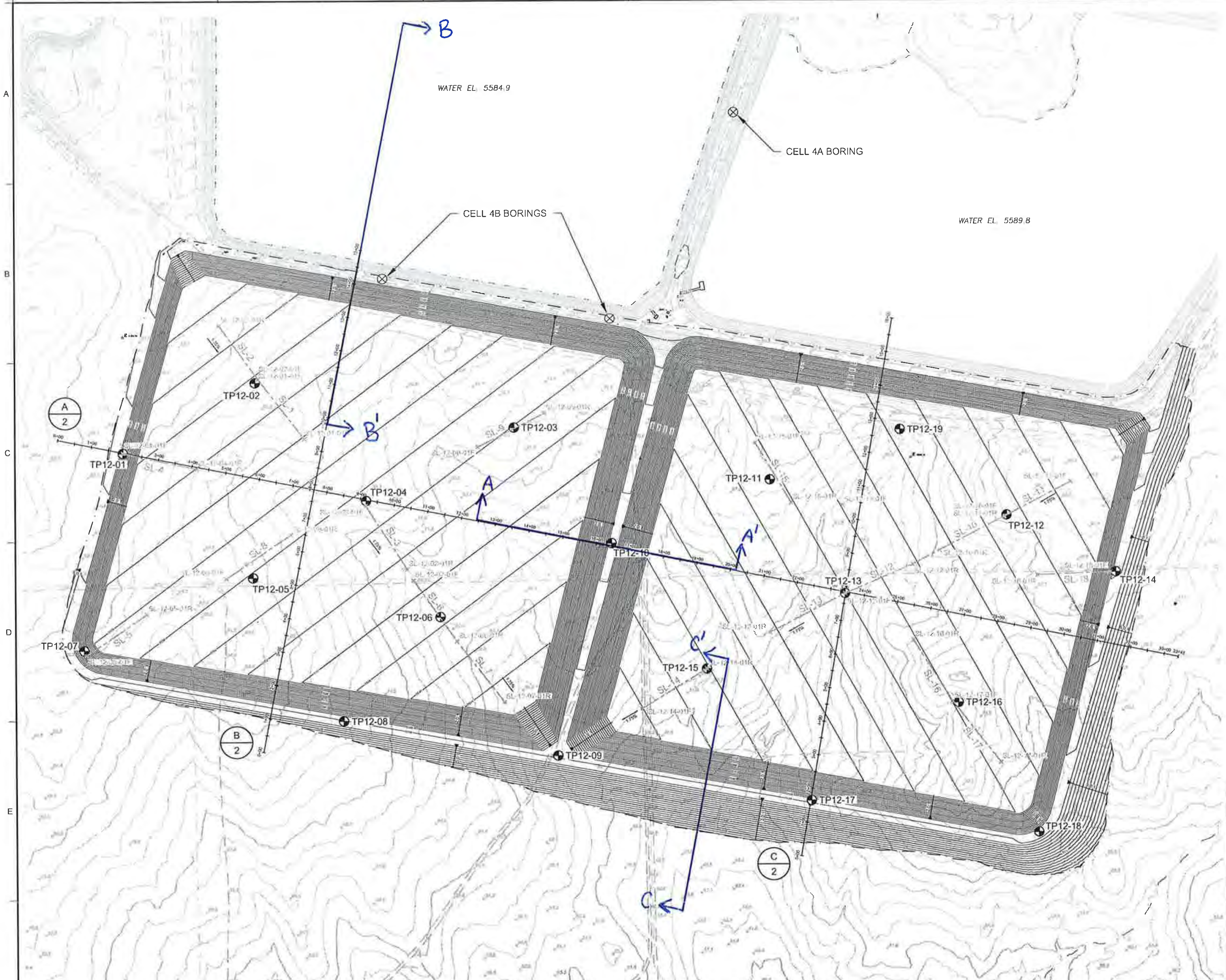
REFERENCES

Harder, L.F., Jr. [1991], "Performance of Earth Dams During the Loma Prieta Earthquake," Proc. Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, University of Missouri, Rolla, pp. 11-15.

Makdisi and Seed [1978], “Simplified Procedure for Estimating Dam and Embankment Earthquake Induced Deformation,” *Journal of the Geotechnical Engineering Division,* ASCE, Vol 104, No. GT7, pp 849-867.

MFG, Inc. [2006], “White Mesa Uranium Facility, Cell 4 Seismic Study, Blanding, Utah,” letter to International Uranium (USA) Corporation, dated 27 November 2006.

Seed, H.B., and Bonaparte, R., [1992], “Seismic Analysis and Design of Lined Waste Fills: Current Practice,” Proceedings of ASCE Specialty Conference on Stability and Performance of Slopes and Embankments – II, pp. 1521 – 1545.



LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- PROPOSED GRADING MAJOR CONTOUR (10')
- PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- 1 AS-BUILT TRENCH LOCATION
- AS-BUILT SEISMIC LINES

PRELIMINARY VOLUME REPORT

JUNE 2011 EXISTING SURFACE VS. REVISED CELL 5A PROPOSED GRADING:

CUT = 1,228,929 CUBIC YARDS

FILL = 196,323 CUBIC YARDS

NET = 1,032,606 CUBIC YARDS <CUT>

JUNE 2011 EXISTING SURFACE VS. REVISED CELL 5B PROPOSED GRADING

CUT = 704,105 CUBIC YARDS

FILL = 240,573 CUBIC YARDS

NET = 463,532 CUBIC YARDS <CUT>

0 150' 300'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUTE 200
SAN DIEGO, CA 92127
PHONE 858 674 6559

ENERGY FUELS INC.
6425 S. HIGHWAY 191
P.O. BOX 809
BLANDING, UTAH 84511
PHONE: 858.674.6559

TITLE: CELL 5A AND 5B PROPOSED GRADING

PROJECT: CELL 5A AND 5B PRELIMINARY CELL DESIGN

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	GTC	DATE:	OCTOBER 2012
DRAWN BY:	MMC	PROJECT NO.:	SC0349
CHECKED BY:	GTC	FILE:	
REVIEWED BY:	GTC	FIGURE NO.:	
APPROVED BY:	GTC	1 OF 2	

FIGURE 1

PRELIMINARY DESIGN DRAWINGS
NOT FOR CONSTRUCTION

P:\PRJ\SDCadd\CADD\SC0349\SC0349-07-01\Working\10-2-12 CELL 5A & 5B REVISED GRADING.dwg

13898 JULY 1978 MATASOVIC GT7

JOURNAL OF THE GEOTECHNICAL ENGINEERING DIVISION

Simplified Procedure for Estimating Dam and Embankment Earthquake-Induced Deformations

1973

By Faiz I. Makdisi,[1] A. M. ASCE and H. Bolton Seed,[2] F. ASCE

Introduction

In the past decade major advances have been achieved in analyzing the stability of dams and embankments during earthquake loading. Newmark (13) and Seed (18) proposed methods of analysis for predicting the permanent displacements of dams subjected to earthquake shaking and suggested this as a criterion of performance as opposed to the concept of a factor of safety based on limit equilibrium principles. Seed and Martin (26) used the shear beam analysis to study the dynamic response of embankments to seismic loads and presented a rational method for the calculation of dynamic seismic coefficients for earth dams. Ambraseys and Sarma (1) adopted the same procedure to study the response of embankments to a variety of earthquake motions.

Later the finite element method was introduced to study the two-dimensional response of embankments (5,7) and the equivalent linear method (21) was used successfully to represent the strain-dependent nonlinear behavior of soils. In addition the nature of the behavior of soils during cyclic loading has been the subject of extensive research (10,20,23,29). Both the improvement in the analytical tools to study the response of embankments and the knowledge of material behavior during cyclic loading led to the development of a more rational approach to the study of stability of embankments during seismic loading. Such an approach was used successfully to analyze the Sheffield Dam failure during the 1925 Santa Barbara earthquake (24) and the behavior of the San Fernando Dams during the 1971 earthquake (25). This method has since been used extensively in the design and analysis of many large dams in the State of California and elsewhere.

Note.—Discussion open until December 1, 1978. To extend the closing date one month, a written request must be filed with the Editor of Technical Publications, ASCE. This paper is part of the copyrighted Journal of the Geotechnical Engineering Division, Proceedings of the American Society of Civil Engineers, Vol. 104, No. GT7, July, 1978. Manuscript was submitted for review for possible publication on August 30, 1977.

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[2] Prof. of Civ. Engrg., Univ. of California, Berkeley, Calif.

Attachment A 1/9

From the study of the performance of embankments during strong earthquakes, two distinct types of behavior may be discerned: (1) That associated with loose to medium dense sandy embankments, susceptible to rapid increases in pore pressure due to cyclic loading resulting in the development of pore pressures equal to the overburden pressure in large portions of the embankment, associated reductions in shear strength, and potentially large movements leading to almost complete failure; and (2) the behavior associated with compacted cohesive clays, dry sands, and some dense sands; here the potential for buildup of pore pressures is much less than that associated with loose to medium dense sands, the resulting cyclic strains are usually quite small, and the material retains most of its static undrained shearing resistance so that the resulting post-earthquake behavior is a limited permanent deformation of the embankment.

The dynamic analysis procedure proposed by Seed, et al. (25) has been used to predict adequately both types of embankment behavior using the "Strain Potential" concept. Procedures for integrating strain potentials to obtain the overall deformation of an embankment have been proposed by Seed, et al. (25), Lee (9), and Serff, et al. (27).

The dynamic analysis approach has been recommended by the Committee on Earthquakes of the International Commission on Large Dams (3): "high embankment dams whose failure may cause loss-of-life or major damage should be designed by the conventional method at first, followed by a dynamic analysis in order to investigate any deficiencies which may exist in the pseudo-statical design of the dam." For low dams in remote areas the Committee recommended the use of conventional pseudostatic methods using a constant horizontal seismic coefficient selected on the basis of the seismicity of the area. However, the inadequacy of the pseudostatic approach to predict the behavior of embankments during earthquakes has been clearly recognized and demonstrated (19,24,25,26, 28). Furthermore in the same report (3) the Commission refers to the conventional method as follows: "There is a need for early revision of the conventional method since the results of dynamic analyses, model tests and observations of existing dams show that the horizontal acceleration due to earthquake forces varies throughout the height of the dam . . . in several instances, this method predicts a safe condition for dams which are known to have had major slides."

It is this need for a simple yet rational approach to the seismic design of small embankments that prompted the development of the simplified procedure described herein.

This approximate method uses the concept originally proposed by Newmark (13) for calculating permanent deformations but it is based on an evaluation of the dynamic response of the embankment as proposed by Seed and Martin (26) rather than rigid body behavior. It assumes that failure occurs on a well-defined slip surface and that the material behaves elastically at stress levels below failure but develops a perfectly plastic behavior above yield. The method involves the following steps:

1. A yield acceleration, i.e., an acceleration at which a potential sliding surface would develop a factor of safety of unity is determined. Values of yield acceleration are a function of the embankment geometry, the undrained strength of the material (or the reduced strength due to shaking), and the location of the potential sliding mass.

Attachment A, 2/9

2. Earthquake induced accelerations in the embankment are determined using dynamic response analyses. Finite element procedures using strain-dependent soil properties can be used for calculating time histories of acceleration, or simpler one-dimensional techniques might be used for the same purpose. From these analyses, time histories of average accelerations for various potential sliding masses can be determined.

3. For a given potential sliding mass, when the induced acceleration exceeds the calculated yield acceleration, movements are assumed to occur along the direction of the failure plane and the magnitude of the displacement is evaluated by a simple double integration procedure.

The method has been applied to dams with heights in the range of 100 ft–200 ft (30 m–60 m), and constructed of compacted cohesive soils or very dense cohesionless soils, but may be applicable to higher embankments. A similar approach has been proposed by Sarma (16) using the assumption of a rigid block on an inclined plane rather than a deformable earth structure that responds with differential motions to the imposed base excitation.

In the following sections the steps involved in the analyses will be described in detail and design curves prepared on the basis of analyzed cases will be presented, together with an example problem to illustrate the use of the method. Note, however, that the method is an approximate one and involves simplifying assumptions. The design curves are averages based on a limited number of cases analyzed and should be updated as more data become available and more cases are studied.

Determination of Yield Acceleration

The yield acceleration, k_y, is defined as that average acceleration producing a horizontal inertia force on a potential sliding mass so as to produce a factor of safety of unity and thus cause it to experience permanent displacements.

For soils that do not develop large cyclic strains or pore pressures and maintain most of their original strength after earthquake shaking, the value of k_y can be calculated by stability analyses using limiting equilibrium methods. In conventional slope stability analyses the strength of the material is defined as either the maximum deviator stress in an undrained test, or the stress level that would cause a certain allowable axial strain, say 10%, in a test specimen. However, the behavior of the material under cyclic loading conditions is different than that under static conditions. Due to the transient nature of the earthquake loading, an embankment may be subjected to a number of stress pulses at levels equal to or higher than its static failure stress that simply produce some permanent deformation rather than complete failure. Thus the yield strength is defined, for the purpose of this analysis, as that maximum stress level below which the material exhibits a near elastic behavior (when subjected to cyclic stresses of numbers and frequencies similar to those induced by earthquake shaking) and above which the material exhibits permanent plastic deformation of magnitudes dependent on the number and frequency of the pulses applied. Fig. 1 shows the concept of cyclic yield strength. The material in this case has a cyclic yield strength equal to about 90% of its static undrained strength and as shown in Fig. 1(*a*) the application of 100 cycles of stress amounting to 80%

of the undrained strength resulted in essentially an elastic behavior with very little permanent deformation. On the other hand, the application of 10 cycles of stress level equal to 95% of the static undrained strength led to substantial permanent strain as shown in Fig. 1(*b*). On loading the material monotonically to failure after the series of cyclic stress applications, the material was found to retain the original undrained strength. This type of behavior is associated with various types of soils that exhibit small increases in pore pressure during cyclic loading. This would include clayey materials, dry or partially saturated cohesionless soils, or very dense saturated cohesionless materials that will not undergo significant deformations, even under cyclic loading conditions, unless the undrained static strength of the soil is exceeded.

Seed and Chan (20) conducted cyclic tests on samples of undisturbed and compacted silty clays and found that for conditions of no stress reversal and for different values of initial and cyclic stresses, the total stress required to produce large deformations in 10 cycles and 100 cycles ranged between 90%–110% of the undrained static strength.

Sangrey, et al. (15) investigated the effective stress response of clay under repeated loading. They tested undisturbed samples of clay (LL = 28, PI = 10) and found that the cyclic yield strength of this material was of the order of 60% of its static undrained strength.

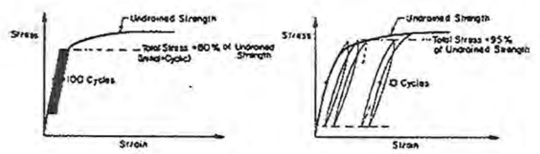

FIG. 1.—Determination of Dynamic Yield Strength

Rahman (14) performed similar tests on remolded samples of a brittle silty clay (LL = 91, PI = 49) and found that the cyclic yield strength was a function of the initial effective confining pressure. For practical ranges of effective confining pressures the cyclic yield strength for this material ranged between 80%–95% of its static undrained strength. At cyclic stress levels below the yield strength, in all cases, the material reached equilibrium and assumed an elastic behavior at strain levels less than 2% irrespective of the number of stress cycles applied.

Thiers and Seed (28) performed tests on undisturbed and remolded samples of different clayey materials to determine the reduction in static undrained strength due to cyclic loading. Their results are summarized in Fig. 2 which shows the reduction in undrained strength after cyclic loading as a function of the ratio of the "maximum cyclic strain" to the "static failure strain." These results were obtained from strain controlled cyclic tests; after the application of 200 cycles of a certain strain amplitude, the sample was loaded to failure monotonically at a strain rate of 3%/min. Thus from Fig. 2 it could be argued that if a clay is subjected to 200 cycles of strain with an amplitude less than half its static failure strain, the material may be expected to retain at least 90% of its original static undrained strength.

Andersen (2), on the basis of cyclic simple shear tests on samples of Drammen clay, determined that the reduction in undrained shear strength was found to be less than 25% as long as the cyclic shear strain was less than ±3% even after 1,000 cycles. Some North Sea clays, however, have shown a strength reduction of up to 40% for the same level of cyclic loading.

On the basis of the experimental data reported previously and for values

TABLE 1.—Maximum Cyclic Shear Strains Calculated from Dynamic Finite Element Response Analyses

Magnitude (1)	Embankment height, in feet (2)	Slope, *H*:*V* (3)	Maximum base acceleration, *g* (4)	Maximum shear strain, as a percentage (5)
6-1/2 (Caltech record)	75	2:1	0.5	0.2–0.4
6-1/2 (Caltech record)	150	2:1	0.2	0.1–0.15
6-1/2 (Caltech record)	150	2:1	0.5	0.2–0.3
6-1/2 (Lake Hughes record)	150	2:1	0.2	0.1–0.15
6-1/2 (Caltech record)	150	2-1/2:1	0.5	0.2–0.3
7-1/2 (Taft record)	150	2:1	0.5	0.2–0.5
7-1/2 (Taft record)	150	2:1	0.2	0.1–0.2
8-1/4 (S-I record)	150	2:1	0.75	0.4–1.0
8-1/4 (S-I record)	135	—	0.4	0.2–0.5

Note: 1 ft = 0.305 m.

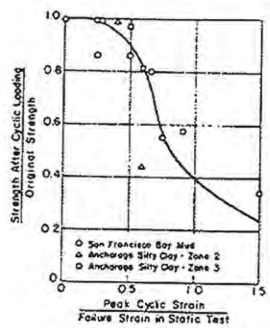

FIG. 2.—Reduction in Static Undrained Strength Due to Cyclic Loading (29)

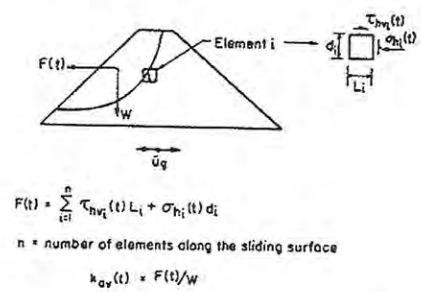

FIG. 3.—Calculation of Average Acceleration from Finite Element Response Analysis

of cyclic shear strains calculated from earthquake response analyses, the value of cyclic yield strength for a clayey material can be estimated. In most cases this value would appear to be 80% or more of the static undrained strength. This value in turn may be used in an appropriate method of stability analysis to calculate the corresponding yield acceleration.

Finite element response analyses (as will be described later) have been carried out to calculate time histories of crest acceleration and average acceleration

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for various potential sliding masses. The method of analysis employs the equivalent linear technique with strain-dependent modulus and damping. The ranges of calculated maximum shear strains, for different magnitude earthquakes and different embankment characteristics, are presented in Table 1. It can be seen from Table 1 that the maximum cyclic shear strain induced during the earthquakes ranged between 0.1% for a magnitude 6-1/2 earthquake with a base acceleration of 0.2 g and 1% for a magnitude 8-1/4 earthquake with a base acceleration of 0.75 g. For the compacted clayey material encountered in dam embankments "static failure strain" values usually range between 3%–10%, depending on whether the material was compacted on the dry or wet side of the optimum moisture content. Thus in both instances the ratio of the "cyclic strain" to "static failure strain" is less than 0.5.

It seems reasonable, therefore, to assume that for these compacted cohesive soils, very little reduction in strength may be expected as a result of strong earthquake loading of the magnitude described previously.

Once the cyclic yield strength is defined, the calculation of the yield acceleration can be achieved by using one of the available methods of stability analysis. In the present study the ordinary method of slices has been used to calculate the yield acceleration for circular slip surfaces using a pseudostatic analysis. As an alternative one of the writers (18) has suggested a method of combining both effective and total stress approaches, where the shear strength on the failure plane during the earthquake is considered to be a function of the initial effective normal stress on that same plane before the earthquake. This method is applicable to noncircular slip surfaces and the horizontal inertia force resulting in a factor of safety of unity can readily be calculated.

Having determined the yield acceleration for a certain location of the slip surface, the next step in the analysis is to determine the time history of earthquake-induced average accelerations for that particular sliding mass. This will be treated in the following section.

Determination of Earthquake Induced Acceleration

In order for the permanent deformations to be calculated for a particular slip surface, the time history of earthquake induced average accelerations must first be determined.

Two-dimensional finite element procedures using equivalent linear strain-dependent properties are available (6) and have been shown to provide response values in good agreement with measured values (8) and with closed-form one-dimensional wave propagation solutions (17).

For most of the case studies of embankments used in the present analysis, the response calculation was performed using the finite element computer program QUAD-4 (6) with strain-dependent modulus and damping. The program uses the Rayleigh damping approach and allows for variable damping to be used in different elements.

To calculate the time history of average acceleration for a specified sliding mass, the method described by Chopra (4) was adopted in the present study. The finite element calculation provides time histories of stresses for every element in the embankment. As shown in Fig. 3, at each time step the forces acting along the boundary of the sliding mass are calculated from the corresponding

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normal and shear stresses of the finite elements along that boundary. The resultant of these forces divided by the weight of the sliding mass would give the average acceleration, $k_{av}(t)$, acting on the sliding mass at that instant in time. The process is repeated for every time step to calculate the entire time history of average acceleration.

For a 150-ft (46-m) high dam subjected to 30 sec of the Taft earthquake record scaled to produce a maximum base acceleration of 0.2 g, the variation

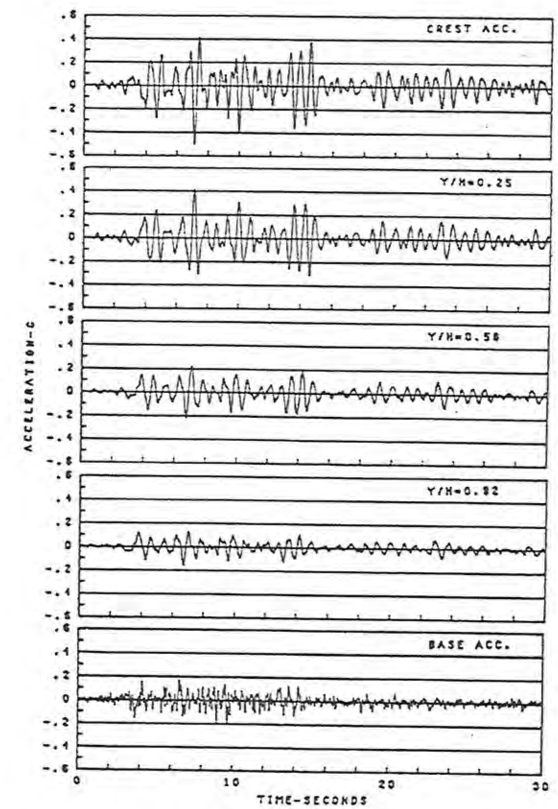

FIG. 4.—Time Histories of Average Acceleration for Various Depths of Potential Sliding Mass

of the time history of k_{av} with the depth of the sliding mass within the embankment, together with the time history of crest accelerations, is shown in Fig. 4.

Comparing the time history of crest acceleration with that of the average acceleration for different depths of the potential sliding mass, the similarity in the frequency content is readily apparent (it generally reflects the first natural period of the embankment), while the amplitudes are shown to decrease as the depth of the sliding mass increases towards the base of the embankment. The maximum crest acceleration is designated by $\ddot{u}_{max}$, and k_{max} is the maximum average acceleration for a potential sliding mass extending to a specified depth, y.

It would be desirable to establish a relationship showing the variation of the maximum acceleration ratio, $k_{max}/\ddot{u}_{max}$, with depth for a range of embankments and earthquake loading conditions. It would then be sufficient, for design purposes, to estimate the maximum crest acceleration in a given embankment due to a specified earthquake and use this relationship to determine the maximum average acceleration for any depth of the potential sliding mass. A simplified procedure to estimate the maximum crest acceleration and the natural period

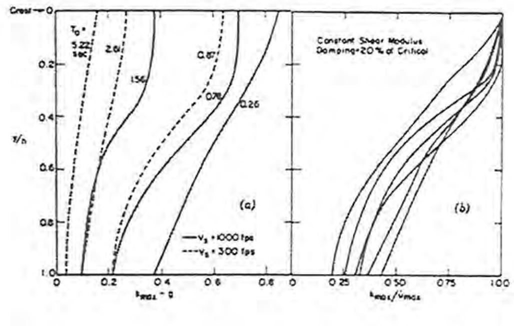

FIG. 5.—El Centro Record (12): (*a*) Variation of Maximum Average Acceleration with Depth of Sliding; (*b*) Variation of Ratio of Average Acceleration to Maximum Crest Acceleration with Depth of Sliding Surface

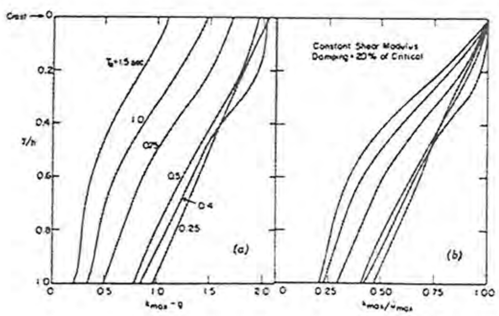

FIG. 6.—Average of Eight Strong Motion Records (1): (*a*) Variation of Maximum Average Acceleration with Depth of Sliding Mass; (*b*) Variation of Ratio of Maximum Average Acceleration to Maximum Crest Acceleration with Depth of Sliding Surface

of an embankment subjected to a given base motion is described in Appendix A of Ref. 11.

To determine the variation of maximum acceleration ratio with depth, use was made of published results of response computations using the one-dimensional shear slice method with visco-elastic material properties (1,26). Martin (12) calculated the response of embankments ranging in height between 100 ft–600 ft (30 m–180 m) and with shear wave velocities between 300 fps–1,000 fps (92 m/s–300 m/s). Using a constant shear modulus and a damping factor of 0.2,

the average acceleration histories for various levels were computed for embankments subjected to ground accelerations recorded in the El Centro earthquake of 1940. The variation of the maximum average acceleration, k_{max}, with depth for these embankments with natural periods ranging between 0.26 sec–5.22 sec is presented in Fig. 5(*a*). The maximum average acceleration in Fig. 5(*a*) is normalized with respect to the maximum crest acceleration and the ratio, $k_{max}/\ddot{u}_{max}$, plotted as a function of the depth of the sliding mass is presented in Fig. 5(*b*).

Ambraseys and Sarma (1) used essentially the same method reported by Seed and Martin (26) and calculated the response of embankments with natural periods ranging between 0.25 sec and 3.0 sec. They presented their results in terms of average response for eight strong motion records. The variation of maximum average acceleration with depth based on the results reported by Ambraseys and Sarma (1) is shown in Fig. 6(*a*) and that for the maximum acceleration ratio, $k_{max}/\ddot{u}_{max}$, is shown in Fig. 6(*b*). A summary of the results obtained

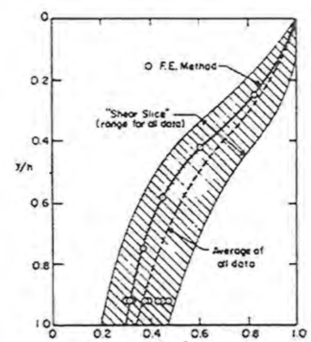

FIG. 7.—Variation of Maximum Acceleration Ratio with Depth of Sliding Mass

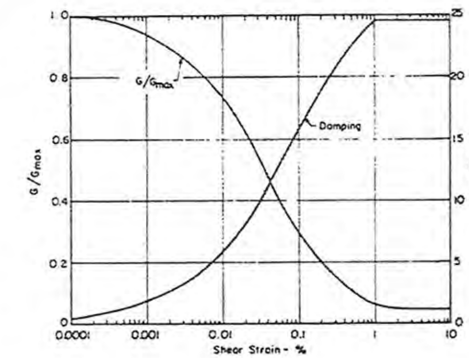

FIG. 8.—Shear Modulus and Damping Characteristics Used in Response Computations

from the different shear slice response calculations mentioned previously is presented in Fig. 7 together with results obtained from finite element calculations made in the present study. As can be seen from Fig. 7 the shape of the curves obtained using the shear slice method and the finite element method are very similar. The dashed curve in Fig. 7 is an average relationship of all data considered. The maximum difference between the envelope of all data and the average relationship ranges from ±10% to ±20% for the upper portion of the embankment and from ±20% to ±30% for the lower portion of the embankment.

Considering the approximate nature of the proposed method of analysis, the use of the average relationship shown in Fig. 7 for determining the maximum average acceleration for a potential sliding mass based on the maximum crest acceleration is considered accurate enough for practical purposes. For design computations where a conservative estimate of the accelerations is desired the upper bound curve shown in Fig. 7 may be used leading to values that are 10%–30% higher than those estimated using the average relationship.

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Once the yield acceleration and the time history of average induced acceleration for a potential sliding mass have been determined, the permanent displacements can readily be calculated.

By assuming a direction of the sliding plane and writing the equation of motion for the sliding mass along such a plane, the displacements that would occur any time the induced acceleration exceeds the yield acceleration may be evaluated by simple numerical integration. For the purposes of the soil types considered in this study, the yield acceleration was assumed to be constant throughout the earthquake.

TABLE 2.—Embankment Characteristics for Magnitude 6-1/2 Earthquake

Case number (1)	Embankment description (2)	Height, in feet (3)	Base acceleration, g (4)	T_0, in seconds (5)[a]	k_{max}, g (6)[b]	Symbol[c] (7)
1	Example slope = 2:1 k_{2max} = 60	150	0.2 (Caltech record)	0.8	(1) 0.31 (2) 0.12	● ■
2	Example slope = 2:1 k_{2max} = 60	150	0.5 (Caltech record)	1.08	(1) 0.4 (2) 0.18	○ □
3	Example slope = 2:1 k_{2max} = 80	150	0.5 (Lake Hughes record)	0.84	(1) 0.33 (2) 0.16	⊙ △
4	Example slope = 2-1/2:1 k_{2max} = 80	150	0.5 (Caltech record)	0.95	(1) 0.49 (2) 0.22	◇ ▽
5	Example slope = 2:1 k_{2max} = 60	75	0.5 (Caltech record)	0.6	(1) 0.86 (2) 0.26	◑ ◪

[a]Calculated first natural period of the embankment.
[b]Maximum value of time history of: (1) Crest acceleration; and (2) average acceleration for sliding mass extending through full height of embankment.
[c]Legend used in Fig. 9(a).
Note: 1 ft = 0.305 m.

The direction of motion for a potential sliding mass once yielding occurs

was assumed to be along a horizontal plane. This mode of deformation is not uncommon for embankments subjected to strong earthquake shaking, and is manifested in many cases in the field by the development of longitudinal cracks along the crest of the embankment. However studies made for other directions of the sliding surface showed that this factor had little effect on the computed displacements (11).

To calculate an order of magnitude of the deformations induced in embankments due to strong shaking a number of cases have been analyzed during the course of this study. The height of embankments considered ranged between 75 ft–150 ft (23 m–46 m) with varying slopes and material properties. The embankments were subjected to ground accelerations representing three different earthquake magnitudes: 6-1/2, 7-1/2, and 8-1/4.

The method used for calculating the response, as mentioned earlier, is a time-step finite element analysis using the equivalent linear method. The strain-dependent modulus and damping relations for the soils used in this study are

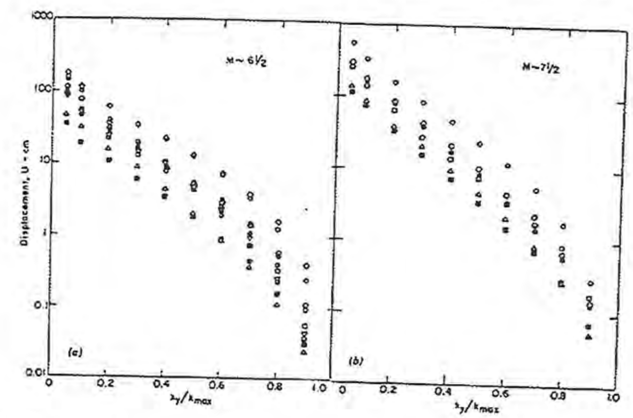

FIG. 9.—Variation of Permanent Displacement with Yield Acceleration: (a) Magnitude 6-1/2 Earthquake; (b) Magnitude 7-1/2 Earthquake

presented in Fig. 8. The response computation for each base motion was repeated for a number of iterations (mostly 3–4) until strain compatible material properties were obtained. In each case both time histories of crest acceleration and the average acceleration for a potential sliding mass extending through almost the full height of the embankment were calculated, together with the first natural period of the embankment. In one case however, time histories of average acceleration for sliding surfaces at five different levels in the embankment were obtained (see Fig. 4), and the corresponding permanent deformations for each time history were calculated for different values of yield acceleration. It was found that for the same ratio of yield acceleration to maximum average acceleration at each level, the computed deformations varied uniformly between a maximum value obtained using the crest acceleration time history to a minimum value obtained using the time history of average acceleration for a sliding mass extending through the full height of the embankment. Thus it was considered

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sufficient for the remaining cases to compute the deformations only for these two levels.

Table 2 shows details of the embankments analyzed using ground motions representative of a magnitude 6-1/2 earthquake. The two rock motions used were those recorded at the Cal Tech Seismographic Laboratory (S90W Component) and at Lake Hughes Station No. 12 (N12E) during the 1971 San Fernando earthquake, with maximum accelerations scaled to 0.2 *g* and 0.5 *g*. The computed natural periods and maximum values of the acceleration time histories are also presented in Table 2. The computed natural periods ranged between a value of 0.6 sec for the 75-ft (23-m) high embankment to a value of 1.08 sec for the 150-ft (46-m) high embankment. Because of the nonlinear strain-dependent

TABLE 3.—Embankment Characteristics for Magnitude 7-1/2 Earthquake

Case number (1)	Embankment description (2)	Height, in feet (3)	Base acceleration, *g* (4)	T_0, in seconds (5)[a]	k_{max}, *g* (6)[b]	Symbol[c] (7)
1	Example slope = 2:1 k_{2max} = 60	150	0.2 (Taft record)	0.86	(1) 0.41 (2) 0.13	● ■
2	Example slope = 2:1 k_{2max} = 60	150	0.5 (Taft record)	1.18	(1) 0.54 (2) 0.21	○ □
3	Example slope = 2-1/2:1 k_{2max} = 80	150	0.2 (Taft record)	0.76	(1) 0.46 (2) 0.15	⊙ △

[a]Calculated first natural period of the embankment.
[b]Maximum value of time history of: (1) Crest acceleration; and (2) average acceleration for sliding mass extending through full height of embankment.
[c]Legend used in Fig. 9(*b*).
Note: 1 ft = 0.305 m.

behavior of the material, the response of the embankment is highly dependent on the amplitude of the base motion. This is clearly demonstrated in the first two cases in Table 2, where the same embankment was subjected to the same ground acceleration history but with different maximum accelerations for each case. In one instance, for a base acceleration of 0.2 *g* the calculated maximum crest accelerations was 0.3 *g* with a magnification of 1.5 and a computed natural period of the order of 0.8 sec. In the second case, for a base acceleration of 0.5 *g* the computed maximum crest acceleration was 0.4 *g* with an attenuation of 0.8 and a computed natural period of 1.1 sec.

From the time histories of induced acceleration calculated for all the cases

described in Table 2 and for various ratios of yield acceleration to maximum average acceleration, k_y/k_{max}, the permanent deformations were calculated by numerical double integration. The results are presented in Fig. 9(*a*) which shows that for relatively low values of yield acceleration, k_y/k_{max} of 0.2 for example, the range of computed permanent displacements was of the order of 10 cm–70 cm (4 in.–28 in.). However, for larger values of k_y/k_{max}, say 0.5 or more, the calculated displacements were less than 12 cm (4.8 in.). It should be emphasized that for very low values of yield accelerations (in this case $k_y/k_{max} \leq 0.1$) the basic assumptions used in calculating the response by the finite element

TABLE 4.—Embankment Characteristics of Magnitude 8-1/4 Earthquake

Case number (1)	Embankment description (2)	Height, in feet (3)	Base acceleration, *g* (4)	T_0, in seconds (5)[a]	k_{max}, *g* (6)[b]	Symbol[c] (7)
1	Chabot Dam (average properties)	135	0.4 (S-I Synth. record)	0.99	(1) 0.57	○
	Chabot Dam (Lower bound)	135	0.4 (S-I Synth. record)	1.07	(1) 0.53	△
	Chabot Dam (Upper bound)	135	0.4	0.83	(1) 0.68	□
2	Example slope = 2:1 k_{2max} = 60	150	0.75	1.49	(1) 0.74 (2) 0.34	● ■

[a]Calculated first natural period of the embankment.
[b]Maximum value of time history of: (1) Crest acceleration; and (2) average acceleration for sliding mass extending through full height of embankment.
[c]Legend used in Fig. 10(*a*).
Note: 1 ft = 0.305 m.

method, i.e., the equivalent linear behavior and the small strain theory, become invalid. Consequently, the acceleration time histories calculated for such a case do not represent the real field behavior and the calculated displacements based on these time histories may not be realistic.

The procedure described previously was repeated for the case of a magnitude 7-1/2 earthquake. The base acceleration time history used for this analysis was that recorded at Taft during the 1952 Kern County earthquake and scaled to maximum accelerations of 0.2 *g* and 0.5 *g*. The details of the three cases analyzed are presented in Table 3 and the results of the computations of the

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permanent displacements are shown in Fig. 9(b). For a ratio of k_y/k_{max} of 0.2 the calculated displacements in this case ranged between 30 cm–200 cm (12 in.–80 in.), and for ratios greater than 0.5 the displacements were less than 25 cm (0.8 ft).

In the cases analyzed for the 8-1/4 magnitude earthquake, an artificial accelerogram proposed by Seed and Idriss (21) was used with maximum base accelerations of 0.4 g and 0.75 g. Two embankments were analyzed in this case and their calculated natural periods ranged between 0.8 sec and 1.5 sec. Table 4 shows the details of the calculations and in Fig. 10(a) the results of the permanent displacement computations are presented. As can be seen from Fig. 10(a) the permanent displacements computed for a ratio of k_y/k_{max} of 0.2 ranged between 200 cm–700 cm (80 in.–28 in.), and for ratios higher than 0.5 the values were less than 100 cm (40 in.). Note in this case that values of deformations calculated for a yield ratio less than 0.2 may not be realistic.

An envelope of the results obtained for each of the three earthquake loading

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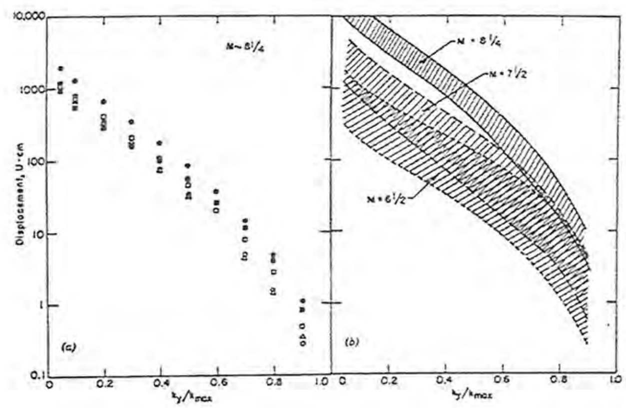

FIG. 10.—Variation of Permanent Displacement with Yield Acceleration: (*a*) Magnitude 8-1/4 Earthquake; (*b*) Summary of All Data

conditions is presented in Fig. 10(b) and reveals a large scatter in the computed results reaching, in the case of the magnitude 6-1/2 earthquake, about one order of magnitude.

It can reasonably be expected that for a potential sliding mass with a specified yield acceleration, the magnitude of the permanent deformation induced by a certain earthquake loading is controlled by the following factors: (1) The amplitude of induced average accelerations, which is a function of the base motion, the amplifying characteristics of the embankment, and the location of the sliding mass within the embankment; (2) the frequency content of the average acceleration time history, which is governed by the embankment height and stiffness characteristics, and is usually dominated by the first natural frequency of the embankment; and (3) the duration of significant shaking, which is a function of the magnitude of the specified earthquake.

Thus to reduce the large scatter exhibited in the data in Fig. 10(b), the permanent

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displacements for each embankment were normalized with respect to its calculated first natural period, T_0, and with respect to the maximum value, k_{max}, of the average acceleration time history used in the computation. The resulting normalized permanent displacements for the three different earthquakes are presented in Fig. 11(a). It may be seen that a substantial reduction in the scatter of the data is achieved by this normalization procedure as evidenced by comparing the results in Figs. 10(b) and 11(a). This shows that for the ranges of embankment heights considered in this study [75 ft–150 ft (50 m–65 m)] the first natural period of the embankment and the maximum value of acceleration time history may be considered as two of the parameters having a major influence on the calculated permanent displacements. Average curves for the normalized permanent displacements based on the results in Fig. 11(a) are presented in Fig. 11(b). Although some scatter still exists in the results as shown in Fig. 11(a), the average curves presented in Fig. 11(b) are considered adequate to provide an order of magnitude of the induced permanent displacements for different

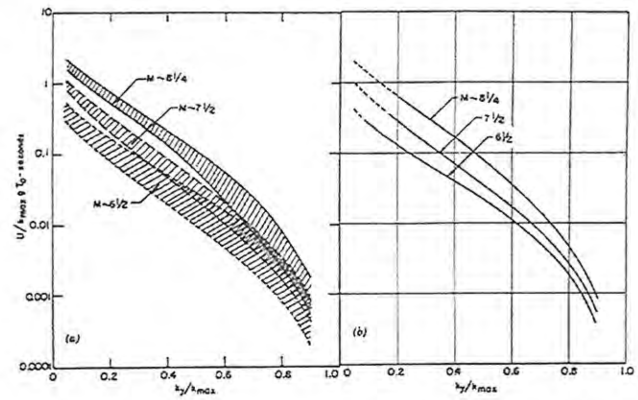

FIG. 11.—Variation of Yield Acceleration with: (*a*) Normalized Permanent Displacement—Summary of All Data; and (*b*) Average Normalized Displacement

magnitude earthquakes. At yield acceleration ratios less than 0.2 the average curves are shown as dashed lines since, as mentioned earlier, the calculated displacements at these low ratios may be unrealistic.

Thus, to calculate the permanent deformation in an embankment constructed of a soil that does not change in strength significantly during an earthquake, it is sufficient to determine its maximum crest acceleration, $\ddot{u}_{max}$, and first natural period, T_0, due to a specified earthquake. Then by the use of the relationship presented in Fig. 7, the maximum value of average acceleration history, k_{max}, for any level of the specified sliding mass may be determined. Entering the curves in Fig. 11(b) with the appropriate values of k_{max} and T_0, the permanent displacements can be determined for any value of yield acceleration associated with that particular sliding surface.

It has been assumed earlier in this paper that in the majority of embankments, permanent deformations usually occur due to slip of a sliding mass on a horizontal failure plane. For those few instances where sliding might occur on an inclined strength of the material and in estimating the maximum accelerations in the embankment, the calculated deformations for this 135-ft (40-m) clayey embankment ranged between 0.1 ft–1.5 ft (0.3 m–0.46 m). These approximate displacement values are in good accord with the actual performance of the embankment during the earthquake.

Whereas the method described herein provides a rational approach to the design of embankments and offers a significant improvement over the conventional pseudostatic approach, the nature of the approximations involved requires that it be used with caution and good judgment especially in determining the soil characteristics of the embankment to which it may be applied.

For large embankments, for embankments where failure might result in a loss of life or major damage and property loss, or where soil conditions cannot be determined with a significant degree of accuracy to warrant the use of the method, the more rigorous dynamic method of analysis described earlier might well provide a more satisfactory alternative for design purposes.

Acknowledgment

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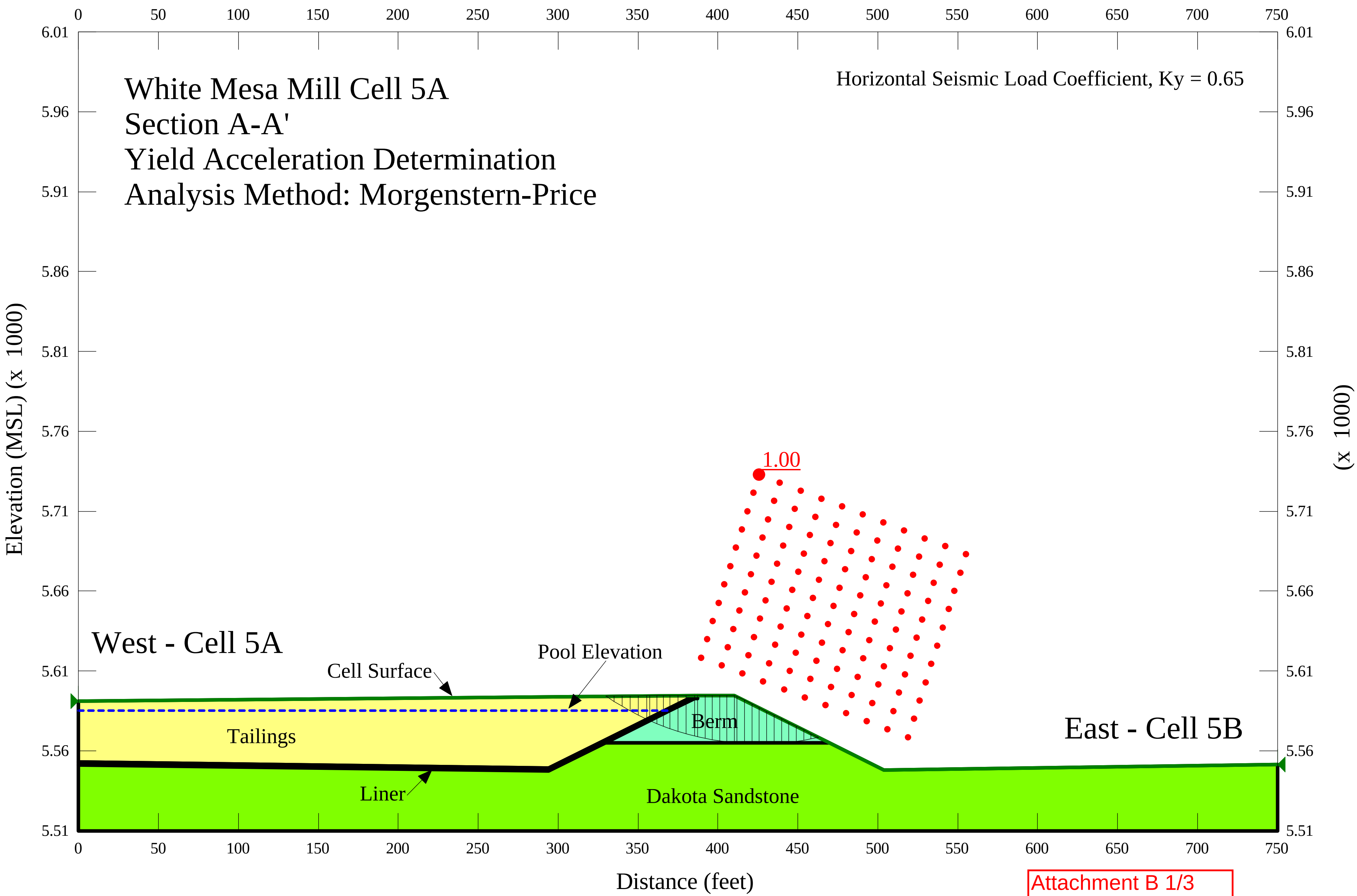
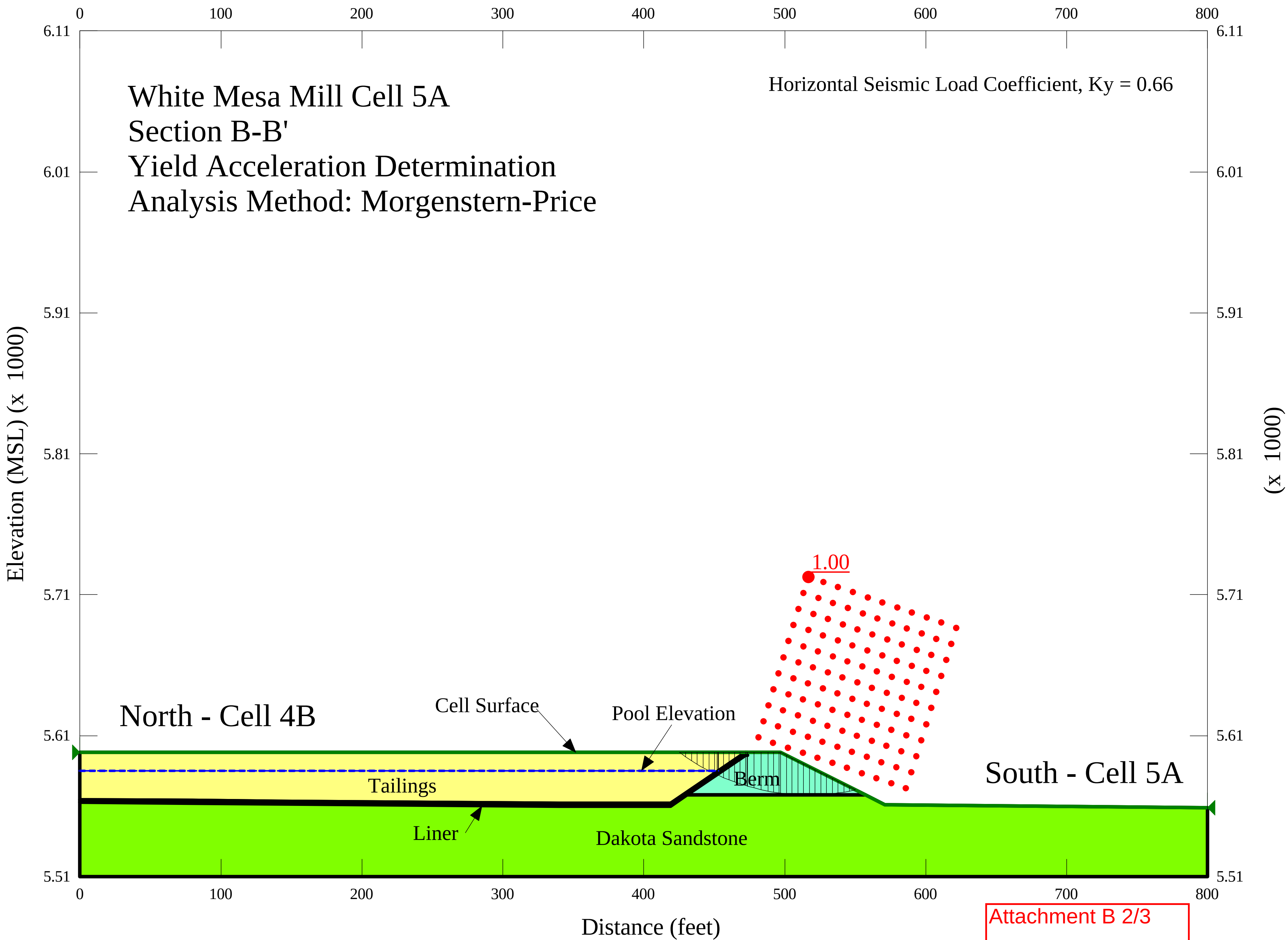
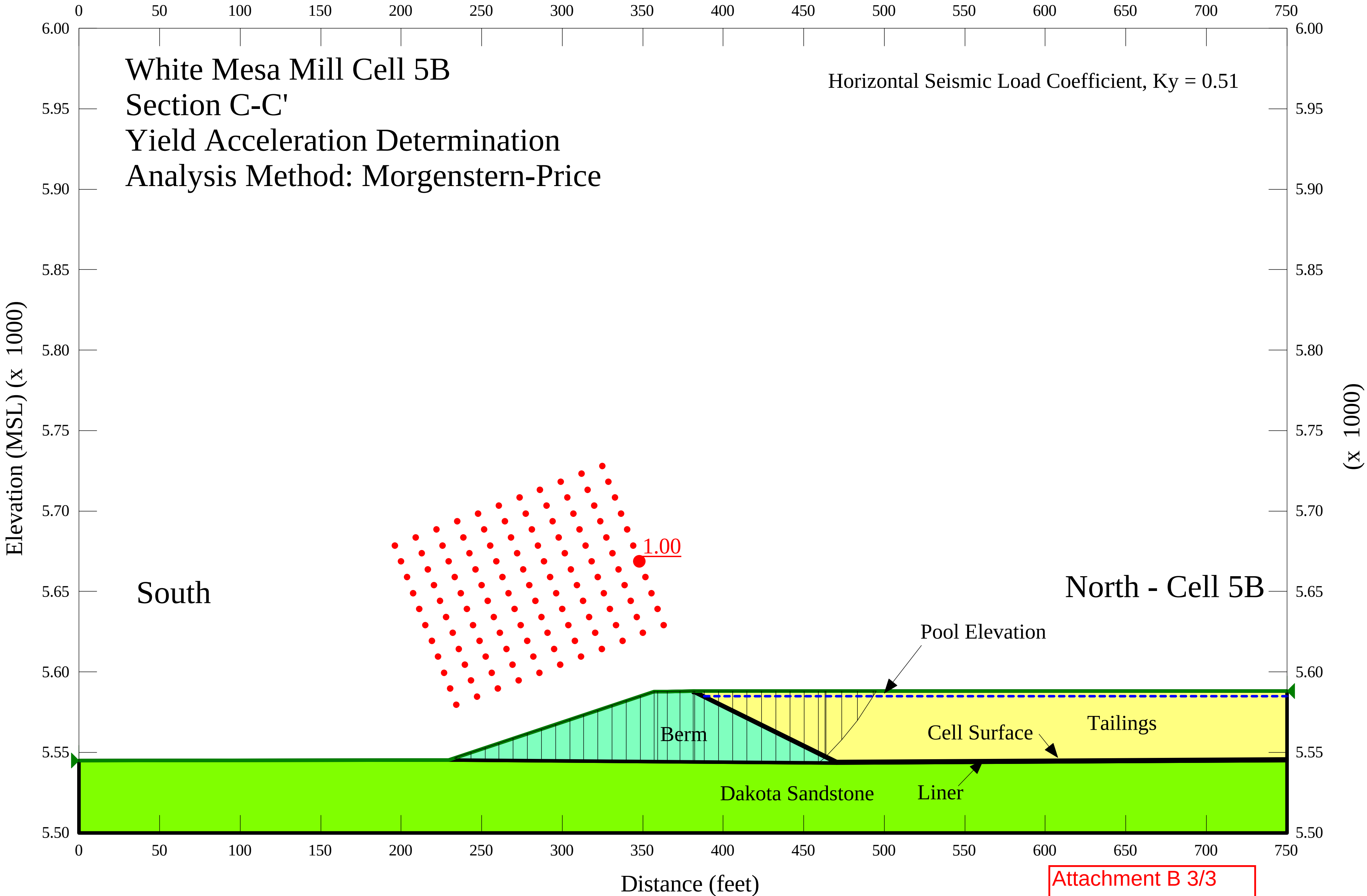


Attachment B 1/3



Attachment B 2/3



Attachment B 3/3

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F
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November 27, 2006

MFG Project No. 181413x.102

Mr. Harold R. Roberts
International Uranium (USA) Corporation
1050 Seventeenth Street, Suite 950
Denver, CO 80265

Subject: **White Mesa Uranium Facility**
Cell 4 Seismic Study
Blanding, Utah

Dear Mr. Roberts:

This document has been prepared to examine the seismicity of the White Mesa site and to recommend a design peak ground acceleration (PGA) to be incorporated in the Cell 4A design. This letter addresses concerns brought forth in comments by Utah Department of Environmental Quality (UDEQ) as documented in Interrogatory IUC R313-24-4-05/05: Dike Integrity.

Comments in Interrogatory IUC R313-24-4-05/05

Comments from UDEQ state that the seismic loading used (0.10 g) for stability analysis of the Cell 4A slopes is based on an outdated seismic analysis presented in the 1988 Cell 4 Design Report (UMETCO), and that updated seismic hazard analysis should be performed. As stated in the Interrogatory 05, it is not thought that there is any new information on active faults that would impact the hazard at White Mesa. However, UDEQ requested ground motion attenuation relationships be updated to reflect current evaluation methods.

Original Design Basis for Cell 4

This original design report for Cell 4 (UMETCO, 1988), characterized the geologic conditions at the site. Section 1.3.4 identified potential earthquake hazards to the project. The specified hazards include minor random earthquakes not associated with a known seismic structure, and an unnamed fault located 57 km north of the project site (north of Monticello), with a fault length well defined for 3 km, and possibly as long as 11 km. The fault is considered a suspected Quaternary fault, but does not have strong evidence for Quaternary movement. Estimates of the maximum credible earthquake (MCE) associated with this fault were estimated to have a magnitude of 6.4 based on relationships developed by Slemmons in 1977. Ground motions at the project site were estimated using attenuation curves established in 1982 by Seed and Idriss. Peak horizontal accelerations at the site from the fault were estimated to be 0.07 g.

Attachment C, 1/4

Updated attenuation relationships

A search of the Quaternary Fault and Fold Database (USGS 2006) lists Shay graben faults as a Class B (suspected) Quaternary fault. No other faults within 50 km of the site are included in the database. Shay graben faults were included in the Lawrence Livermore National Laboratory (LLNL) report. Other faults considered as possible seismic sources include the unnamed fault north of Monticello that was the design basis of the design accelerations in the 1988 report.

Many attenuation relationships have been developed within the last ten years and are currently being used to estimate ground motions. Three relationships are used in this report to estimate the peak ground motion at the White Mesa site. Abrahamson and Silva (1997) is a well accepted relationship used for shallow crustal earthquakes in Western North America. In addition, Spudich et al. (1999) is used because it has been specifically developed for extensional tectonic regimes, such as those encountered in the area of the site. Campbell and Bozorgnia (2003), is also examined as a current, applicable model, which accounts for normal faulting. In all cases, mean values plus one standard deviation are reported. A comparison of the three methods can be found in Table 1.

Design Peak Ground Acceleration for Cell 4

The above discussion is based on the PGA associated with MCE predicted for a known tectonic feature, and as such, cannot be correlated to a specific return period. 10 CFR 100 Appendix A and 10 CFR 40 Appendix A of Nuclear Regulatory Commission (NRC) regulations are interpreted to apply to long-term, reclaimed impoundments. A distinction should be made between seismic conditions that apply to operational conditions versus long-term conditions. Disposal areas are required to demonstrate closure performance that provides control of radiological hazards to be effective for one thousand years, to the extent reasonably achievable, and, in any case, for at least 200 years. However, this standard should not apply to the operational time-period of the disposal cell. In 2002, the USGS updated the National Seismic Hazard Maps (NSHM), which show peak ground and spectral accelerations at 2 percent and 10 percent probability of exceedance in 50 years. From these maps, the PGA for the White Mesa site is shown to be 0.090 g with a 2 percent probability of exceedance in 50 years. The probability of exceedance can be represented by the following equation:

$$PE = 1 - e^{-(n/T)}$$

Where PE = probability of exceedance, n = time period, in years, and T = return period, in years.

It can be shown that the return period associated with a PGA of 0.090 g is equivalent to 2,475 years, and if the life of the project is conservatively taken to be 100 years, the probability of exceedance of 0.090 g is approximately 4 percent. Therefore, the PGA taken from the USGS maps is an appropriate design acceleration to use for operational conditions of the disposal cell.

Conclusions

The seismic loading of 0.1 g used in analysis of the Cell 4A dikes exceeds the PGA associated with a 2 percent probability of exceedance within 50 years, and is appropriate for the operational life of the disposal cell. At the time when design of closure is implemented, design PGA based on the MCE associated with known or suspected Quaternary features and the background seismicity of the area should be incorporated into the design long-term seismic loading.

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If we can be of further assistance, please do not hesitate to contact the undersigned.

Sincerely,

TETRA TECH COMPANY
MFG, INC.

Roslyn Stern

Roslyn Stern
Senior Staff Geotechnical Engineer

Reviewed by:

Thomas A. Chapel, PE
Senior Geotechnical Engineer

REGISTERED PROFESSIONAL ENGINEER
No. 6232722-2202
THOMAS A. CHAPEL
11-27-06
STATE OF UTAH

cc: Tetra Tech EM
Ms. JoAnn Tischler

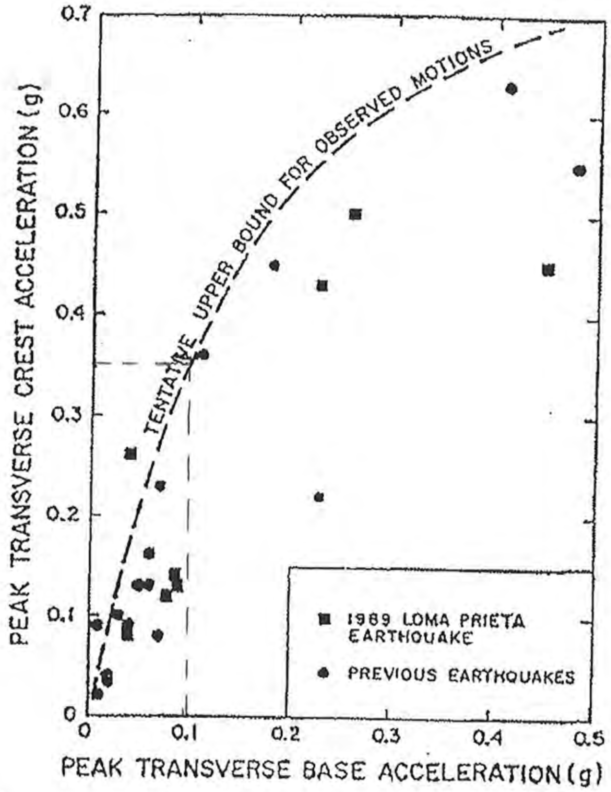
Attachment(s)

Table 1: Peak Ground Accelerations – White Mesa

Name	Fault Length (km)	Fault Type[1]	Site Class[2]	Distance from site (km)	MCE (Wells and Coppersmith, 1994)	PGA Mean plus 1 SD (Spudich et al., 1999)	PGA Mean plus 1 SD (Abrahamson and Silva, 1997)	PGA Mean plus 1 SD, Campbell-Bozorgnia 2003	PGA Mean plus 1 SD average
unnamed fault north of Monticello, defined length	3.0	N	R	57.4	5.49	0.034	0.027	0.037	0.032
unnamed fault north of Monticello, possible total length	11.0	N	R	57.4	6.23	0.050	0.059	0.055	0.055
unnamed fault north of Monticello, 1/2 total rupture	5.5	N	R	57.4	5.84	0.041	0.039	0.044	0.041
Shay graben faults (Class B)	40.0	N	R	44.6	6.97	0.096	0.116	0.113	0.108

[1]Fault Type: N = Normal
[2]Site Class: R =Rock or shallow soils

Att C, 4/4



Source: Harder [1991]

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PEAK TRANSVERSE CREST ACCELERATION VERSUS PEAK TRANSVERSE BASE ACCELERATION	FIGURE NO.
	PROJECT NO. SC0349
	DATE: April 2008

Attachment D
1/1

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF**	Project: **White Mesa Mill – Cells 5A and 5B**	Project/ Proposal No.:	**SC0634**
		Task No.	**02**

Title of Computations **SETTLEMENT ANALYSIS OF BERMS**

Computations by:	Signature		Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		Date 12/20/12
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations Checked by:	Signature		Date 12/18/12
	Printed Name	Jay Griffin	
	Title	Senior Staff Engineer	
Computations backchecked by: (originator)	Signature		Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature		Date 12/18/12
	Printed Name	Gregory T. Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

SC0643.BermSettlement5A-5B.20121213.F.calc.docx

Written by:	R. Flynn	Date:	11/9/12	Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	Cells 5A and 5B	Project No.:	SC0634	Task No.:	02

SETTLEMENT EVALUATION OF BERMS

OBJECTIVE

The objective of this calculation is to evaluate the differential settlement under the loading from the berms at the perimeter of the cells to assess the potential effect on the system.

SUMMARY OF DESIGN

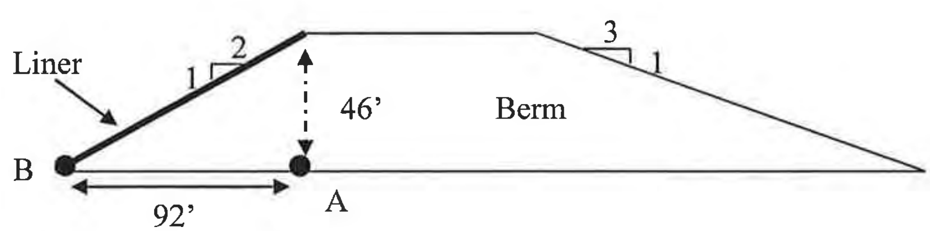
Based on the assumptions and calculations presented herein, the differential settlement of the berms will be approximately 0.20 inches at the toe of the slope and approximately 0.33 inches at the top of the slope, causing a strain of approximately 0.01% of the liner, when the cell is empty. When the cell is full, the differential settlement of the berms will be approximately 2.89 inches at the toe of the slope and approximately 3.13 inches at the top of the slope, causing a strain of approximately 0.002% of the liner.

ANALYSIS

Task 1: Evaluate the settlement of the berm in empty conditions.

Evaluate the settlement under the center of the berm versus at the toe of the berm.

Based on the proposed grading for Cells 5A and 5B (Attachment A), the following cross-section can be evaluated for the highest berm of the two cells (the south berm of Cell 5B).



Written by:	R. Flynn	Date:	11/9/12	Reviewed by:	G. Corcoran	Date:	12/18/12
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A unit weight of 137 pounds per cubic foot (pcf) for the berm material was estimated using data from a boring advanced in the existing berm between Cell 4A and 4B (Attachment B):

$$P, load = \gamma \times H = (137\,pcf)(46\,ft) = 6{,}302\ psf$$

Assuming the foundation for the berm consists of formational soil consisting of silty and clayey coarse to fine sandstone with layered shale (Attachment C), and based on the dense nature of the soil and underlying sandstone, the conservative stress-strain modulus is assumed to be as follows:

E_s = 1500 MPa (Boyles, 5th Ed., Attachment D)

$$E_S = 1500\ MPa \times \frac{145\frac{lb}{in^2}}{1\ MPa} \times \frac{144 in^2}{1 ft^2} \times \frac{1 kip}{1000 lb} = 31{,}320\ ksf$$

The settlement, S, is calculated in Table 1 using the elastic theory (Attachment E,1/2).

Elastic Theory: $\Delta = \frac{PL}{AE_E}$

Where:
- Δ = deformation
- P = force (F)
- L = length of material column (L)
- A = area of material column (L^2)
- E_E = Modulus of Elasticity (F/L^2)

For this analysis, the Boussinesq case for influence under a triangular load will be used, as presented in DM7.1-171. (Attachment E, 1/2). Translating the terms from Elastic Theory to apply to the Boussinesq approach to settlement calculation, the following equation is derived:

$$S = \frac{(4I \times P)(\Delta H)}{(A)(Es)} \times (\frac{12\ in}{1\ ft})$$ (Attachment E, 2/2)

Where:
- S = Settlement (Δ in Elastic Theory)
- P = 6302 lb

Written by:	R. Flynn	Date:	11/9/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project No.:	SC0634	Task No.:	02

A = 1 ft^2
ΔH = incremental depth, ft (L in Elastic Theory)
E_S = Soil Modulus, = E_E in Elastic Theory
I = Boussinesq zone of influence, obtained from Figure 7 on page DM7.1-171 using m and n parameters (Attachment F, 1/2).

To Find I:

n = B/z (Attachment F)
m = L/z (Attachment F)
B = 92 ft, distance from outer edge of berm
L = 1,410 ft, length along berm edge
z = depth, ft
σz = 4I*P, ksf

Table 1. Settlement due to load under the embankment at the top of the slope, using Figure 7, "Beneath Corner O" chart, (Point A):

z (ft)	n = B/z	m = L/z	I	4I	σz=4I*P (ksf)	E_s (ksf)	ΔH (ft)	S (in)
5	18.4	282.0	0.240	0.96	6.0	31,320	5	0.012
10	9.2	141.0	0.235	0.94	5.9	31,320	5	0.011
15	6.1	94.0	0.230	0.92	5.8	31,320	5	0.011
20	4.6	70.5	0.220	0.88	5.5	31,320	5	0.011
40	2.3	35.3	0.200	0.80	5.0	31,320	20	0.039
60	1.5	23.5	0.175	0.70	4.4	31,320	20	0.034
80	1.2	17.6	0.158	0.63	4.0	31,320	20	0.031
100	0.9	14.1	0.140	0.56	3.5	31,320	20	0.027
150	0.6	9.4	0.108	0.43	2.7	31,320	50	0.052
200	0.5	7.1	0.075	0.30	1.9	31,320	50	0.036
250	0.4	5.6	0.046	0.18	1.2	31,320	50	0.022
300	0.3	4.7	0.042	0.17	1.1	31,320	50	0.020
350	0.3	4.0	0.028	0.11	0.7	31,320	50	0.014
400	0.2	3.5	0.028	0.11	0.7	31,320	50	0.014
							Total S, in.	0.333

Settlement under A (S_A), the center of the berm, is approximately **0.33inches**.

The calculation is repeated in Table 2 for settlement at the toe of the berm also using Figure 7, but the influence chart used is "Beneath Corner Q" chart.

Table 2. Settlement due to load at toe of the slope (Point B):

z (ft)	n = B/z	m = L/z	I	4I	σz=4I*P (ksf)	E_s (ksf)	ΔH (ft)	S (in)
5	18.4	282.0	0.080	0.32	2.0	31,320	5	0.004
10	9.2	141.0	0.080	0.32	2.0	31,320	5	0.004
15	6.1	94.0	0.080	0.32	2.0	31,320	5	0.004
20	4.6	70.5	0.080	0.32	2.0	31,320	5	0.004
40	2.3	35.3	0.080	0.32	2.0	31,320	20	0.015
60	1.5	23.5	0.080	0.32	2.0	31,320	20	0.015
80	1.2	17.6	0.080	0.32	2.0	31,320	20	0.015
100	0.9	14.1	0.077	0.31	1.9	31,320	20	0.015
150	0.6	9.4	0.061	0.24	1.5	31,320	50	0.029
200	0.5	7.1	0.053	0.21	1.3	31,320	50	0.026
250	0.4	5.6	0.042	0.17	1.1	31,320	50	0.020
300	0.3	4.7	0.041	0.16	1.0	31,320	50	0.020
350	0.3	4.0	0.029	0.12	0.7	31,320	50	0.014
400	0.2	3.5	0.028	0.11	0.7	31,320	50	0.014
							Total S, in.	0.199

Settlement under point B (S_B), the toe of the berm, is approximately **0.20 inches**.

Evaluate the elastic strain of the side slope liner system related to settlement.

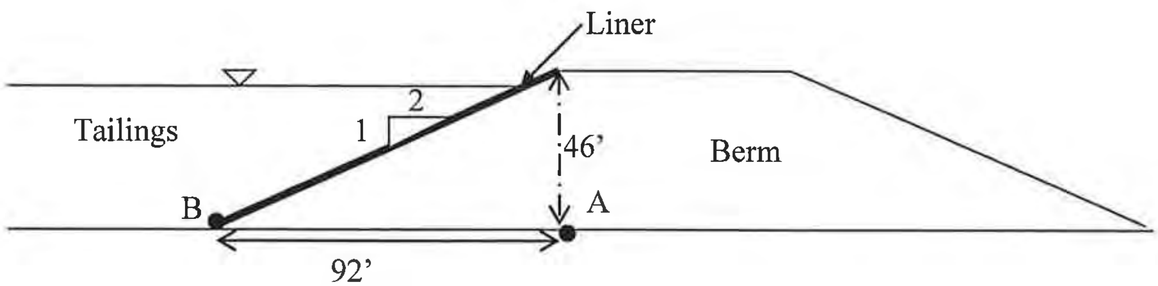
ΔS = 0.33-0.20 = 0.13 inches.

The liner is $\sqrt{[(92\,ft)^2 + (46\,ft)^2]} = 103\ ft$ in length.

Therefore, the strain in the liner is $\dfrac{0.13\,in}{103\,ft \times \dfrac{12in}{1\,ft}} = 0.01\%$

Task 2: Evaluate the settlement under the berm upon filling of the Cell.

Upon filling the Cell, the foundation may show differential settlement between Point A and Point B on the liner.



Written by:	R. Flynn	Date:	11/9/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project No.:	SC0634	Task No.:	02

Assume the following conditions:

Berm Material: $\gamma = 137\ psf$
Tailing Material: $\gamma = 125\ psf$
Foundation Soil: E_s = 31,320 ksf
Length L = 1,410 ft
Width B = 1,000 ft

Load over Point A:

P_A = 6,302 *psf* at a distance of 92 ft

Load over Point B:

P_B = (125 *psf*)(46 *ft*) = 5,750 *psf*

Calculations are performed using the equation defined in the previous section. Calculations are shown in Table 3 use influence values obtained from Figure 3 on page 7.1-167 of DM 7.1 (Attachment F, 2/2) for infinitely long footing.

Table 3. Settlement due to load under the embankment (filled condition)

z (ft)	z/B	I	σz=I*P (ksf)	E_s (ksf)	ΔH (ft)	S (in)
5	0.01	1.00	6.30	31,320	5	0.012
10	0.01	1.00	6.30	31,320	5	0.012
15	0.02	1.00	6.30	31,320	5	0.012
20	0.02	1.00	6.30	31,320	5	0.012
40	0.04	1.00	6.30	31,320	20	0.048
60	0.06	1.00	6.30	31,320	20	0.048
80	0.08	1.00	6.30	31,320	20	0.048
100	0.10	0.97	6.11	31,320	20	0.047
150	0.15	0.92	5.80	31,320	50	0.111
200	0.20	0.90	5.67	31,320	50	0.109
300	0.30	0.89	5.61	31,320	100	0.215
400	0.40	0.85	5.36	31,320	100	0.205
500	0.50	0.75	4.73	31,320	100	0.181

Written by:	R. Flynn	Date:	11/9/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project No.:	SC0634	Task No.:	02

z (ft)	z/B	I	σz=I*P (ksf)	Es (ksf)	ΔH (ft)	S (in)
600	0.60	0.70	4.41	31,320	100	0.169
700	0.70	0.66	4.16	31,320	100	0.159
800	0.80	0.61	3.84	31,320	100	0.147
900	0.90	0.58	3.66	31,320	100	0.140
1000	1.00	0.53	3.34	31,320	100	0.128
1100	1.10	0.50	3.15	31,320	100	0.121
1200	1.20	0.49	3.09	31,320	100	0.118
1300	1.30	0.44	2.77	31,320	100	0.106
1400	1.40	0.40	2.52	31,320	100	0.097
1500	1.50	0.39	2.46	31,320	100	0.094
1600	1.60	0.37	2.33	31,320	100	0.089
1700	1.70	0.35	2.21	31,320	100	0.085
1800	1.80	0.34	2.14	31,320	100	0.082
1900	1.90	0.32	2.02	31,320	100	0.077
2000	2.00	0.30	1.89	31,320	100	0.072
2100	2.10	0.29	1.83	31,320	100	0.070
2200	2.20	0.28	1.76	31,320	100	0.068
2300	2.30	0.27	1.70	31,320	100	0.065
2400	2.40	0.26	1.64	31,320	100	0.063
2500	2.50	0.25	1.58	31,320	100	0.060
2600	2.60	0.24	1.51	31,320	100	0.058
					Total	3.130

Settlement under A (S_A), the center of the berm, is **3.13 inches.**

For point B, assume uniform loading (aerial fill) and B = 1000 feet for infinitely long footing, again using Figure 3 on page DM7.1-167 (Attachment D, 2/2). The calculation of settlement for this condition is shown in Table 4.

Table 4. Settlement due to load under the toe of the slope (filled condition)

z (ft)	z/B	I	σz=I*P (ksf)	E_s (ksf)	ΔH (ft)	S (in)
5	0.01	1.00	5.75	31,320	5	0.011
10	0.01	1.00	5.75	31,320	5	0.011
15	0.02	1.00	5.75	31,320	5	0.011
20	0.02	1.00	5.75	31,320	5	0.011
40	0.04	1.00	5.75	31,320	20	0.044

Written by:	R. Flynn	Date:	11/9/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	EF	Project:	Cells 5A and 5B	Project No.:	SC0634	Task No.:	02

z (ft)	z/B	I	σz=I*P (ksf)	Es (ksf)	ΔH (ft)	S (in)
60	0.06	1.00	5.75	31,320	20	0.044
80	0.08	1.00	5.75	31,320	20	0.044
100	0.10	0.98	5.64	31,320	20	0.043
150	0.15	0.95	5.46	31,320	50	0.105
200	0.20	0.92	5.29	31,320	50	0.101
300	0.30	0.90	5.18	31,320	100	0.198
400	0.40	0.83	4.77	31,320	100	0.183
500	0.50	0.75	4.31	31,320	100	0.165
600	0.60	0.71	4.08	31,320	100	0.156
700	0.70	0.69	3.97	31,320	100	0.152
800	0.80	0.61	3.51	31,320	100	0.134
900	0.90	0.60	3.45	31,320	100	0.132
1000	1.00	0.55	3.16	31,320	100	0.121
1100	1.10	0.52	2.99	31,320	100	0.115
1200	1.20	0.49	2.82	31,320	100	0.108
1300	1.30	0.46	2.65	31,320	100	0.101
1400	1.40	0.41	2.36	31,320	100	0.090
1500	1.50	0.39	2.24	31,320	100	0.086
1600	1.60	0.37	2.13	31,320	100	0.082
1700	1.70	0.35	2.01	31,320	100	0.077
1800	1.80	0.34	1.96	31,320	100	0.075
1900	1.90	0.32	1.84	31,320	100	0.070
2000	2.00	0.31	1.78	31,320	100	0.068
2100	2.10	0.29	1.67	31,320	100	0.064
2200	2.20	0.28	1.61	31,320	100	0.062
2300	2.30	0.27	1.55	31,320	100	0.059
2400	2.40	0.26	1.50	31,320	100	0.057
2500	2.50	0.25	1.44	31,320	100	0.055
2600	2.60	0.24	1.38	31,320	100	0.053
					Total	2.891

Settlement under point B (S_B), the toe of the berm, is **2.89 inches**.

Evaluate for strain

ΔS = 3.13-2.89 = 0.24 inches.

Written by:	**R. Flynn**	Date:	**11/9/12**	Reviewed by:	**G. Corcoran**	Date:	12/18/12
Client:	**EF**	Project:	**Cells 5A and 5B**	Project No.:	**SC0634**	Task No.:	**02**

The liner is $\sqrt{[(92\,ft)^2 + (46\,ft)^2]} = 103\ ft$ in length.

Therefore, the strain in the liner is $\dfrac{0.24\,in}{103\ ft \times \dfrac{12in}{1\,ft}} = 0.002\%$

REFERENCES

Bowles, Joseph E., *Foundation Analysis and Design, 5th Edition,* Mc-Graw-Hill, 1996.

Holtz, Robert D. and Kovacs, William D., *An Introduction to Geotechnical Engineering,* Prentice- Hall International, 1981.

Navy Design Manual DM-7.1

PEEL Environmental Services, *WMMW-16 Boring and Well Construction Log,* December, 1992.

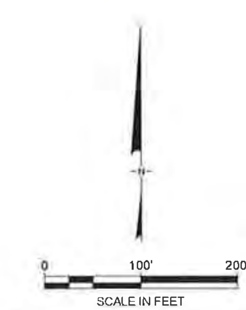
LEGEND

	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
	JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
	EXISTING DIRT ROAD
	EXISTING FENCE
5600	PROPOSED GRADING MAJOR CONTOUR (10')
5602	PROPOSED GRADING MINOR CONTOUR (2')
	PROPOSED GRADING LIMIT
	PROPOSED GRADE BREAK
	LIMIT OF LINER
5570	APPROXIMATE TOP OF ROCK CONTOUR (1') (SEE NOTES 4 AND 5)
21 / 06	SPLASH PAD
TP12-03	EXPLORATORY TRENCH LOCATION
	SEISMIC LINE LOCATIONS (SEE NOTE 4)
⊗	CELL 4B SOIL BORINGS

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BE ENERGY FUELS RESOURCES (USA) INC.
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER.
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.
4. SEISMIC LINE DATA IS PROVIDED IN SECTION 02200 OF THE TECHNICAL SPECIFICATIONS.
5. APPROXIMATE TOP OF ROCK CONTOURS WITH QUESTION MARKS REFER TO CONTOURS THAT WERE ESTIMATED.

Attachment A (2/2)



REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858.674.6559

Energy Fuels Resources (USA) Inc

TITLE: CELL 5B PROPOSED GRADING

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION UNLESS SEALED

SIGNATURE

DATE

DESIGN BY	GTC	DATE	JANUARY 2013
DRAWN BY	MMC	PROJECT NO.	SC0634
CHECKED BY	RBF	FILE	SC0634 - 03A-04B
REVIEWED BY	GTC	DRAWING NO.	
APPROVED BY	GTC	03B OF 12	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

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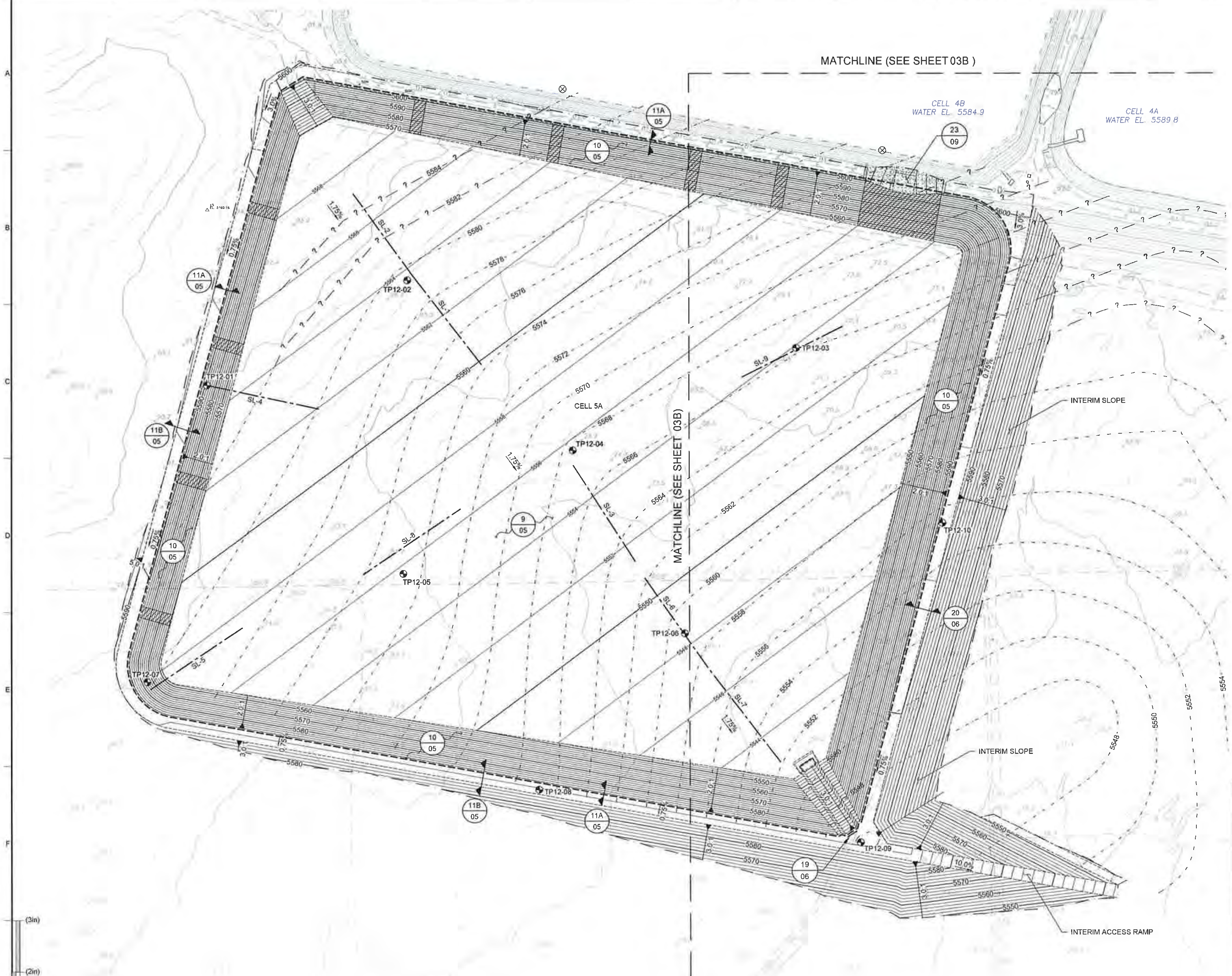

LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- 5602 — PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- PROPOSED GRADE BREAK
- LIMIT OF LINER SYSTEM
- 5570 — APPROXIMATE TOP OF ROCK CONTOUR (1') (SEE NOTES 4 AND 5)
- SPLASH PAD (21/06)
- TP12-03 EXPLORATORY TRENCH LOCATION
- SEISMIC LINE LOCATIONS (SEE NOTE 4)
- CELL 4B SOIL BORINGS

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011 THIS INFORMATION WAS PROVIDED BE ENERGY FUELS RESOURCES (USA) INC
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4. SEISMIC LINE DATA IS PROVIDED IN SECTION 02200 OF THE TECHNICAL SPECIFICATIONS
5. APPROXIMATE TOP OF ROCK CONTOURS WITH QUESTION MARKS REFER TO CONTOURS THAT WERE ESTIMATED

ATTACHMENT A (1/2)

0 100' 200'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE 858 674 6559

EF Energy Fuels Resources (USA) Inc

TITLE: CELL 5A PROPOSED GRADING

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION UNLESS SEALED

SIGNATURE

DATE

DESIGN BY	GTC	DATE	JANUARY 2013
DRAWN BY	MMC	PROJECT NO	SC0634
CHECKED BY	RBF	FILE	SC0634 - 03A-04B
REVIEWED BY	GTC	DRAWING NO	
APPROVED BY	GTC	03A OF 12	

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

P:\PRJ\SDCads\CADD\SC0634 ENERGY FUELS\SC0634-02-02\Plansets_Current Set\SC0634 - 03A-04B.dwg Last Edited by MikeC on 12/13/2012 11:35 AM

M
F
G
consulting
scientists and
engineers

MFG, Inc.
A TETRA TECH COMPANY
Fort Collins Office
3801 Automation Way, Suite 100
Fort Collins, CO 80525
970.223.9600
Fax: 970.223.7171

July 13, 2006

Tetra Tech EM, Inc.
950 17th Street, 22nd Floor
Denver, Colorado 80202

MFG Project No. 181413x

Attn: Ms. JoAnn Tischler

Subject: Draft
Soil Property Verification and
Slope Stability Analyses
Earthen Embankment between Cells 4A and 4B,
IUC White Mesa Project
Blanding, Utah

Tetra Tech MFG prepared a technical memorandum dated June 7, 2006, and a letter dated June 9, 2006 describing slope stability analyses, assumptions, and recommendations for verification of soil properties for an earthen embankment at the International Uranium (USA) Corporation, White Mesa Project near Blanding, Utah.

On June 15, 2006, Tetra Tech drilled an exploratory boring in the embankment between Cell 4A and Cell 4B at the approximate location shown on Figure 1 (attached). Descriptions of soils encountered in the boring are shown on the Borehole log (also attached). The boring was drilled to a depth of 30 feet and sampled at 5 foot intervals using a 2 inch diameter California sampler driven into the soil by a 140 pound weight dropped 30 inches (a Standard Penetration Test, SPT). Samples were examined by a geotechnical engineer in our soils laboratory. Samples were selected and tested for moisture and density and Atterberg Limits to determine their classification and similarity to properties identified in previous geotechnical reports for the project. A triaxial test was performed to compare the angle of internal friction and cohesion of the in-place soil with the values determined by the original designers in 1981.

The moisture and density of the samples tested are shown in Table 1 below:

Attachment B (1/3)

Table 1. Soil Properties

Depth	Description	Wet Density (pcf)	Dry Density (pcf)	Moisture content (%)
10	Silty sand	136.5	125.0	9.2
20	Silty sand	140.5	126.3	11.3
25	Silty sand	134.7	122.6	9.9
-	Average	137.2	124.6	10.1

Atterberg limits tests indicate a liquid limit of 25, and a Plasticity Index of 13, with 50 percent silt and clay sized particles (passing the number 200 sieve). Triaxial testing indicated an effective angle of internal friction of 26.5 degrees and a drained cohesion of 957.5 psf.

These test results indicate although the samples were visually classified as silty sand, laboratory tests indicate the embankment soils tested are a very sandy clay rather than sand and silty sand as reported by others and assumed in our initial analysis.

We performed additional slope stability analyses using the following soil properties: an average moist unit weight of 137 pcf, an angle of internal friction of 26 degrees, and an effective cohesion of 900 psf. We calculated the minimum factors of safety shown in Table 2.

Table 2. Revised Minimum Factors of Safety

Condition	Calculated Minimum Factor of Safety
Unlined alternative, static, steady state	2.45
Unlined Alternative, 0.1g seismic	1.67
Lined Alternative, static	4.61
Lined Alternative, 0.1g seismic	3.21

Therefore the factors of safety calculated and presented in our June 2 Technical Memorandum are conservative. In fact, analyses using the measured soil properties indicate that the embankment exceeds typical minimum acceptable safety factors even in the event leakage were to occur from the liner and produce a saturated condition as shown in Figure 3 of our previous memorandum.

If you have any questions regarding our analysis, our previous correspondence, or this letter, please contact the undersigned.

Respectfully submitted,

Tetratech MFG, Inc.

Thomas A. Chapel, CPG, PE
Senior Geotechnical Engineer

2 copies sent

PEEL Environmental Services
Arvada, CO (303)422-5116

Bore Hole No. : WMMW-16

UMETCO Minerals Corporation

Project: White Mesa	Surface Elev. 5588.18	T. D. = 91.5
Date: 12/07/92	Depth to Water: Dry	Geologist: F. A. Peel

Gamma (Nat) 0–250	Depth	Graphic Description	Neutron - API 0–7000	Sample Description	Comments	Well Costruction
Soil	0			Sand: quartz,reddish brown,fine-grained subrounded silty.	1/4" Steel Surface Csg	
Dakota Fm				Sandstone: quartz, reddish brown, very fine grained, subround, silty friable.		
	10			Sandstone: quartz, light buff, very fine- to fine-grained, subangular to angular, friable, good inter granular porosity.		
	20		Core #1 Rec 9.5'	Sandstone: quartz, light buff to light gray, very fine- to fine-grained,kaolinitic, massive to thin bedded,trough cross bedding trace porosity.	Cement/Bentonite Grout	
				Claystone: light gray, silty, slightly sandy,thin carbonaceous partings, hard.		
				Sandstone: quartz, light gray, very fine grained, subrounded, kaolinitic, thin cross bedding, hard.	4" schedual 40 PVC	
	Test #1			Sandstone: quartz, light yellow gray, fine to medium grained, subrounded to round kaolinitic, tr iron staining, thin cross bedding.	K= 9.1E-4 cm/sec	
			Core #2 Rec 9.5'	Sandstone: quartz, light gray, medium to coarse grained, kaolinitic, conglomeratic pebbles are angular lithic fragments.		
				Sandstone: quartz, light gray, fine to medium grained, subrounded, silty, trace intergranular porosity, occasionally coarse grained, occasional pebble.		
	40		Core #3 Rec 9.75'	Sandstone: quartz, light gray, fine- to medium-grained, subround to rounded, Conglomerate: Brownish gray, angular to subangular, chert & sandstone clasts, Siltstone: greenish gray,sandy in part, occasional iron staining.		
Burro Canyon Fm	Test #2			Sandstone: quartz, light greenish gray, very fine grained silty.	K= 5.1E-5 cm/sec	
	50			Shale: greenish gray, thinbedded soft, bentonitic.	Centralizer	
			Core #4 Rec 9.4'	Sandstone: quartz, light buff to light gray, very fine grained, sub angular, trace intergranular porosity, limonite concreations, trace iron staining.		
				Sandstone: quartz, light brownish gray, fine grained, thin cross bedding, trace porosity, becomming greenish gray & very fine grained toward base, shale parting at 64'		
	60		Core #5 Rec 9.5'			
	Test #3				K= 7.8E-5 cm/sec	
	70			Sandstone: quartz, light brownish gray, fine grained, well sorted, good intergranular porosity, 1" shale iron stained shale parting at top.	Bentonite Seal	
			Core #6 Rec 8.5'	Sandstone: quartz, light gray, grading downward from very fine grained to medium grained, subrunded, layers vell sorted, kaolinitic, conglomeratic in part, trace iron staining.		
	80		Core #7 Rec 9.4'	Sandstone: quartz, light gray, medium grained, subangular to subround, well sorted, kaolinitic, poor to good intergranular porosity, occasional coarse sand grains and pebble conglomerate stringers, trace iron staining.	10-20 Colorado Silica Sand	
	Test #4				K= 2.9E-5 cm/sec	
Brushy Basin Member	90			Shale: dark green, thinbedded, soft.	Well Dry	

Screened Interval

Attachment C (1/1)

TABLE 2-8
Value range* for the static stress-strain modulus E_s for selected soils (see also Table 5-6)

Field values depend on stress history, water content, density, and age of deposit

Soil	E_s, MPa
Clay	
Very soft	2–15
Soft	5–25
Medium	15–50
Hard	50–100
Sandy	25–250
Glacial till	
Loose	10–150
Dense	150–720
Very dense	500–1440
Loess	15–60
Sand	
Silty	5–20
Loose	10–25
Dense	50–81
Sand and gravel	
Loose	50–150
Dense	100–200
Shale	150–5000 ← Use 1500 MPa
Silt	2–20

*Value range is too large to use an "average" value for design.

in situ, it is reasonable for confined compression tests to produce better "elastic" parameters. Although it is difficult to compare laboratory and field E_s values, there is some evidence that field values are often four to five times larger than laboratory values from the unconfined compression test. For this reason, current practice tends to try to obtain "field" values from in situ testing whenever possible. This topic will be taken up in more detail in the next chapter.

Table 2-8 gives a range of E_s values that might be obtained. Note that the range is very large, owing to the foregoing factors as well as those factors given on the table. With this wide range of values the reader should not try to use "averaged" values from this table for design.

If laboratory test plots similar to Fig. 2-43*a* are used, it is most common to use the initial tangent modulus to compute the stress-strain modulus E_s for the following reasons:

1. Soil is elastic only near the origin.
2. There is less divergence between all plots in this region.
3. The largest values are obtained—often three to five times larger than a tangent or secant modulus from another point along the curve.

Bowles, Joseph E. Foundation Analysis and Design, 5th Ed., 1996.
Attachment D (1/1)

Definition

ı index (Eq. 8-8)
(Eq. 8-15); C_E and C_s are sometimes used
on index
ıetric modulus (Eq. 8-6)
ratio

a soil layer (Eq. 8-3)
f a soil layer (Eq. 8-3)
8-30)
(Eq. 8-23)
(Eq. 8-20)
width to depth (Eqs. 8-28 and 8-29)
change (Eq. 8-6)
8-25)
8-34)
io (Eq. 8-2)

4)
ss (Eq. 8-27)
om load to a point (Eq.8-24)

ent (Eq. 8-1)
n settlement (Eq. 8-1)
n (Eq. 8-1)
8-1)

ore water pressure

8-
3)
33)
ss (Eq. 8-22)
olidation stress
stress or maximum past
(Eq. 8-2); p_c' and σ_{om}'

rburden stress (Eq. 8-2)
z (Eq. 8-22)

MENT

ample by a structure or a
otal vertical deformation at
tlement. The movement may
ard (called *swelling*) with a

decrease in load. Temporary construction excavations and permanent excavations such as highway cuts will cause a reduction in the stress, and swelling may result. As shown in Chapter 7, a lowering of the water table will also cause an increase in the effective stresses within the soil, which will lead to settlements. Another important aspect about settlements of especially fine-grained soils is that they are often time-dependent.

In the design of foundations for engineering structures, we are interested in how much settlement will occur and how fast it will occur. Excessive settlement may cause structural as well as other damage, especially if such settlement occurs rapidly. The total settlement, s_t, of a loaded soil has three components, or

$$s_t = s_i + s_c + s_s \qquad (8\text{-}1)$$

where s_i = the *immediate*, or *distortion*, settlement,
s_c = the *consolidation* (time-dependent) settlement, and
s_s = the *secondary* compression (also time-dependent).

The immediate, or distortion, settlement although not actually elastic is usually estimated by using elastic theory. The equations for this component of settlement are in principle similar to the deformation of a column under an axial load P, where the deformation is equal to PL/AE. In most foundations, however, the loading is usually three dimensional, which causes some distortion of the foundation soils. Problems arise concerning the proper evaluation of a compression modulus and the volume of soil that is stressed. Immediate settlements must be considered in the design of shallow foundations, and procedures for dealing with this problem can be found in textbooks on foundation engineering.

The consolidation settlement is a time-dependent process that occurs in saturated fine-grained soils which have a low coefficient of permeability. The rate of settlement depends on the rate of pore water drainage. Secondary compression, which is also time-dependent, occurs at constant effective stress and with no subsequent changes in pore water pressure. Settlement computations are discussed in this chapter; the time rate of consolidation and secondary compression are discussed in Chapter 9.

8.3 COMPRESSIBILITY OF SOILS

Assume for the time being that the deformations of our compressible soil layer will occur in only one dimension. An example of one-dimensional compression would be the deformation caused by a fill covering a very large area. Later on we shall discuss what happens when a structure of finite size loads the soil and produces deformation.

Holtz, Robert D. and Kovacs, William M., An Introduction to Geotechnical Engineering, 1981.

Attachment E (1/2)

b. Find the vertical stress under the center of the footing at a depth of 2 m.

c. Compare results with Fig. Ex. 8.17a.

Solution:

a. $x = 3$ m

$y = 4$ m

$z = 2$ m: therefore from Eqs. 8-28 and 8-29,

$$m = \frac{x}{z} = \frac{3}{2} = 1.5$$

$$n = \frac{y}{z} = \frac{4}{2} = 2$$

From Fig. 8.21, find $I = 0.223$. From Eq. 8-30,

$$\sigma_z = q_o I$$
$$= 117 \times 0.223$$
$$= 26 \text{ kPa}$$

b. To compute the stress under the center, it is necessary to divide the 3×4 m rectangular footing into four sections of 1.5×2 m in size. Find the stress under one corner and multiply this value by 4 to take into account the four quadrants of the uniformly loaded area. We can do this because, for an elastic material, superposition is valid.

$x = 1.5$ m

$y = 2$ m

$z = 2$ m; then

$$m = \frac{x}{z} = \frac{1.5}{2} = 0.75$$

$$n = \frac{y}{z} = \frac{2}{2} = 1$$

The corresponding value of I from Fig. 8.21 is 0.159. From Eq. 8-30,

$$\sigma_z = 4q_o I = 4 \times 117 \times 0.159 = 74 \text{ kPa}$$

Thus the vertical stress under the center for this case is about three times that under the corner. This seems reasonable since the center is loaded from all sides but under the corner it is not.

c. At a depth of 2 m below the 3×4 m footing, the vertical stress according to the 2:1 theory is 47 kPa (see Fig. Ex. 8.17b). This value represents the *average* stress beneath the footing at -2 m. The average of the corner and center stress by elastic theory is $(26 + 74.2)/2 = 50.1$ kPa.

ATTACHMENTE (2/2)

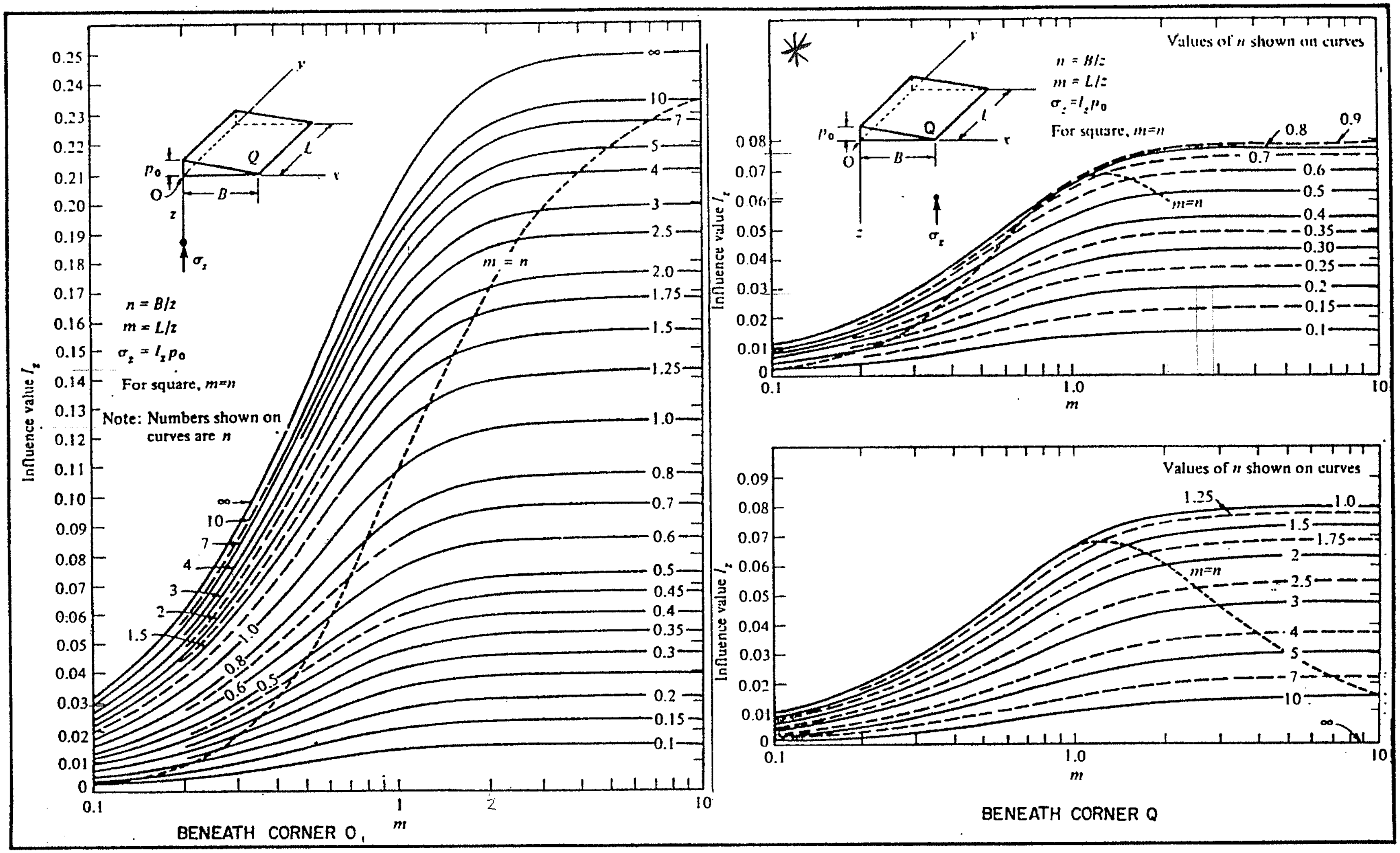
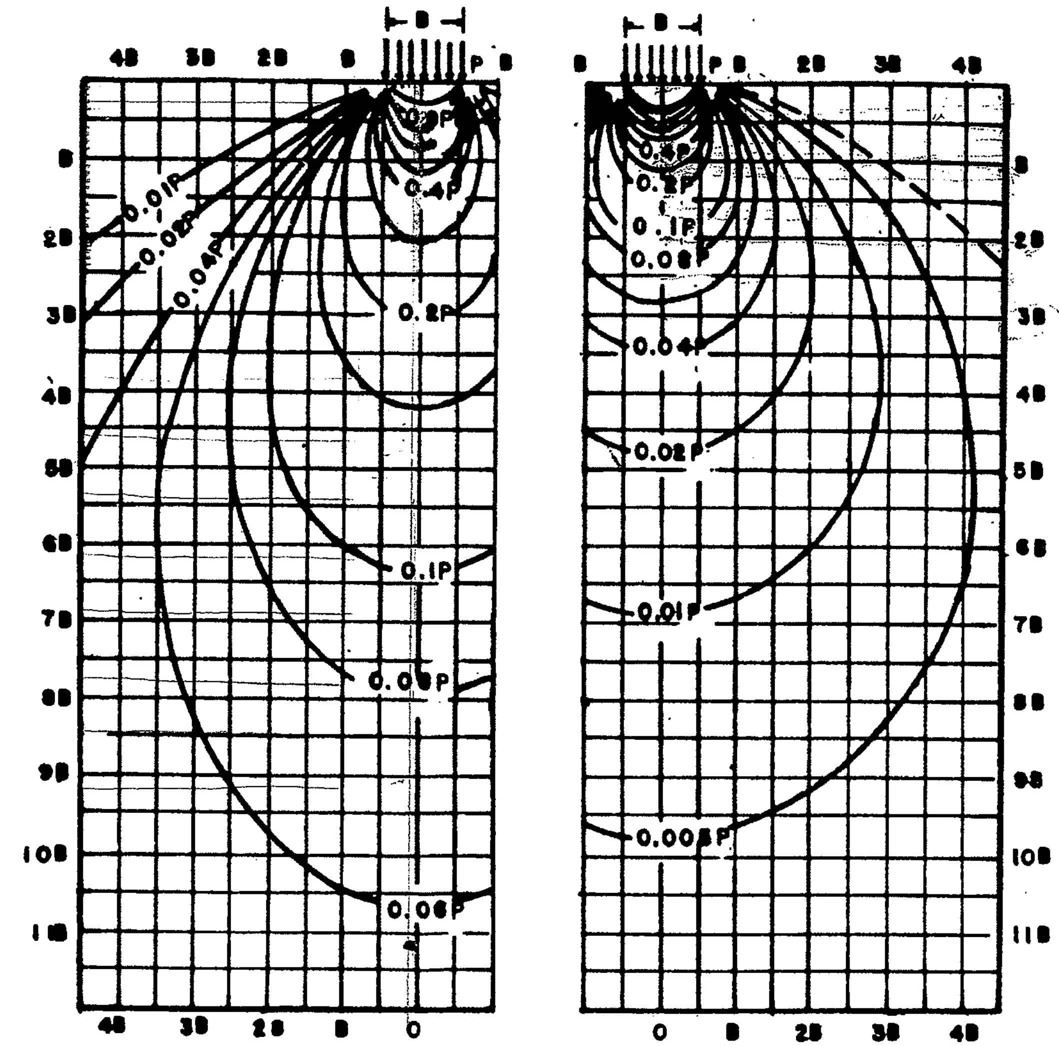


FIGURE 7
Influence Value for Vertical Stress Beneath Triangular Load
(Boussinesq Case)

ATTACHMENT F 1/2



a. INFINITELY LONG FOOTING

b. SQUARE FOOTING

SQUARE FOOTING

GIVEN

FOOTING SIZE = 20'X 20'

UNIT PRESSURE P=2TSF

FIND

PROFILE OF STRESS INCREASE BENEATH CENTER OF FOOTING DUE TO APPLIED LOAD

B = 20' P = 2 TSF

Z (FT)	Z/B	σ_z TSF
10	0.5	0.70 X 2 = 1.4
20	1	0.38 X 2 = 0.76
30	1.5	0.19 X 2 = 0.38
40	2.0	0.12 X 2 = 0.24
50	2.5	0.07 X 2 = 0.14
60	3.0	0.05 X 2 = 0.10

Z/B : 2.5

FIGURE 3
Stress Contours and Their Application

ATTACHMENT F 2/2

Geosyntec
consultants

COMPUTATION COVER SHEET

Client:	**Energy Fuels**	Project:	**White Mesa Mill – Cells 5A and 5B**	Project/ Proposal No.:	**SC0634**
				Task No.	**02**

Title of Computations **SLOPE STABILITY ANALYSIS**

Computations by:	Signature		Date 12/18/12
	Printed Name	Jay L. Griffin	
	Title	Senior Staff Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		Date 12/18/12
	Printed Name	Steven M. Fitzwilliam, P.E.	
	Title	Associate Engineer	
Computations Checked by:	Signature		Date 12/18/12
	Printed Name	Steven M. Fitzwilliam, P.E.	
	Title	Associate Engineer	
Computations backchecked by: (originator)	Signature		Date 12/18/12
	Printed Name	Jay L. Griffin	
	Title	Senior Staff Engineer	
Approved by: (pm or designate)	Signature		Date 12/18/12
	Printed Name	Gregory Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	J. Griffin	Date:	11/28/12	Reviewed by:	S. Fitzwilliam	Date:	12/18/12
Client:	Energy Fuels	Project:	White Mesa Mill-Cell 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

SLOPE STABILITY ANALYSES
CELLS 5A AND 5B
WHITE MESA MILL
BLANDING, UTAH

OBJECTIVE

This calculation includes slope stability analyses for the final earthen berms associated with construction of Cells 5A and 5B at the White Mesa Mill facility located in Blanding, Utah. The purpose of the stability analyses is to evaluate final slope stability and operational conditions required to maintain a minimum factor of safety of approximately 1.5 for final berm slope conditions, 1.3 for interim and temporary slope conditions, and 1.1 for seismically-loaded slope conditions based on the proposed design of the cell and its liner system.

METHODOLOGY

Two-dimensional slope stability analyses were performed using the computer program SLOPE/W 2004 (Version 6.22) developed by Geo-Slope International Ltd. (2004). The results of the slope stability analyses are based on the Morgenstern-Price method that satisfies both moment and force equilibrium. The analyzed slopes were kinematically modeled using either circular or linear/circular sliding surfaces.

For each condition analyzed, the program searched for the critical sliding surface that produces the lowest factor of safety using the grid and radius method available in SLOPE/W. Factors of safety are defined as the ratio of the shear forces/moments resisting movement along a sliding surface to the forces/moments driving the instability.

To model the various stability conditions encountered in Cells 5A and 5B before and after filling, three cross-sections were selected for analysis and are shown in Figure 1. The first cross section, Section A-A', is a west-east cross section that models Cell 5A filled with tailings and Cell 5B empty. The section spans Cells 5A and 5B, with berm slopes inclined at approximately 2:1 (Horizontal:Vertical) and a base grade sloping toward the berm at approximately 1 percent. The second cross section, Section B-B', is a north-south cross section that models Cell 5A before filling and spans the berm separating the southern portion of existing Cell 4B and Cell 5A. Section B-B' was modeled with Cell 4B full of tailings and Cell 5A empty. Both sections were modeled without a liner on the empty cell in order to evaluate berm stability. The third cross section, Section C-C' is a north-south cross section that spans the embankment on the south side of Cell 5A. Section C-C' is modeled with Cell 5A filled with tailings. The embankment back slope is inclined at 3:1.

Sections A-A', B-B', and C-C' were modeled for four conditions. These four conditions included static analyses, pseudo-static evaluation of the seismic loading conditions, interim construction loading, and evaluation of the yield acceleration.

Pseudo-static evaluations for slope stability were performed for a seismic acceleration of 0.1g in accordance with the Cell 4 Design Report (UMETCO, 1988) as referenced by MFG, Inc. in a letter to International Uranium Corporation (presently Energy Fuels) dated 27 November 2006.

Interim loading was considered for the four cross sections from construction and maintenance vehicle traffic on the access roads and haul roads on top of the embankment berms. AASHTO H 20 loading was assumed for the interim construction and maintenance vehicle loading (Attachment A). Two 16-kip loads were applied 6-feet apart to model a vehicle traveling along the top of the berm. The first load was applied 2-feet from the top of the slope.

Cells 5A and 5B will be constructed with the following liner system on the bottom area (from top to bottom):

- Slimes Drain System;
- 60 mil smooth HDPE geomembrane;
- 300 mil geonet
- 60 mil smooth HDPE geomembrane;
- 60 mil HDPE Drain Liner™; and
- Prepared Subgrade.

Cells 5A and 5B will be constructed with the following liner system on the side slope areas (from top to bottom):

- 60 mil smooth HDPE geomembrane;

- 60 mil HDPE Drain Liner™;
- 60 mil HDPE Drain Liner™; and
- Prepared Subgrade.

During operations, tailings/waste deposits are expected to be pumped into the cells below the water surface where the tailings will settle out creating a gradual build-up of solids along the base of the cell. Generally, the tailings will be pumped into the cells from north to south, beginning at splash pads located along the northern slopes of the cells. We have assumed that the tailings will extend up to the top of the berm. In the modeling, the phreatic surface (water surface) is assumed to apply to only the waste and liner materials, since the composite liner system minimizes infiltration of liquids into the underlying subgrade/foundation. The phreatic surface is set at elevation 5585, which is three feet below the top of the south berm. Groundwater at the site is reportedly greater than 50 feet below the ground surface.

MATERIAL PARAMETERS

Based on existing operations at the site, tailings/waste deposits are anticipated to be primarily fine sands with silt and some clay (Attachment B). We have estimated a total unit weight of 125 pounds per cubic foot (pcf) for this material based on Table 6 from the Naval Design Manual for Soil Mechanics DM7-01, (Attachment C). The value selected is based on the minimum wet weight (under loose placement to simulate the tailings settling underwater) for a similar type of material. Based on Figure 3.7 (Attachment D) for a 0% relative density silty sand, a friction angle of 26 degrees could be expected. We have conservatively estimated a friction angle of 25 degrees, with no cohesion, for these materials.

Laboratory interface friction testing for the proposed liner system resulted in a friction angle of 11 degrees for the base liner (smooth geomembrane to geonet) and 15 degrees for the side slope liner (Drain Liner™ to smooth geomembrane) (Attachment G). A unit weight of 90 pcf and a cohesion of 0 are used with the friction angles of 15 and 11 degrees to model the liner system.

Geosyntec reviewed previous geotechnical investigations for the site performed by others, including a memorandum from MFG, Inc. (MFG) dated 13 June 2006 and a follow-up letter dated 7 July 2006 (Attachments E and F). MFGs follow-up letter described their geotechnical investigation at the site, which included an exploratory boring through the existing berm between Cell 4A and 4B and a triaxial compression test on the recovered soil samples. Based on material parameters selected for the design of Cell 4B (Geosyntec, 2009), our field investigation for the design of Cells 5A and 5B, and our review of previous geotechnical investigations, we have selected material properties for the fill material in the berm that are consistent with the properties used previous slope stability analyses (unit weight = 137 pcf, friction angle = 26°, cohesion = 900 psf). As the embankment fill material will be derived from on-site soil, similar to the embankment between Cell 4A and 4B, the same berm material properties were used for the embankment fills associated with Cells 5A and 5B.

The foundation material (Dakota Sandstone) is modeled as bedrock within the SLOPE/W (i.e., impenetrable) to force slip surfaces to occur within the earth fill portion of the berms.

The following table summarizes the material parameters used for slope stability analysis. These parameters are generally consistent with the parameters used in slope stability analysis for the design of Cell 4B.

Material	Unit Weight (pcf)	Friction Angle (degrees)	Cohesion (psf)
Tailings	125	25	0
Liner	90	15 (side) 11 (base)	0
Berm	137	26	900
Dakota Sandstone	Impenetrable Bedrock		

SLOPE STABILITY RESULTS/RECOMMENDATIONS

As discussed above, four cross-sections were analyzed which represent critical conditions for Cells 5A and 5B.

Numerous potential failure surfaces were performed to evaluate various slip surface geometries and to identify the critical slip surface for each cross-section and conditions. The results of the slope stability analyses for Cross Sections A-A', B-B', and C-C' are presented in Table 1. Table 1 also presents the results of interim stability analysis for

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The slope stability analysis results are presented as Figures 2 through 14. Slope stability analysis for interim loading conditions from construction and maintenance vehicles was evaluated for deep-seated failure surfaces. Temporary wheel loading at the top of the embankment may results in surficial failures; however this condition is considered a maintenance issue and not a global stability concern.

For the cross sections evaluated to assess the yield acceleration of the slope, the critical failure surface tends to recede from the slope face with respect to the static analyses for the cross section. For these conditions the computer program was allowed to search for the critical failure surface with the lowest factor of safety provided that the base of the failure surface remained within the berm. If allowed to search for the critical failure surface with the absolute lowest factor of safety for the cross sections analyzed, the critical failure surface would extend down onto the liner of the adjacent cell. As this is not a kinematically feasible condition for the cross sections analyzed in these analyses, the base of the critical failure surface was fixed to remain within the berm to evaluate the yield acceleration of the slopes.

These results indicate the minimum factors of safety are met during and after filling operations for Cells 5A and 5B. We recommend that operations at the site limit the tailings/waste deposits slopes to inclinations of 7:1 or flatter.

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REFERENCES

GeoSlope International, LTD (2004) SLOPE/W Version 6.17.

Geosyntec Consultants, 2009. "Round 1 – Interrogatory Response for the Cell 4B Design Report, White Mesa Mill, Blanding, Utah," dated January 2009.

MFG, Inc. 2006. "Technical Memorandum: White Mesa Stability Analysis," dated 7 June 2006.

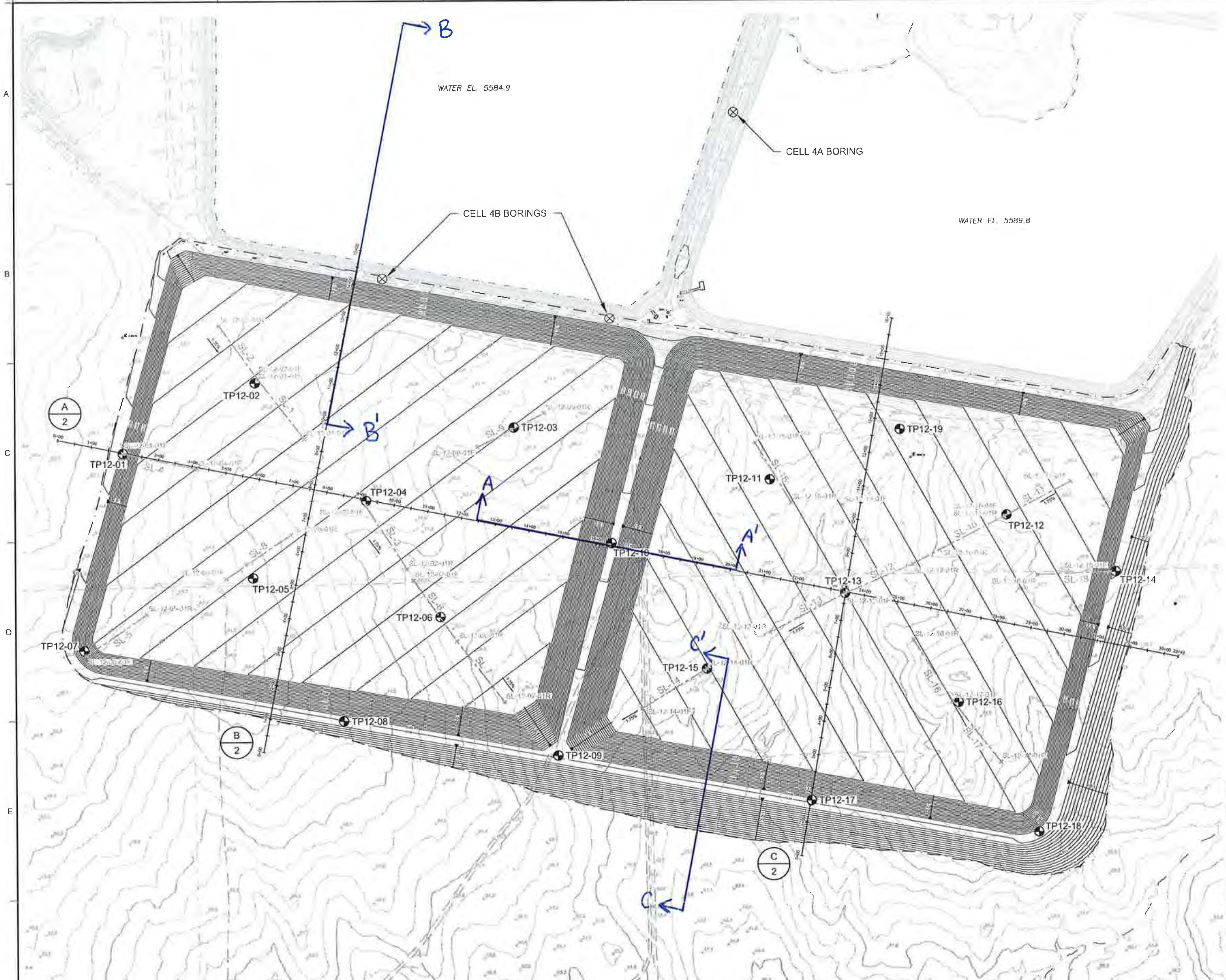
MFG, Inc. 2006. "Draft, Soil Property Verification and Slope Stability Analyses, Earthen Embankment between Cells 4A and 4B, IUC White Mesa Project, Blanding, Utah," dated 13 July 2006.

MFG, Inc. 2006. "White Mesa Uranium Facility, Cell 4 Seismic Study, Blanding, Utah," dated 27 November 2006.

TABLE 1
SUMMARY OF SLOPE STABILITY ANALYSES
Energy Fuels - White Mesa Mill, Cells 5A & 5B
Blanding, Utah

Cross Section	Loading Condition	Cell Condition	Yield Acceleration	Minimum Factor of Safety	Calculated Factor of Safety
A-A'	Static	Cell 5A filled with tailings; Cell 5B empty	--	1.5	3.2
	Seismic Loading (0.1g)		--	1.3	2.6
	Construction Loading		--	1.1	2.0
	Yield Acceleration		0.65	1.0	1.0
B-B'	Static	Cell 4B filled with tailings; Cell 5A empty	--	1.5	3.2
	Seismic Loading (0.1g)		--	1.3	2.6
	Construction Loading		--	1.1	2.1
	Yield Acceleration		0.66	1.0	1.0
C-C'	Static	Cell 5B filled with tailings	--	1.5	3.4
	Seismic Loading (0.1g)		--	1.3	2.5
	Construction Loading		--	1.1	2.8
	Yield Acceleration		0.51	1.0	1.0
Tailings Slope	Interim Tailings Slope	Cell 4B filled with tailings; Cell 5A partially full	--	1.3	1.3

Geosyntec consultants



LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- PROPOSED GRADING MAJOR CONTOUR (10')
- PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- 1 AS-BUILT TRENCH LOCATION
- AS-BUILT SEISMIC LINES

PRELIMINARY VOLUME REPORT

JUNE 2011 EXISTING SURFACE VS. REVISED CELL 5A PROPOSED GRADING:

CUT = 1,228,929 CUBIC YARDS

FILL = 196,323 CUBIC YARDS

NET = 1,032,606 CUBIC YARDS <CUT>

JUNE 2011 EXISTING SURFACE VS. REVISED CELL 5B PROPOSED GRADING

CUT = 704,105 CUBIC YARDS

FILL = 240,573 CUBIC YARDS

NET = 463,532 CUBIC YARDS <CUT>

0 150' 300'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUTE 200
SAN DIEGO, CA 92127
PHONE 858 674 6559

ENERGY FUELS INC.
6425 S. HIGHWAY 191
P.O. BOX 809
BLANDING, UTAH 84511
PHONE: 858.674.6559

TITLE: CELL 5A AND 5B PROPOSED GRADING

PROJECT: CELL 5A AND 5B PRELIMINARY CELL DESIGN

SITE: WHITE MESA MILL
BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

DATE

DESIGN BY:	GTC	DATE:	OCTOBER 2012
DRAWN BY:	MMC	PROJECT NO.:	SC0349
CHECKED BY:	GTC	FILE:	
REVIEWED BY:	GTC	FIGURE NO.:	
APPROVED BY:	GTC	1 OF 2	

FIGURE 1

PRELIMINARY DESIGN DRAWINGS
NOT FOR CONSTRUCTION

P:\PRJ\SDCadd\CADD\SC0349\SC0349-07-01\Working\10-2-12 CELL 5A & 5B REVISED GRADING.dwg

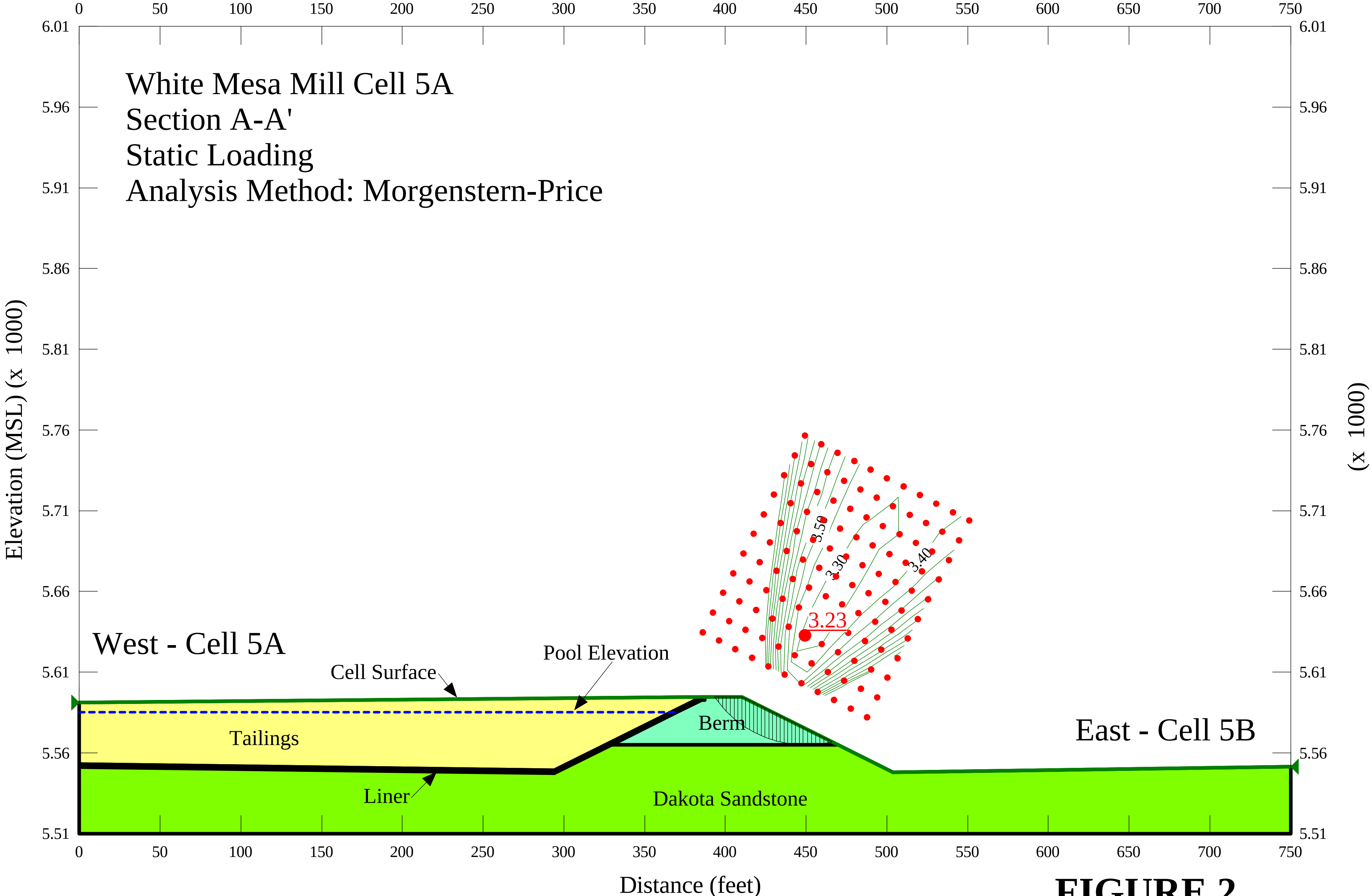

White Mesa Mill Cell 5A
Section A-A'
Static Loading
Analysis Method: Morgenstern-Price
West - Cell 5A
East - Cell 5B
Cell Surface
Pool Elevation
Tailings
Berm
Liner
Dakota Sandstone
3.23
3.30
3.40
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.01
5.96
5.91
5.86
5.81
5.76
5.71
5.66
5.61
5.56
5.51

FIGURE 2

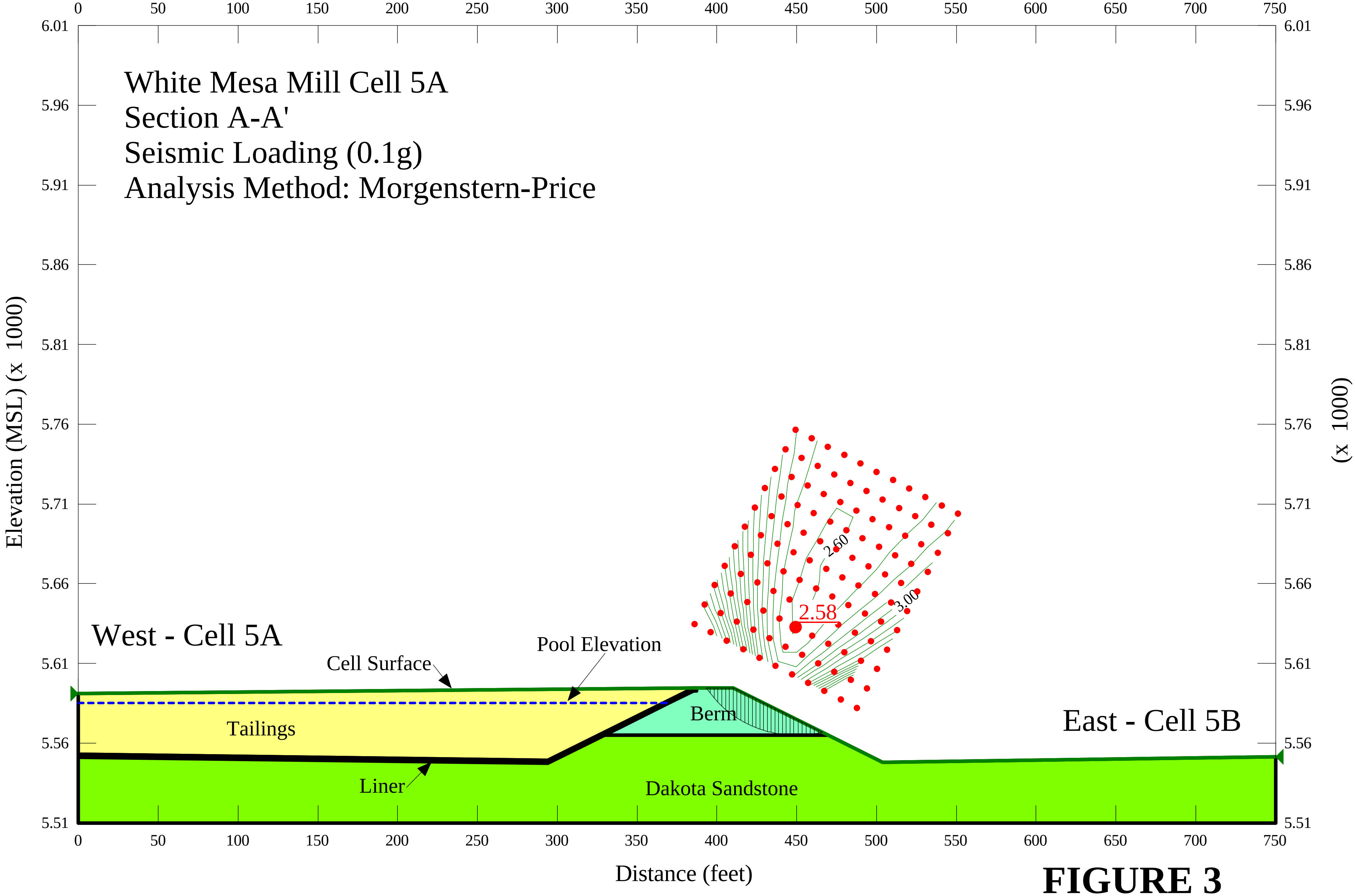

White Mesa Mill Cell 5A
Section A-A'
Seismic Loading (0.1g)
Analysis Method: Morgenstern-Price
West - Cell 5A
East - Cell 5B
Cell Surface
Pool Elevation
Tailings
Berm
Liner
Dakota Sandstone
2.58
2.60
3.00
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.01
5.96
5.91
5.86
5.81
5.76
5.71
5.66
5.61
5.56
5.51

FIGURE 3

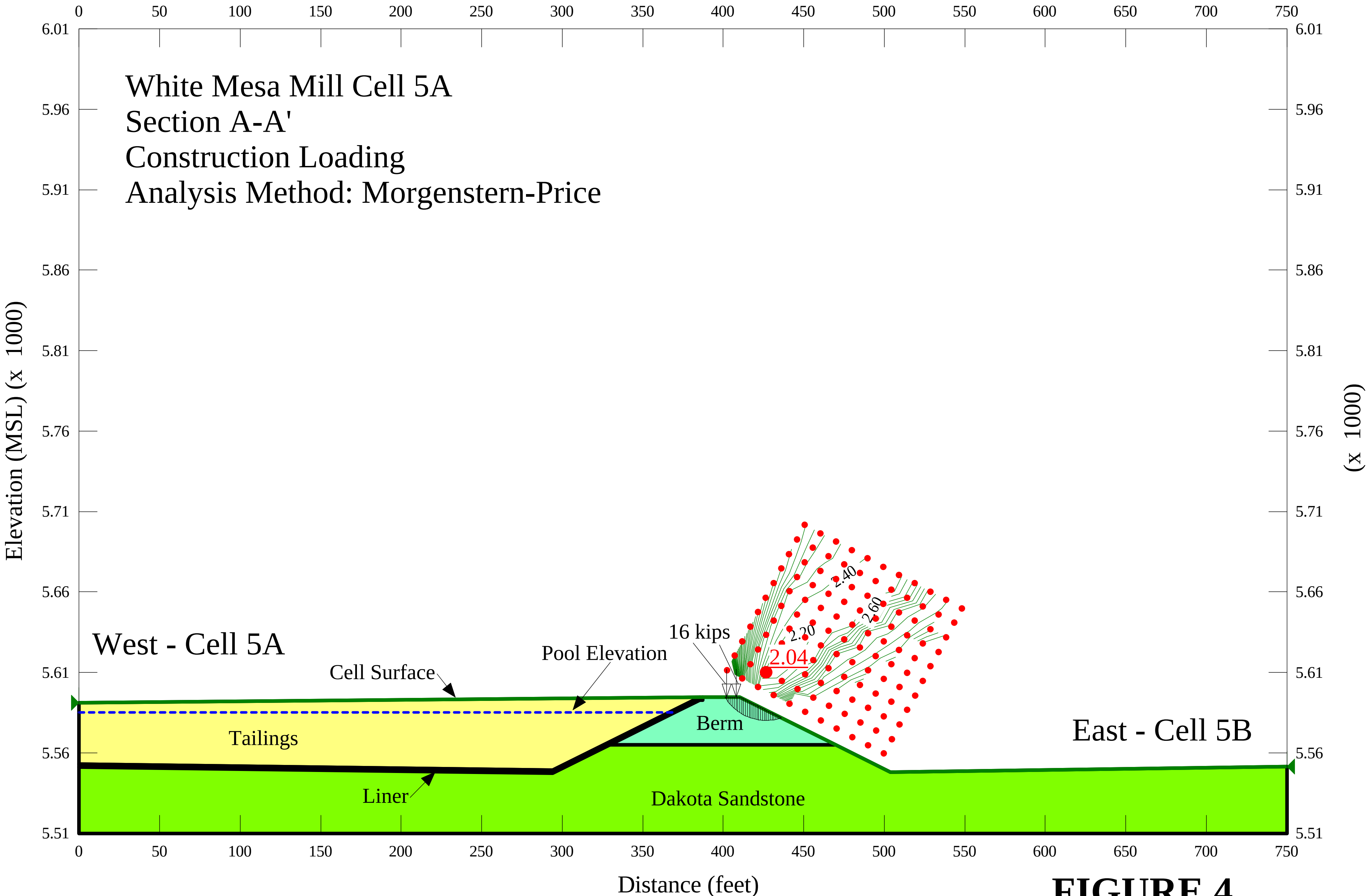

White Mesa Mill Cell 5A
Section A-A'
Construction Loading
Analysis Method: Morgenstern-Price
West - Cell 5A
East - Cell 5B
Cell Surface
Pool Elevation
16 kips
2.04
2.20
2.40
2.60
Tailings
Berm
Liner
Dakota Sandstone
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.01
5.96
5.91
5.86
5.81
5.76
5.71
5.66
5.61
5.56
5.51

FIGURE 4

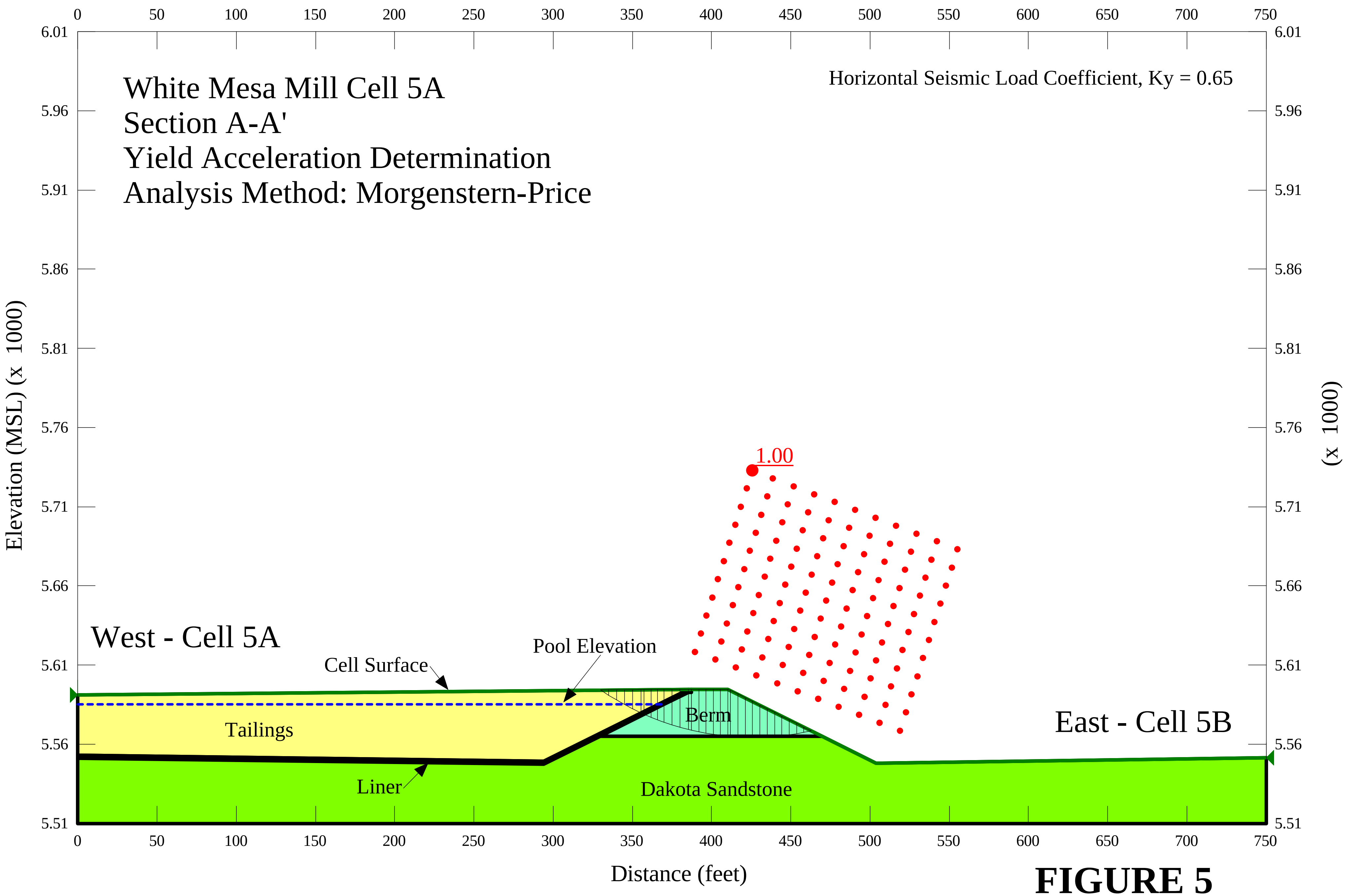

White Mesa Mill Cell 5A
Section A-A'
Yield Acceleration Determination
Analysis Method: Morgenstern-Price
Horizontal Seismic Load Coefficient, Ky = 0.65
1.00
West - Cell 5A
East - Cell 5B
Cell Surface
Pool Elevation
Berm
Tailings
Liner
Dakota Sandstone
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.01
5.96
5.91
5.86
5.81
5.76
5.71
5.66
5.61
5.56
5.51

FIGURE 5

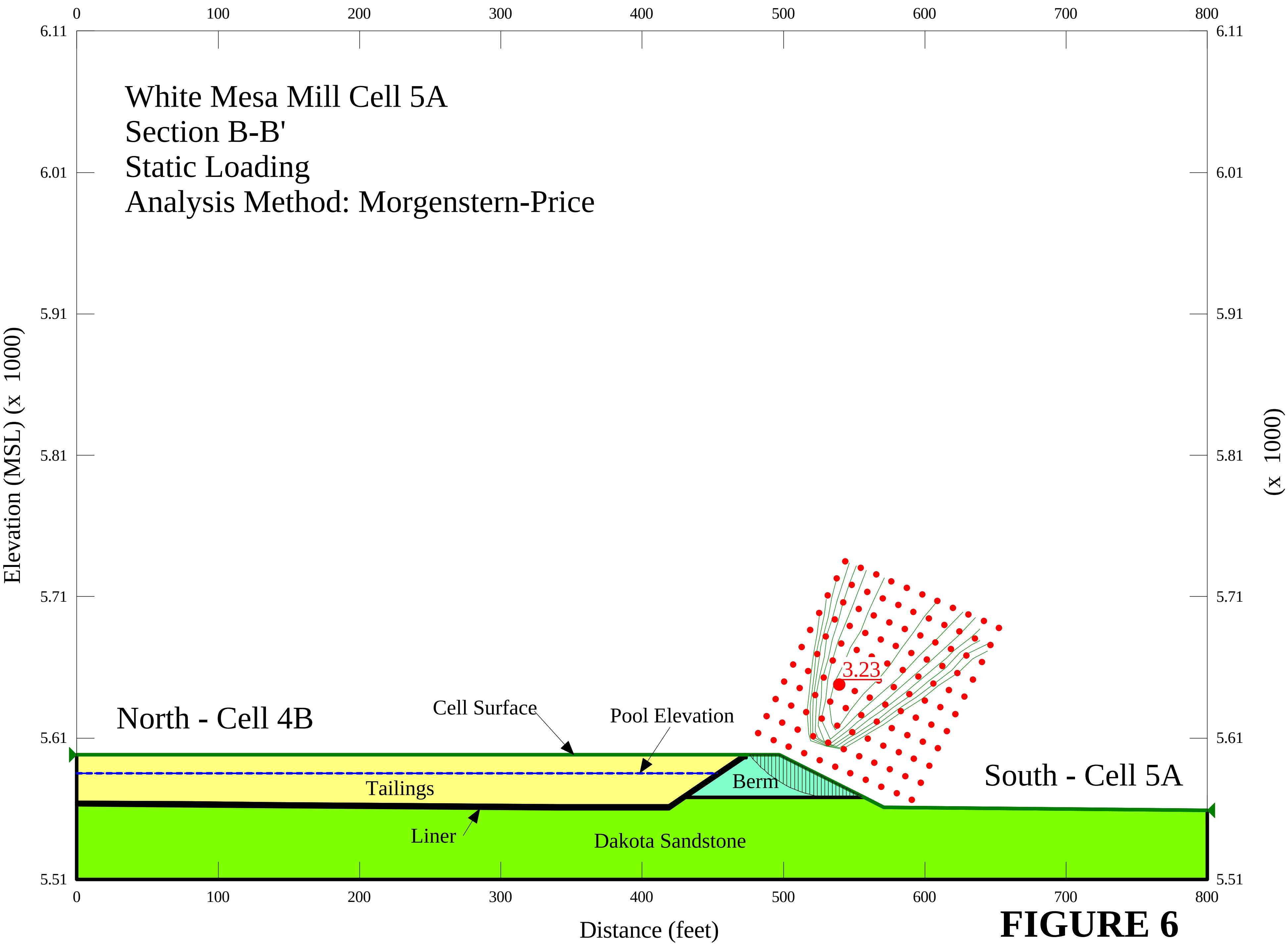

White Mesa Mill Cell 5A
Section B-B'
Static Loading
Analysis Method: Morgenstern-Price
North - Cell 4B
South - Cell 5A
Cell Surface
Pool Elevation
Tailings
Berm
Liner
Dakota Sandstone
3.23
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
100
200
300
400
500
600
700
800
6.11
6.01
5.91
5.81
5.71
5.61
5.51

FIGURE 6

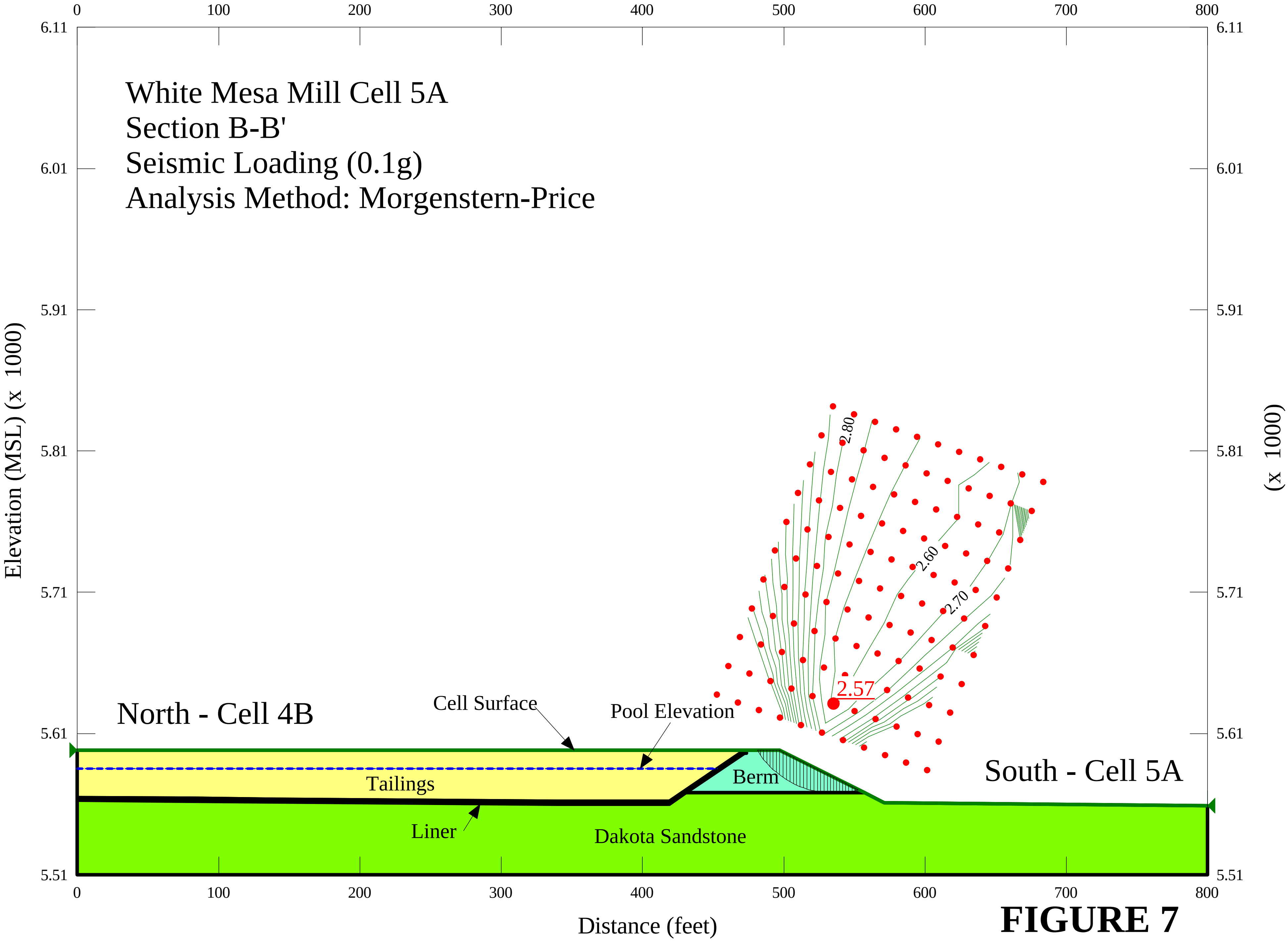
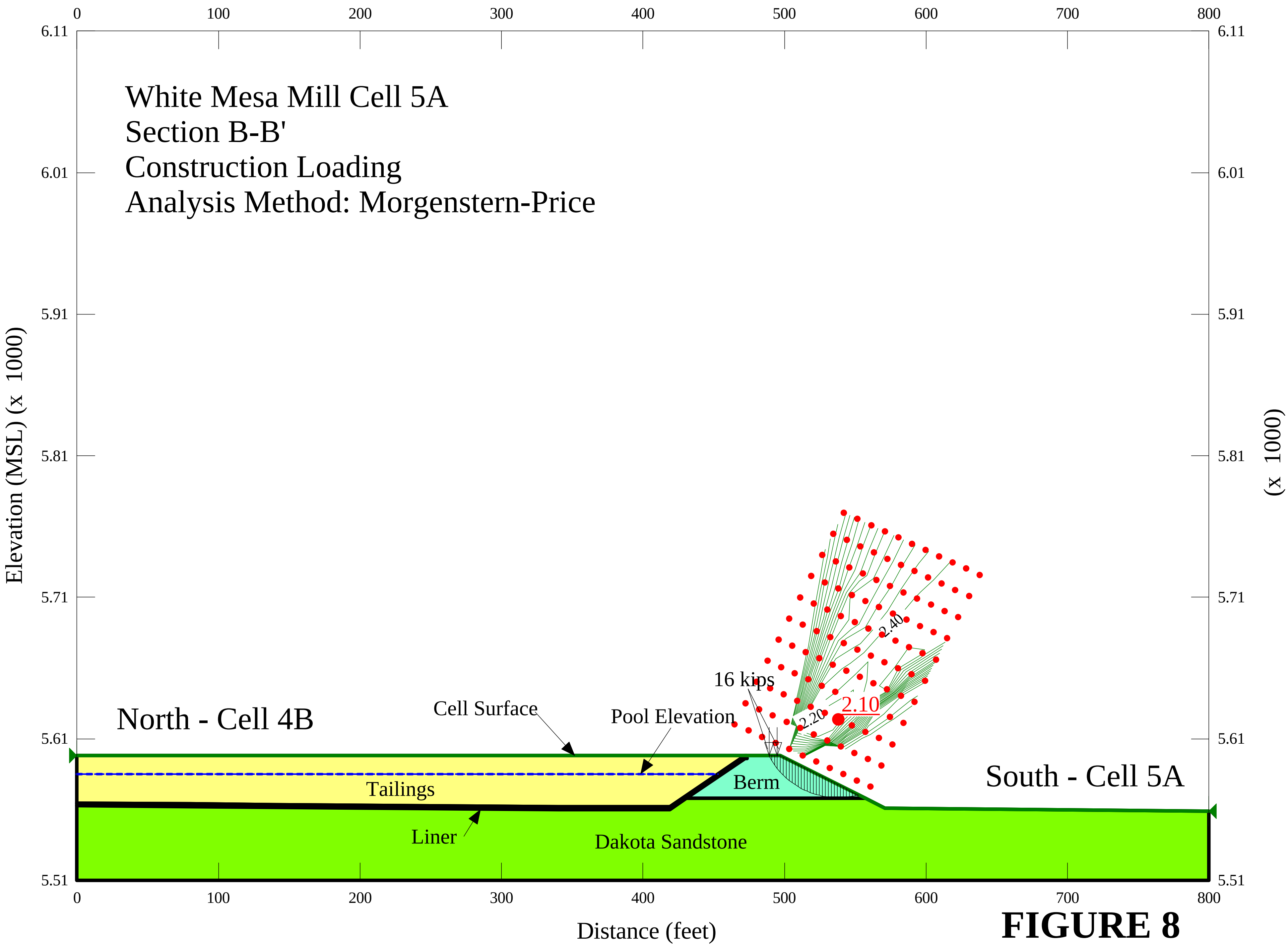

White Mesa Mill Cell 5A
Section B-B'
Seismic Loading (0.1g)
Analysis Method: Morgenstern-Price
North - Cell 4B
South - Cell 5A
Cell Surface
Pool Elevation
Tailings
Berm
Liner
Dakota Sandstone
2.80
2.60
2.70
2.57
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
100
200
300
400
500
600
700
800
6.11
6.01
5.91
5.81
5.71
5.61
5.51

FIGURE 7



White Mesa Mill Cell 5A
Section B-B'
Construction Loading
Analysis Method: Morgenstern-Price
North - Cell 4B
South - Cell 5A
Cell Surface
Pool Elevation
16 kips
2.10
2.20
2.40
Berm
Tailings
Liner
Dakota Sandstone
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
100
200
300
400
500
600
700
800
6.11
6.01
5.91
5.81
5.71
5.61
5.51

FIGURE 8

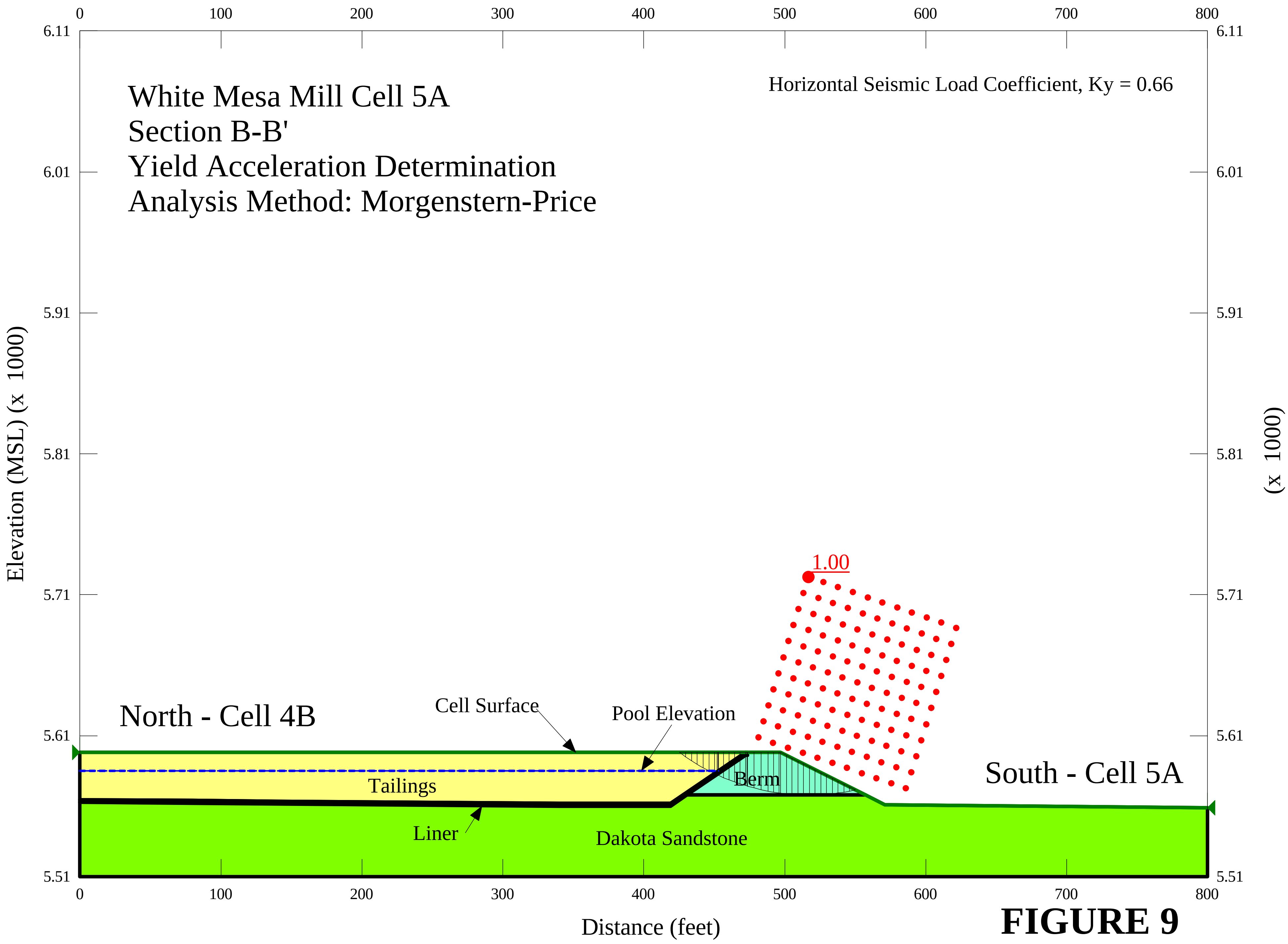

White Mesa Mill Cell 5A
Section B-B'
Yield Acceleration Determination
Analysis Method: Morgenstern-Price
Horizontal Seismic Load Coefficient, Ky = 0.66
1.00
North - Cell 4B
South - Cell 5A
Cell Surface
Pool Elevation
Berm
Tailings
Liner
Dakota Sandstone
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
100
200
300
400
500
600
700
800
6.11
6.01
5.91
5.81
5.71
5.61
5.51

FIGURE 9

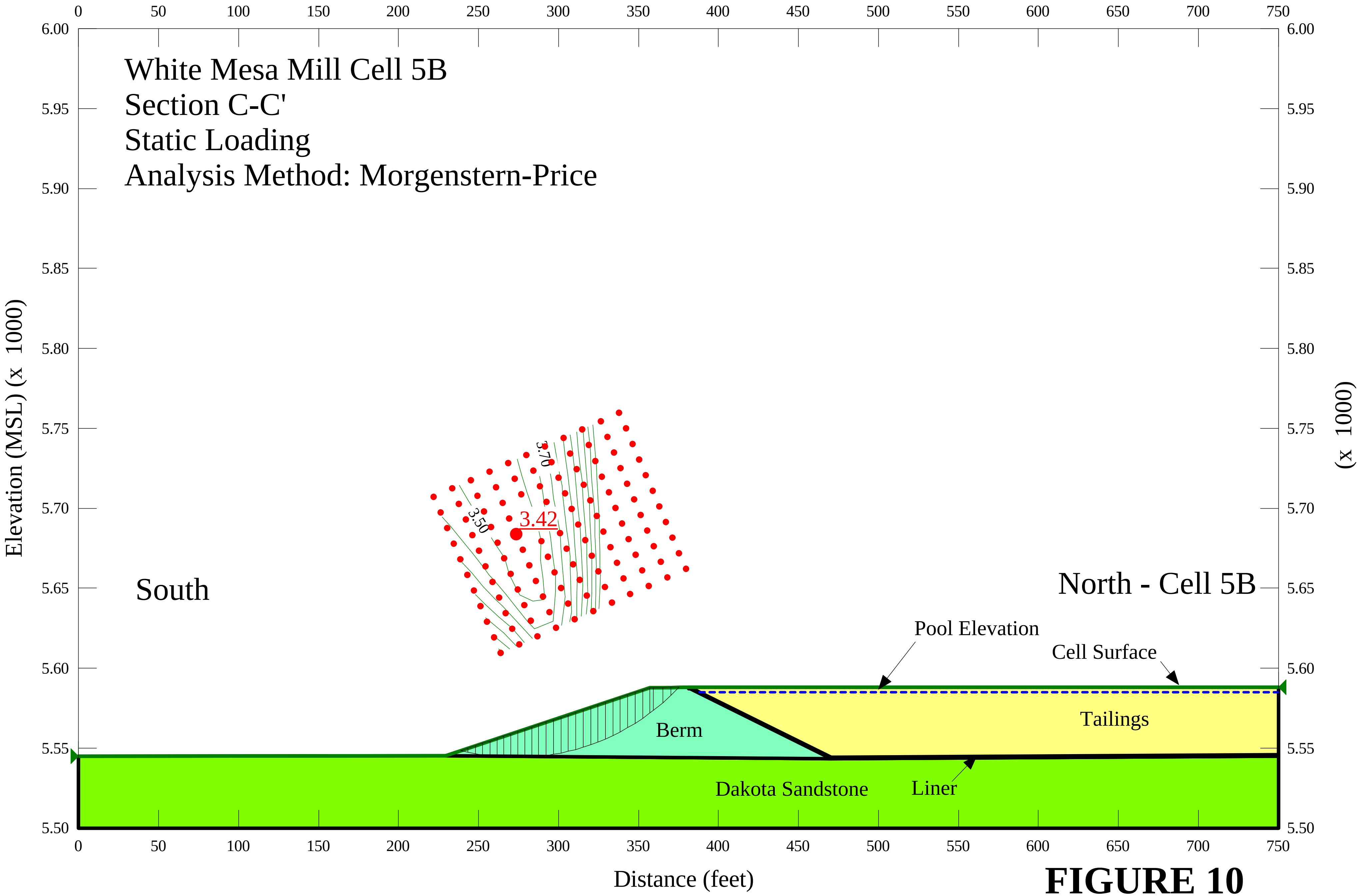

White Mesa Mill Cell 5B
Section C-C'
Static Loading
Analysis Method: Morgenstern-Price
3.70
3.50
3.42
South
North - Cell 5B
Pool Elevation
Cell Surface
Tailings
Berm
Dakota Sandstone
Liner
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)

FIGURE 10

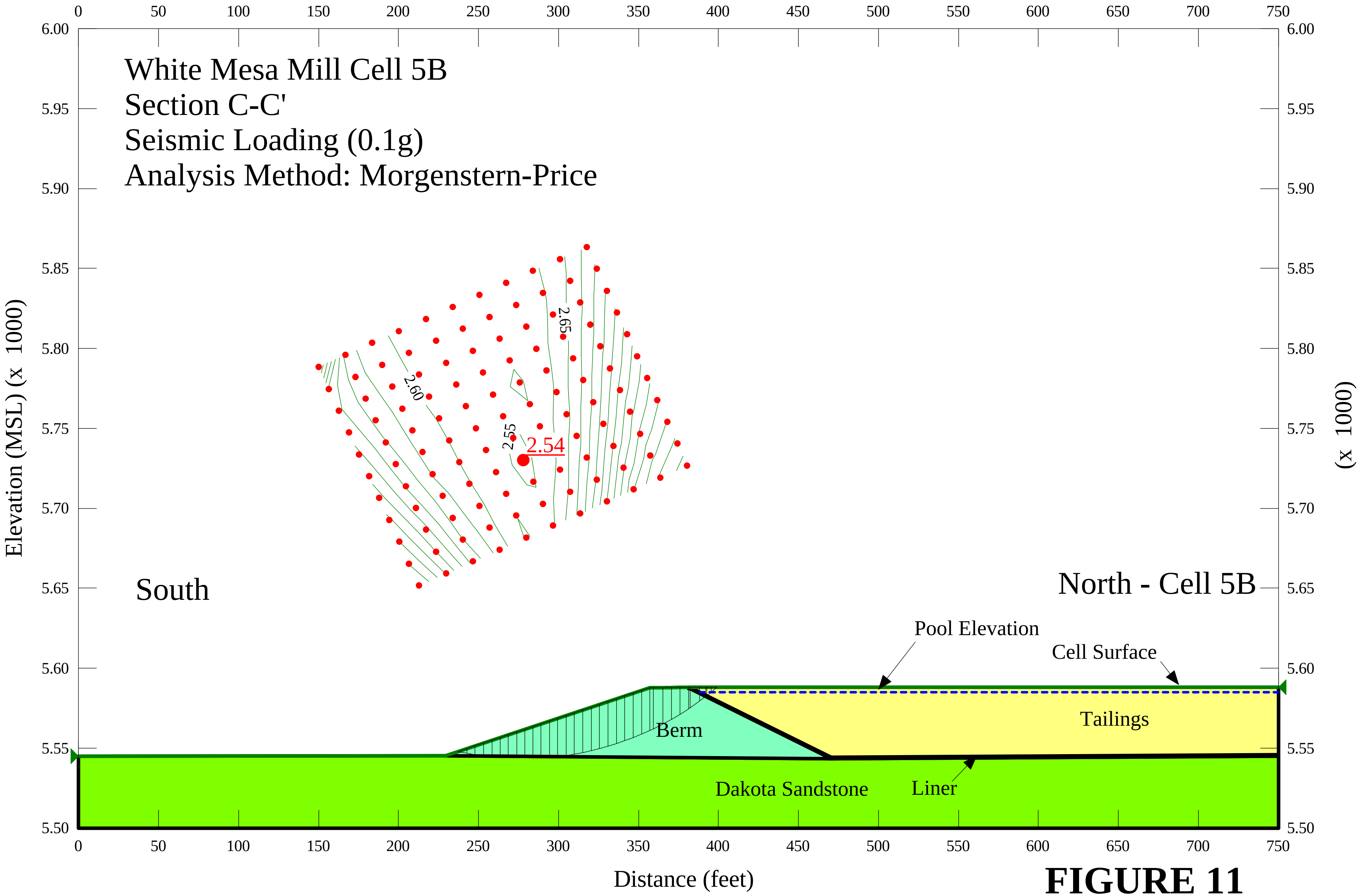
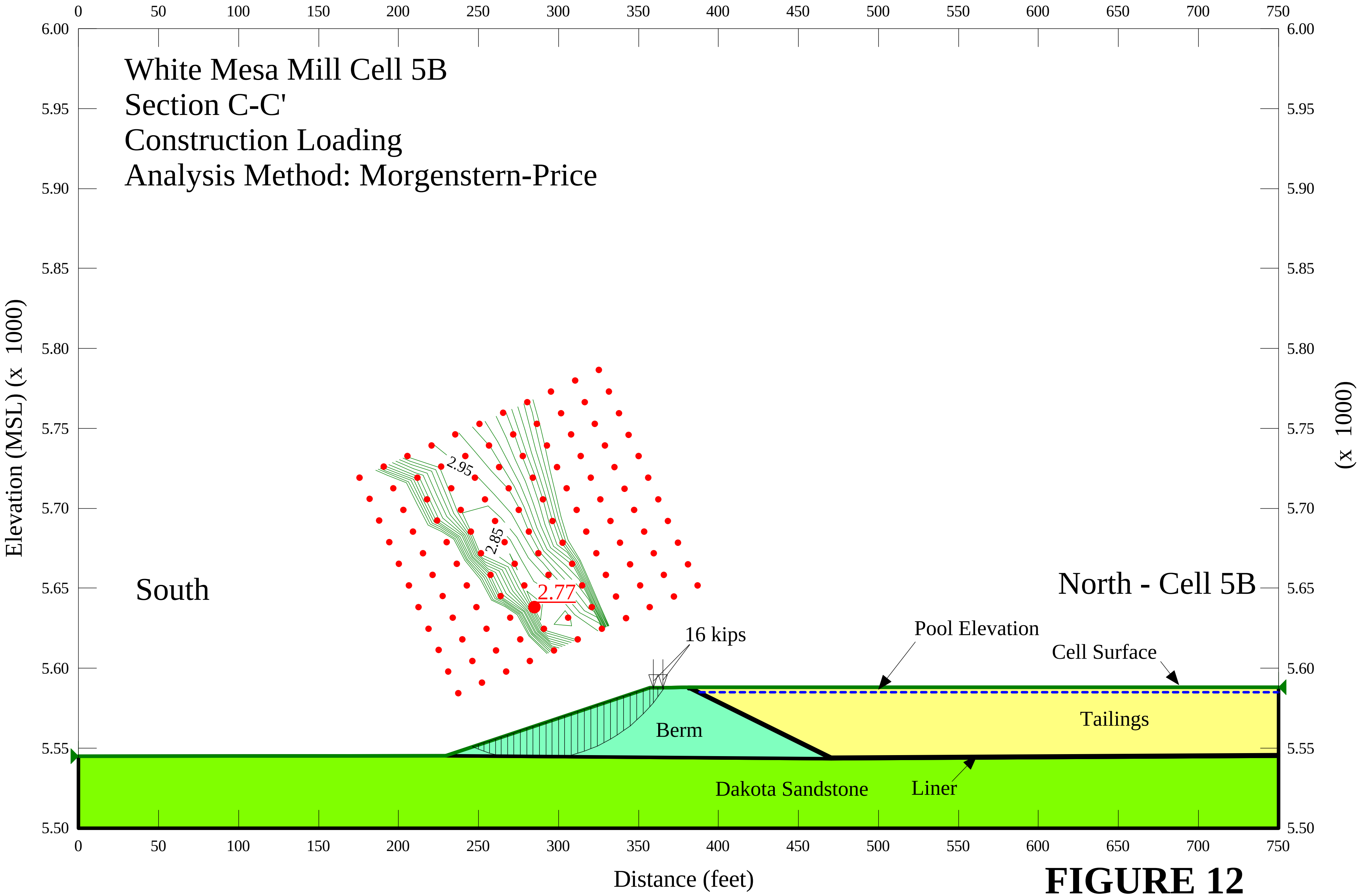

White Mesa Mill Cell 5B
Section C-C'
Seismic Loading (0.1g)
Analysis Method: Morgenstern-Price
2.65
2.60
2.55
2.54
South
North - Cell 5B
Pool Elevation
Cell Surface
Berm
Tailings
Dakota Sandstone
Liner
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.00
5.95
5.90
5.85
5.80
5.75
5.70
5.65
5.60
5.55
5.50

FIGURE 11



White Mesa Mill Cell 5B
Section C-C'
Construction Loading
Analysis Method: Morgenstern-Price
South
North - Cell 5B
2.95
2.85
2.77
16 kips
Pool Elevation
Cell Surface
Berm
Tailings
Dakota Sandstone
Liner
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.00
5.95
5.90
5.85
5.80
5.75
5.70
5.65
5.60
5.55
5.50

FIGURE 12

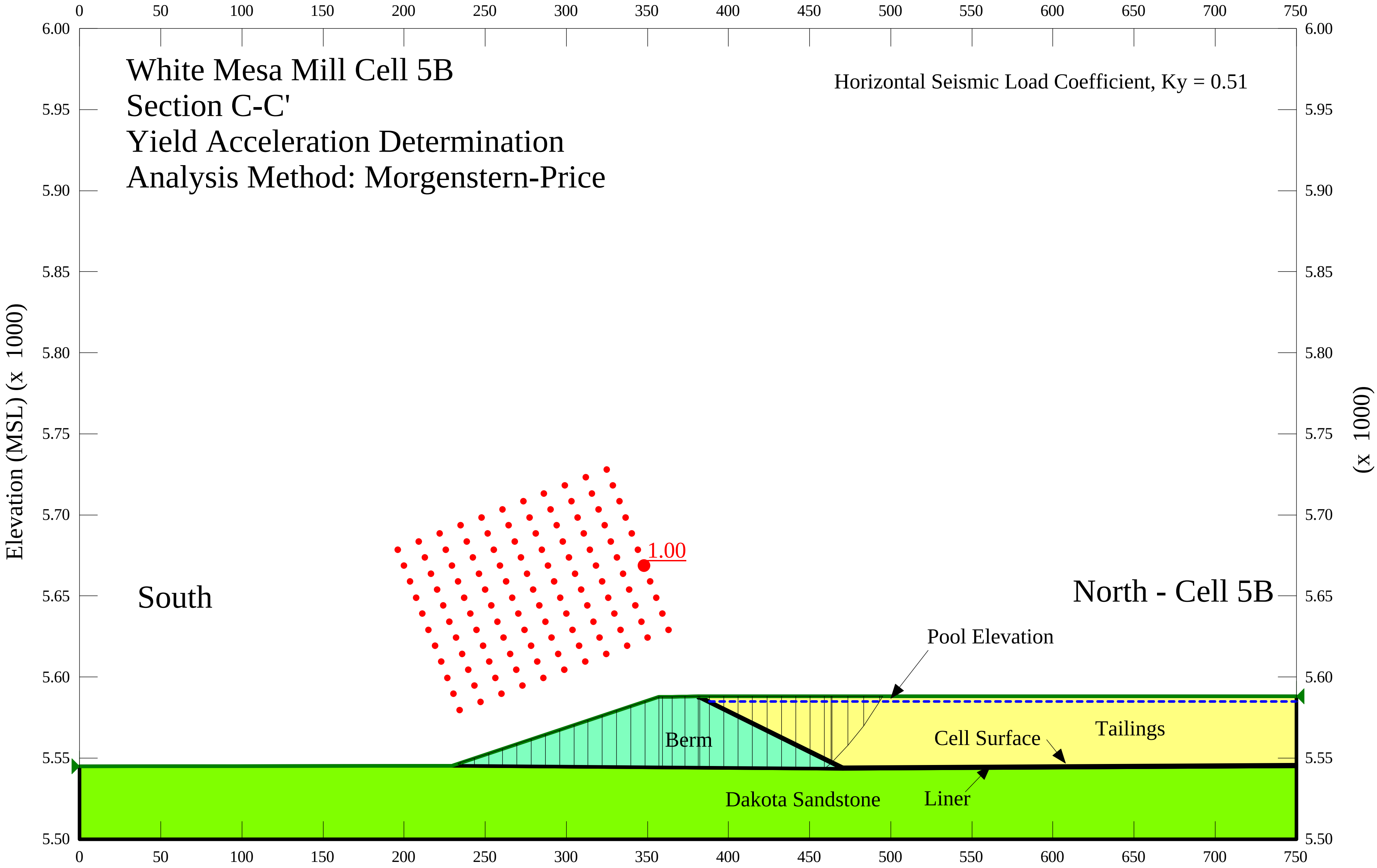
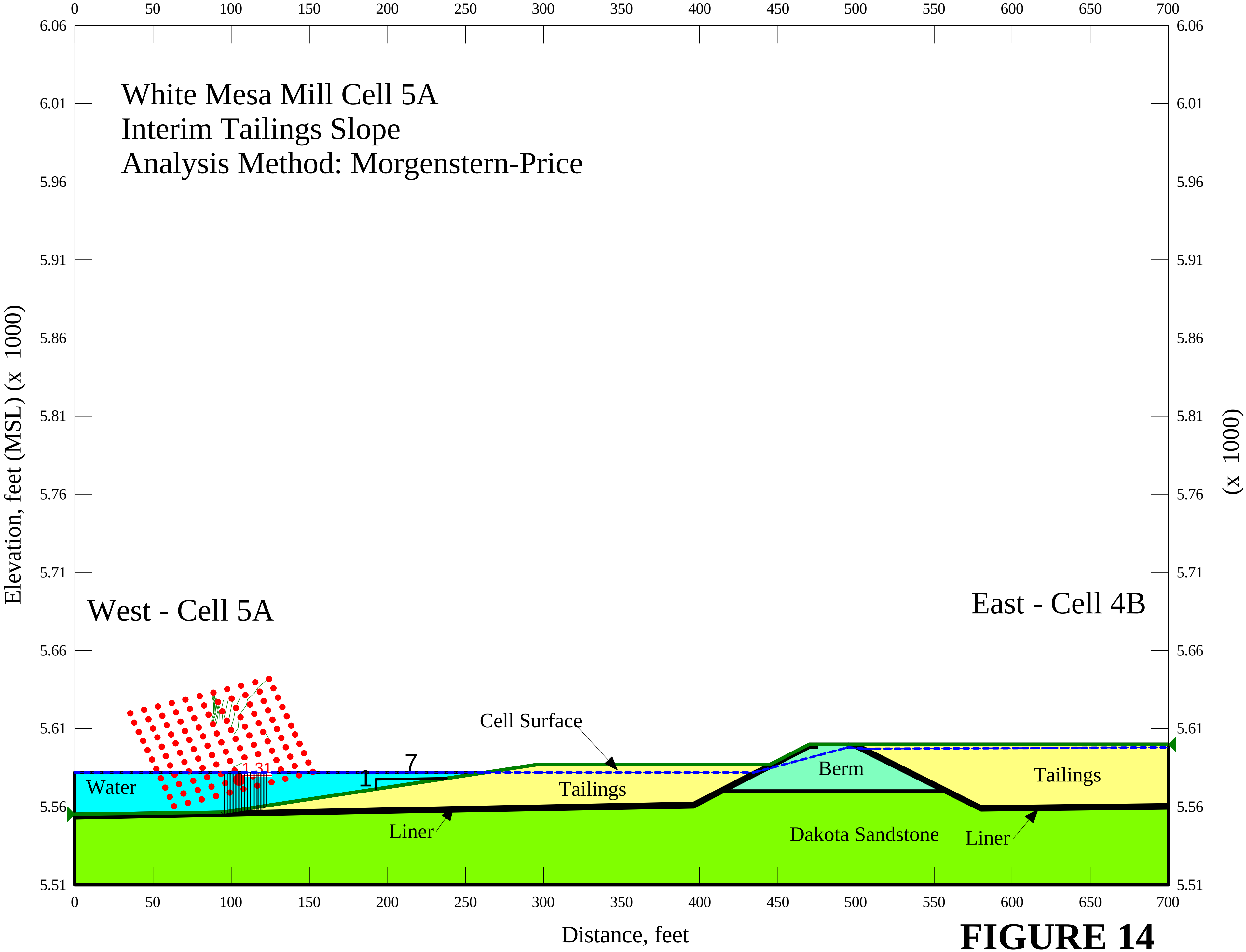

White Mesa Mill Cell 5B
Section C-C'
Yield Acceleration Determination
Analysis Method: Morgenstern-Price
Horizontal Seismic Load Coefficient, Ky = 0.51
1.00
South
North - Cell 5B
Pool Elevation
Berm
Cell Surface
Tailings
Dakota Sandstone
Liner
Elevation (MSL) (x 1000)
(x 1000)
Distance (feet)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
6.00
5.95
5.90
5.85
5.80
5.75
5.70
5.65
5.60
5.55
5.50

FIGURE 13



White Mesa Mill Cell 5A
Interim Tailings Slope
Analysis Method: Morgenstern-Price
West - Cell 5A
East - Cell 4B
Cell Surface
Water
1.31
7
1
Tailings
Berm
Tailings
Liner
Dakota Sandstone
Liner
Elevation, feet (MSL) (x 1000)
(x 1000)
Distance, feet

FIGURE 14

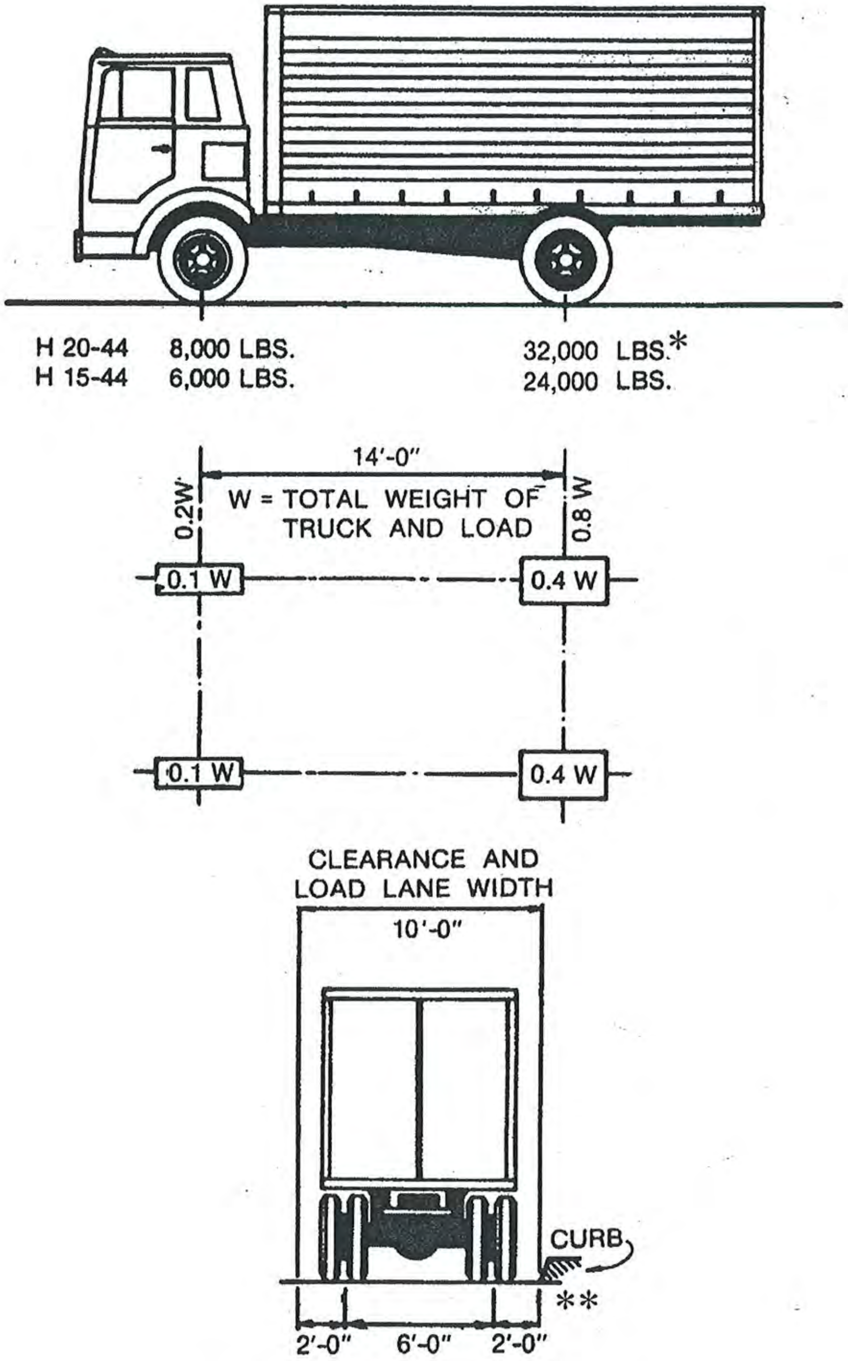


FIGURE 3.7.6A Standard H Trucks

* In the design of timber floors and orthotropic steel decks (excluding transverse beams) for H 20 loading, one axle load of 24,000 pounds or two axle loads of 16,000 pounds each spaced 4 feet apart may be used, whichever produces the greater stress, instead of the 32,000-pound axle shown.

** For slab design, the center line of wheels shall be assumed to be 1 foot from face of curb. (See Article 3.24.2)

Attachment A

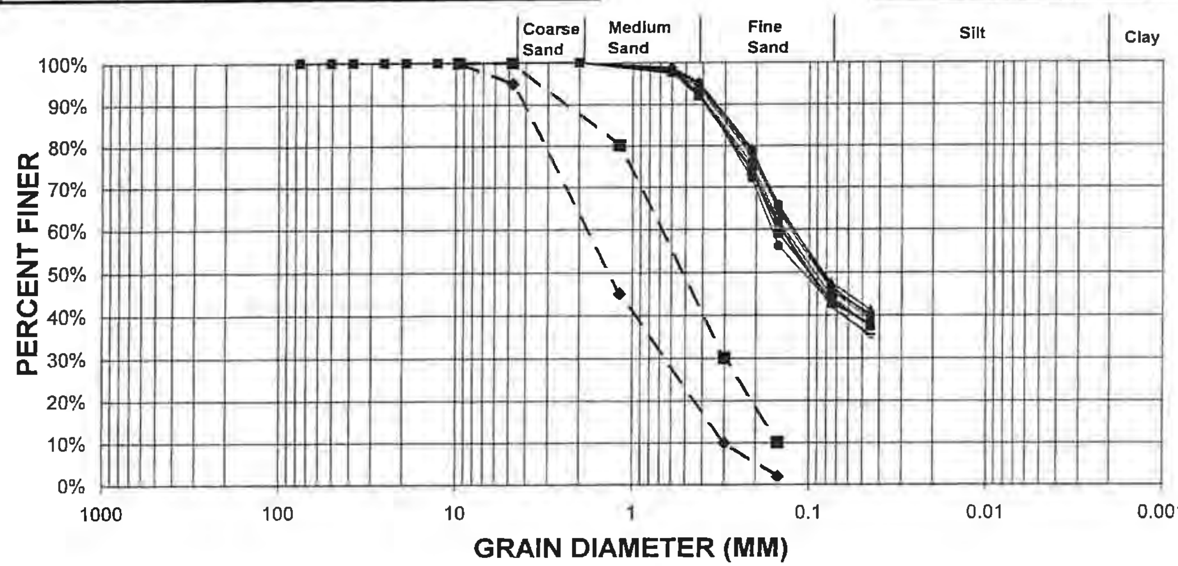
Ta

DSM Screen Undersize Gradation

SIEVE ANALYSIS

Sieve No.	Diameter (mm)	Grinding Test 1 Wt. Retained (grams)	Grinding Test 1 % Retained	Grinding Test 1 % Finer	Grinding Test 2A Wt. Retained (grams)	Grinding Test 2A % Retained	Grinding Test 2A % Finer	Grinding Test 2B Wt. Retained (grams)	Grinding Test 2B % Retained	Grinding Test 2B % Finer	Grinding Test 3A Wt. Retained (grams)	Grinding Test 3A % Retained	Grinding Test 3A % Finer	Grinding Test 3B Wt. Retained (grams)	Grinding Test 3B % Retained	Grinding Test 3B % Finer
3 in.	76.2	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
2 in.	50.8	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 1/2 in.	38.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 in.	25.4	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/4 in.	19.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1/2 in.	12.7	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/8 in.	9.530	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 4	4.750	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 10	2.000	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 30	0.600	1.2	1.2%	98.8%	2.0	2.0%	98.0%	1.7	1.7%	98.3%	2.4	2.4%	97.6%	1.9	1.9%	98.1%
No. 40	0.425	4.6	4.6%	95.4%	7.3	7.3%	92.7%	6.0	6.0%	94.0%	8.1	8.1%	91.9%	6.9	6.9%	93.1%
No. 70	0.212	20.8	20.8%	79.2%	24.5	24.5%	75.5%	22.6	22.6%	77.4%	26.2	26.2%	73.8%	27.9	27.9%	72.1%
No. 100	0.150	34.8	34.8%	65.2%	38.1	38.1%	61.9%	35.5	35.5%	64.5%	41.0	41.0%	59.0%	43.9	43.9%	56.1%
No. 200	0.075	53.4	53.4%	46.6%	55.7	55.7%	44.3%	52.5	52.5%	47.5%	56.6	56.6%	43.4%	57.4	57.4%	42.6%
No. 325	0.045	60.5	60.5%	39.5%	62.7	62.7%	37.3%	58.8	58.8%	41.2%	62.5	62.5%	37.5%	61.9	61.9%	38.1%
Pan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sieve No.	Diameter (mm)	Grinding Test 6A Wt. Retained (grams)	Grinding Test 6A % Retained	Grinding Test 6A % Finer	Grinding Test 6B Wt. Retained (grams)	Grinding Test 6B % Retained	Grinding Test 6B % Finer	Grinding Test 4A Wt. Retained (grams)	Grinding Test 4A % Retained	Grinding Test 4A % Finer	Grinding Test 4B Wt. Retained (grams)	Grinding Test 4B % Retained	Grinding Test 4B % Finer
3 in.	76.2	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
2 in.	50.8	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 1/2 in.	38.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 in.	25.4	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/4 in.	19.1	0.0	0.0%	100.0%	0.0	0.0%	100.0% 3/8 in.	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1/2 in.	12.7	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/8 in.	9.530	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 4	4.750	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 10	2.000	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 30	0.600	1.3	1.3%	98.7%	1.0	1.0%	99.0%	2.7	2.7%	97.3%	2.7	2.7%	97.3%
No. 40	0.425	5.2	5.2%	94.8%	4.7	4.7%	95.3%	7.6	7.6%	92.4%	7.3	7.3%	92.7%
No. 70	0.212	21.7	21.7%	78.3%	21.4	21.4%	78.6%	26.2	26.2%	73.8%	25.9	25.9%	74.1%
No. 100	0.150	34.1	34.1%	65.9%	35.9	35.9%	64.1%	38.7	38.7%	61.3%	39.2	39.2%	60.8%
No. 200	0.075	54.4	54.4%	45.6%	54.4	54.4%	45.6%	57.3	57.3%	42.7%	58.3	58.3%	41.7%
No. 325	0.045	59.7	59.7%	40.3%	61.1	61.1%	38.9%	65.4	65.4%	34.6%	64.6	64.6%	35.4%
Pan	-	-	-	-	-	-	-	-	-	-	-	-	-



Average	
Med Sand	6.4%
Fine Sand	49.1%
Silt	44.4%

Colorado School of Mines
Research Institute
Grinding Reports
5 JUNE 1978
DSM Screen Undersize"

%FINER = 100 - Σ%RETAINED

7/20/2007

Attachment B, 1/1

TABLE 6
Typical Values of Soil Index Properties

	Particle Size and Gradation				Voids(1)					Unit Weight(2) (lb./cu.ft.)						
	Approximate Size Range (mm)		Approx. D_{10} (mm)	Approx. Range Uniform Coefficient C_u	Void Ratio			Porosity (%)		Dry Weight			Wet Weight		Submerged Weight	
	D_{max}	D_{min}			e_{max} loose	e_{cr}	e_{min} dense	n_{max} loose	n_{min} dense	Min loose	100% Mod. AASHO	Max dense	Min loose	Max dense	Min loose	Max dense
GRANULAR MATERIALS																
Uniform Materials																
a. Equal spheres (theoretical values)	-	-	-	1.0	0.92	-	0.35	47.6	26	-	-	-	-	-	-	-
b. Standard Ottawa SAND	0.84	0.59	0.67	1.1	0.80	0.75	0.50	44	33	92	-	110	93	131	57	69
c. Clean, uniform SAND (fine or medium)	-	-	-	1.2 to 2.0	1.0	0.80	0.40	50	29	83	115	118	84	136	52	73
d. Uniform, inorganic SILT	0.05	0.005	0.012	1.2 to 2.0	1.1	-	0.40	52	29	80	-	118	81	136	51	73
Well-graded Materials																
a. Silty SAND	2.0	0.005	0.02	5 to 10	0.90	-	0.30	47	23	87	122	127	88	142	54	79
b. Clean, fine to coarse SAND	2.0	0.05	0.09	4 to 6	0.95	0.70	0.20	49	17	85	132	138	86	148	53	86
c. Micaceous SAND	-	-	-	-	1.2	-	0.40	55	29	76	-	120	77	138	48	76
d. Silty SAND & GRAVEL	100	0.005	0.02	15 to 300	0.85	-	0.14	46	12	89	-	146(3)	90	155(3)	56	92
MIXED SOILS																
Sandy or Silty CLAY	2.0	0.001	0.003	10 to 30	1.8	-	0.25	64	20	60	130	135	100	147	38	85
Skip-graded Silty CLAY with stones or rk fgmts	250	0.001	-	-	1.0	-	0.20	50	17	84	-	140	115	151	53	89
Well-graded GRAVEL, SAND, SILT & CLAY mixture	250	0.001	0.002	25 to 1000	0.70	-	0.13	41	11	100	140	148(4)	125	156(4)	62	94
CLAY SOILS																
CLAY (30%-50% clay sizes)	0.05	0.5μ	0.001	-	2.4	-	0.50	71	33	50	105	112	94	133	31	71
Colloidal CLAY (-0.002 mm: 50%)	0.01	10Å	-	-	12	-	0.60	92	37	13	90	106	71	128	8	66
ORGANIC SOILS																
Organic SILT	-	-	-	-	3.0	-	0.55	75	35	40	-	110	87	131	25	69
Organic CLAY (30% - 50% clay sizes)	-	-	-	-	4.4	-	0.70	81	41	30		100	81	125	18	62

*

Attachment C, NAVFAC DM7-01, 1986
(Navy Soil Design Manual)

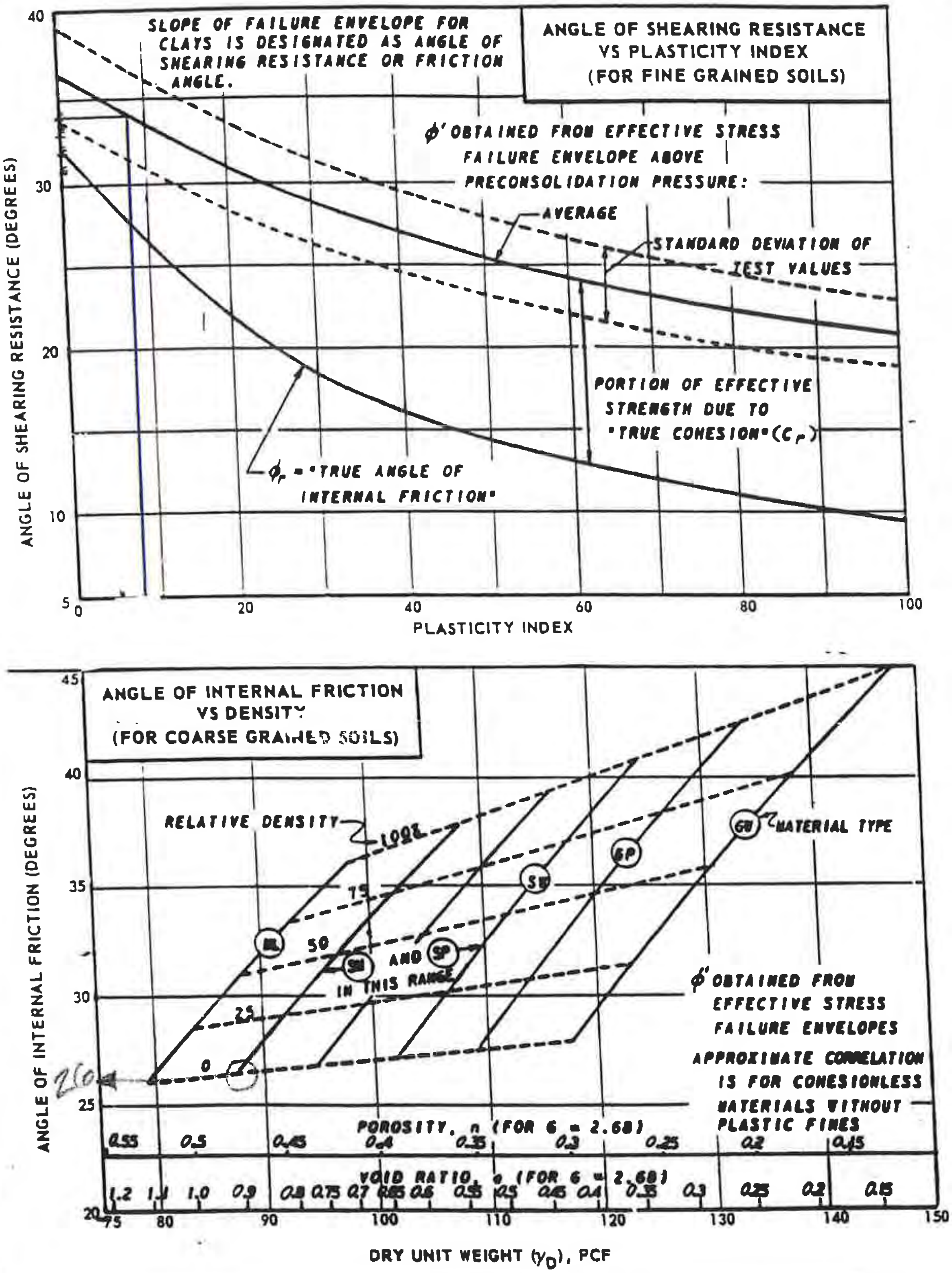


FIGURE 3-7
Correlations of Strength Characteristics

NAVFAC DM7-03, 1986

ATTACHMENT D

M F G

consulting scientists and engineers

TECHNICAL MEMORANDUM

TO: JoAnn Tischler, TetraTech EMI, Denver **MFG PROJECT: 181413X**

FROM: Tom Chapel

DATE: June 7, 2006

SUBJECT: White Mesa Stability Analysis

This memorandum presents details and results of slope stability analyses performed for an earthen embankment at the White Mesa Project near Blanding, Utah. The embankment was designed in approximately 1988 by Umetco Minerals Corporation, with details described in a report titled "*Cell 4 Design, Tailings Management System, White Mesa Project, Blanding, Utah*". The text of that report, excluding appendices was provided for our review, as were Sheet C4-1 and Sheet C4-2, plans prepared by Western Engineers, Inc. and dated January 17, 1989. Sheet C4-1 shows the location of Cell 4 and other facilities; and Sheet C4-2 shows cross sections at specified locations. The locations and configuration of the section used in our analyses are described later in this memorandum. In addition to the design report and plan sheets, we received a packet titled *Dike Construction, Soil Properties*, and one titled *Dike Construction, Compaction Test*. These documents are copies of laboratory and field tests characterizing the site soils from tests performed during design and construction of the embankment.

We understand the International Uranium (IUSA) Corporation is considering using Cell 4 to impound water and tailings. As part of the permitting process, IUSA has been requested to evaluate the stability of the 2h:1v embankment slope that was constructed on the Cell 4-A side of an embankment constructed between Cells 4-A and 4-B. Tetra Tech has evaluated the stability of the 2h:1v embankment slope. Our methodology, results, conclusions, and opinions are presented in the following paragraphs.

The design report indicates Cell 4-A and Cell 4-B are adjacent cells of a tailing impoundment, each approximately 1150 acre feet with final surface areas of 40 acres each. The tailings will be impounded on the upstream side of a homogenous earth dike. The embankment that is the subject of our investigation is a homogenous earthen embankment constructed between Cell 4-A and Cell 4-B. The general site layout and location are shown on Figure 1.

Several geotechnical investigations were conducted at the site between 1978 and 1981 and results are described in the design report. The embankment was constructed of on-site soils classified as CL and/or ML according to the Unified Soil Classification method (USCS). In the vicinity of Cell 4, bedrock is reported to be sandstone of the Dakota Formation that was encountered at depths of 3.5 to 13 feet. The bedrock is described as including discontinuous lenses of claystone and siltstone. Groundwater was found at depths of 70 and 110 feet below the ground surface in the vicinity of Cell 4.

According to the design report, the embankment base was prepared by removing topsoil, then compacting and proof-rolling the base to identify soft areas, which were removed and replaced with suitable soils.

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Telephone (970) 223-9600 / FAX (970) 223-7171

ATTACHMENT E (1/8)

The embankment was constructed using 12 inch loose layers compacted and tested. Test results provided to us support the methods described in the design report.

The design report included a slope stability analysis performed on the Cell 4-B side of the separating embankment using a STABR computer model, the Ordinary Method of slices, and Bishops modified Method of analysis. That analysis indicated a minimum factor of safety of 1.5 for a 25 foot high embankment and a 3h:1v slope, assuming a saturated, steady state condition in which water was impounded to a level 2 feet below the crest of the embankment. The section was also analyzed using a 0.1g lateral load and a minimum factor of safety of 1.1 was calculated.

Tetra Tech modeled the slope using Cell 4 cross section D-D' shown on Sheet C4-2. We assumed a maximum crest elevation of 5608 feet, a crest width of 18 feet, a side slope of 2h:1v on the Cell 4-A side of the embankment, and a side slope of 3h:1v on the Cell 4-B side of the embankment. This resulted in a maximum embankment height of 46 feet, including 28 feet of man-placed, fine, silty sand fill over seven feet of natural silty sand, over sandstone bedrock. Where the excavation penetrated the bedrock we assumed a one foot thick layer was processed to a sand soil condition and recompacted in place. IUSA indicated a minimum 3 foot freeboard will be maintained. The soil parameters used in our analysis were taken from Figure 3.4-1 of the design report, and are shown in Table 1 below:

Table 1. Soil Properties

Unit	Description	Phi (degrees)	Cohesion, c (psf)	Total unit weight (pcf)
1	water	0	0	62.4
2	Compacted fine, silty sand	30	0	123
3	Natural silty sand	28	0	120
4	bedrock	-	-	-

We evaluated the embankment stability with Slope/W software by Geoslope International, using Spencers method, Bishops modified method, and the Ordinary method of slices. We evaluated a steady state condition under static conditions and using a 0.1g seismic loading. IUSA requested we model the slope in a submerged condition assuming a no-strength fluid (water) as one alternative; and in a submerged condition with an impermeable synthetic liner/barrier as a second alternative. We understand that rapid draw down conditions are not applicable for this application. Figures 2 and 3 show the slope conditions and minimum factors of safety for the static and seismic conditions and the steady state, saturated condition. Figures 4 and 5 show the slope conditions and minimum factors of safety for static and seismic conditions assuming an impenetrable barrier between the water and the soil. Minimum safety factors are summarized in Table 2, below:

Table 2. Minimum Factors of Safety

Figure	Condition	Calculated Minimum Factor of Safety
2	Unlined alternative, static, steady state	1.42
3	Unlined Alternative, 0.1g seismic	0.93
4	Lined Alternative, static	1.88
5	Lined Alternative, 0.1g seismic	1.37

The Slope/W software includes a feature called "safety mapping" which plots variable numbers of slip surfaces in addition to the critical failure surface. These radii can be seen in Figures 2 and 3 and show primary failure planes are generally more deep seated, but the slope has a much higher factor of safety against the larger failure planes. A similar plot is included in Figures 4 and 5, however the slip surfaces (including the critical radius) are very small and occur near the crest of the embankment.

The results of our analysis indicate the minimum factors of safety for the unlined alternative are lower than recommended standards. A factor of safety of 1.0 indicates an unstable condition. However, these scenarios assumed an unlined saturated, condition and are therefore not representative of the planned construction. We understand the planned construction is with double synthetic liners with a drain medium and solution recovery system between the liners. The unlined alternative is not a valid analysis if the Cell is completed according to the reported plans. The lined alternative had minimum safety factors greater than commonly accepted standards for both the static and seismic conditions. The impoundment should not be used in an unlined condition unless additional analyses are performed that indicate acceptable performance, but if the construction is completed as described then the dike between Cell 4-A and 4-B with the side slope of 2h:1v meets or exceeds recommended standards for stability and safety factors.

We assumed that as-constructed soil conditions are as indicated in the design report and according to data from tests performed during the actual construction, and significant changes have not occurred since the time of construction. These analyses and results should be considered valid only for the conditions described herein.

We understand the soil/liner stability issues will be addressed by others. If you have any questions regarding our analysis or this memorandum, please contact the undersigned.

Thomas A. Chapel, CPG, PE

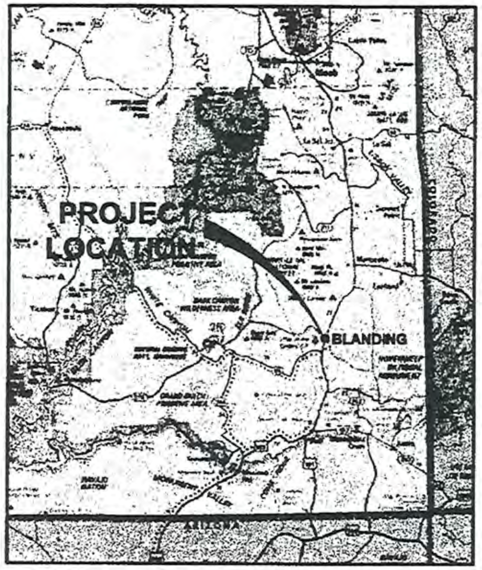
Senior Geotechnical Engineer

Reviewed by:

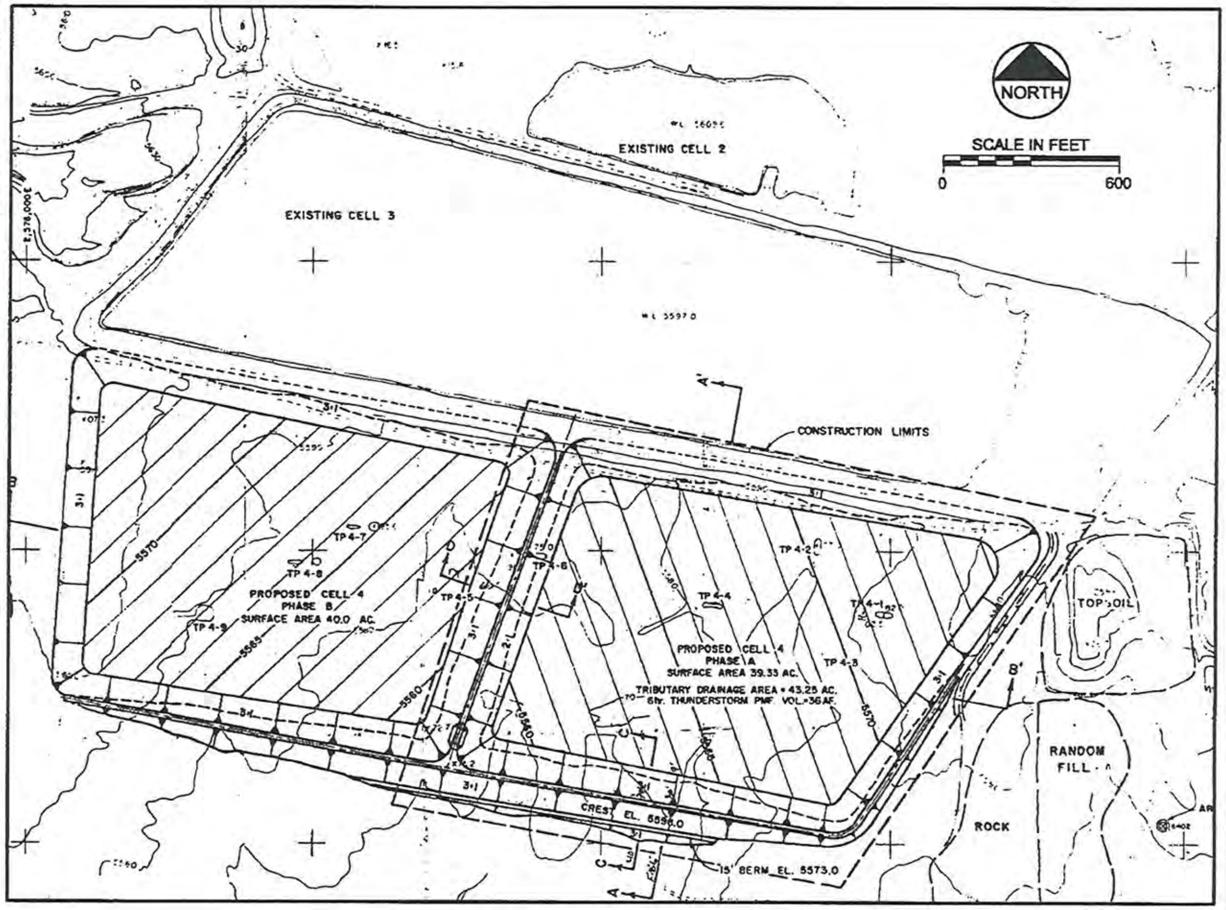
Daniel D. Overton, PE

Senior Geotechnical Engineer

PROFESSIONAL ENGINEER No. 262... DANIEL D. OVERTON STATE OF UTAH 12/21/06



VICINITY MAP



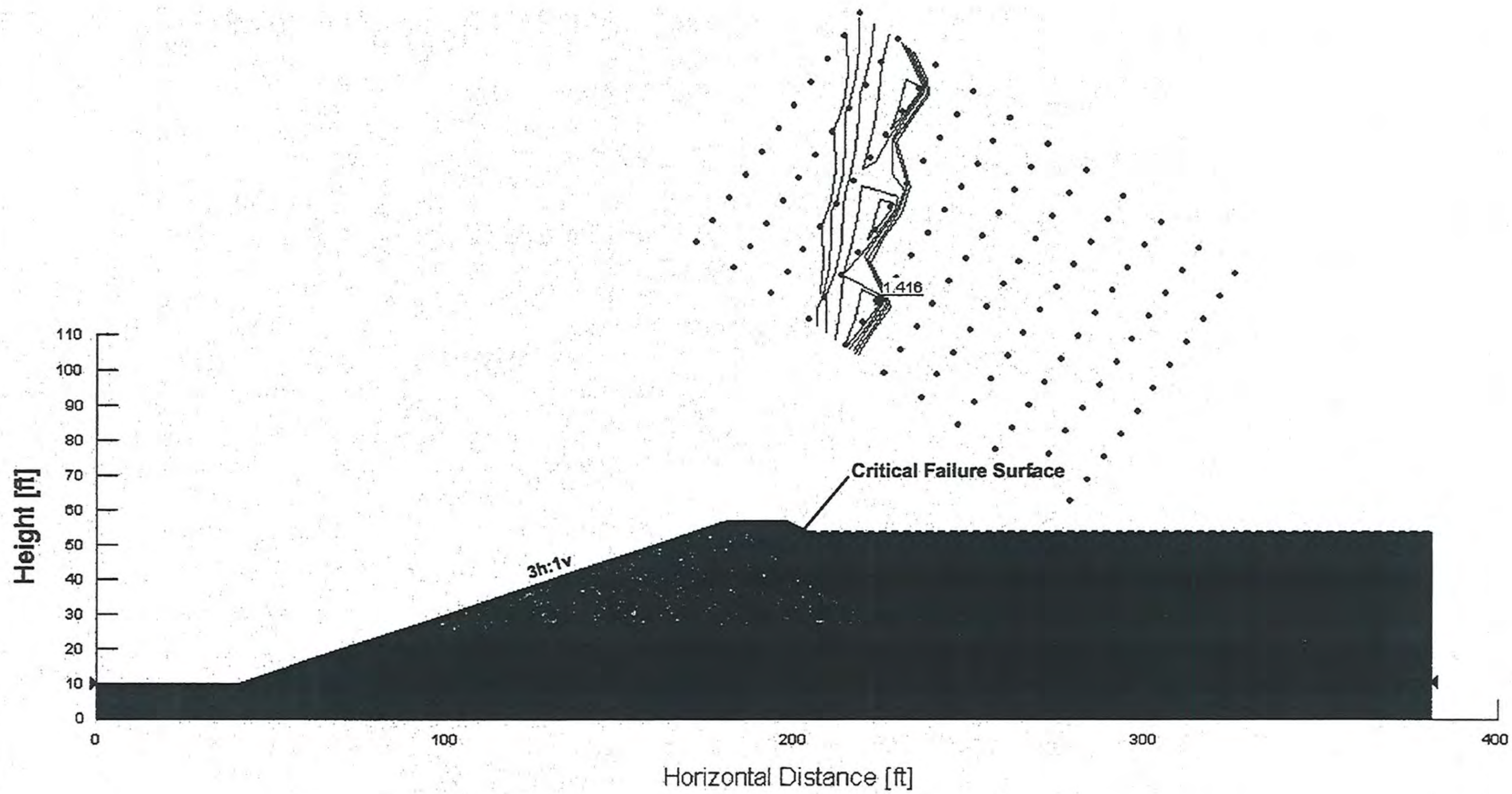
PROJECT AREA

TETRA TECH, INC.

FIGURE 1
SITE LOCATION MAP

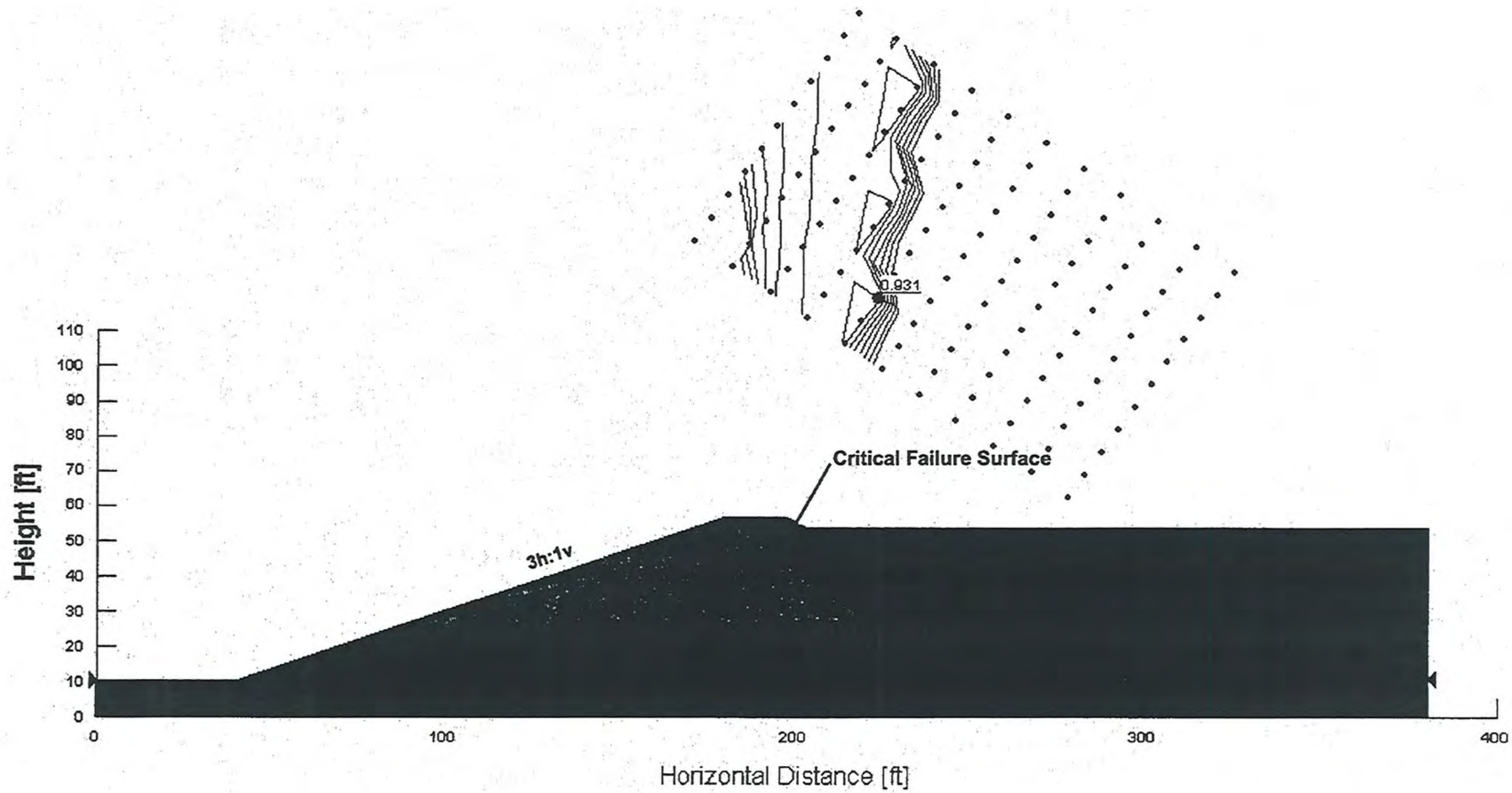
Date:	JUNE 2006
Project:	181413X
File:	LOCATION.DWG

E (4/8)



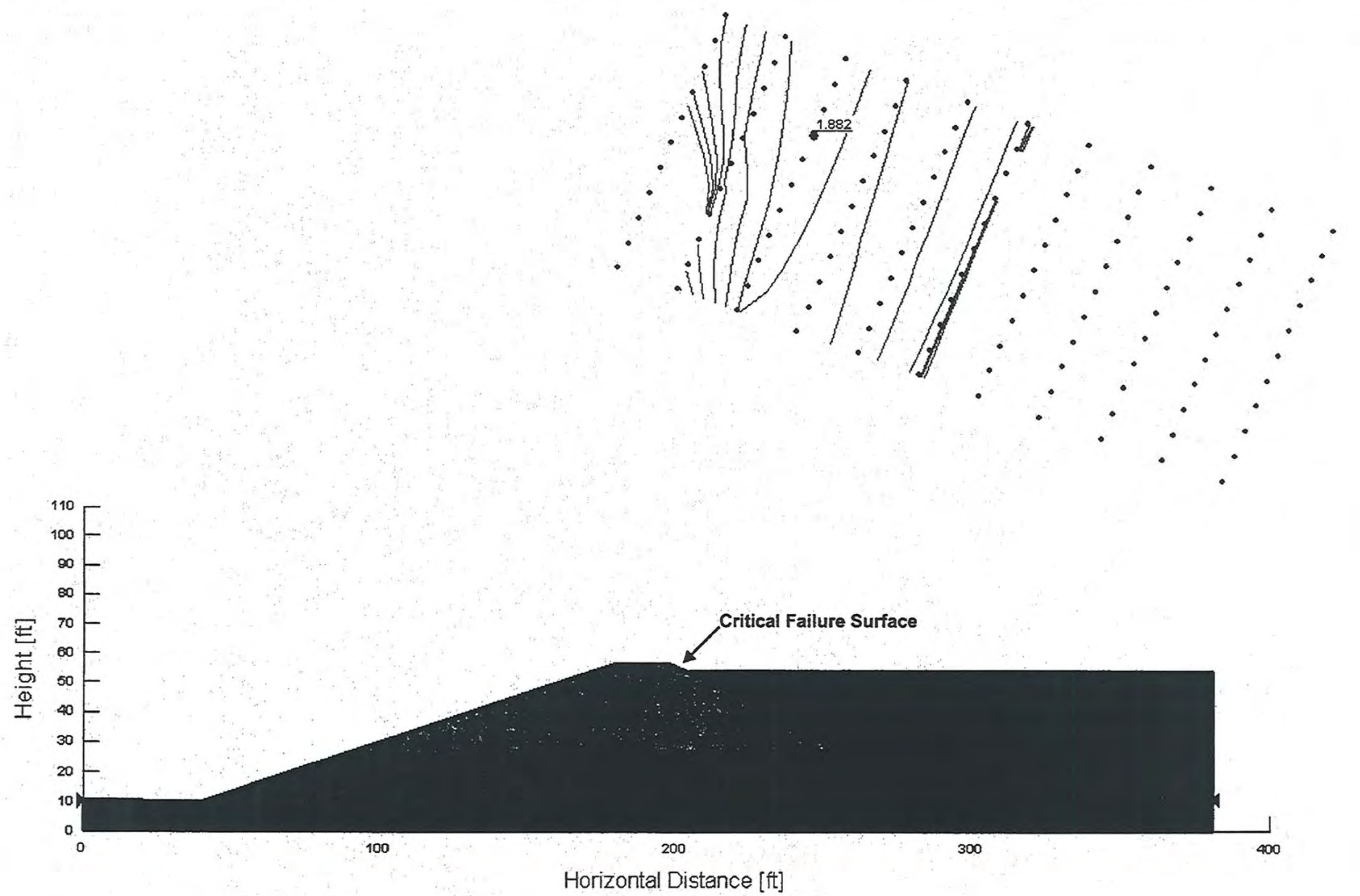
TetraTech, Inc.	FIGURE 2 Unlined Alternative Static Condition	International Uranium Corp. Project: White Mesa (181413x) 06/01/06

E (5/8)



TetraTech, Inc.	FIGURE 3 Unlined Alternative Seismic Condition	International Uranium Corp. Project: White Mesa (181413x) 06/01/06

E(6/8)

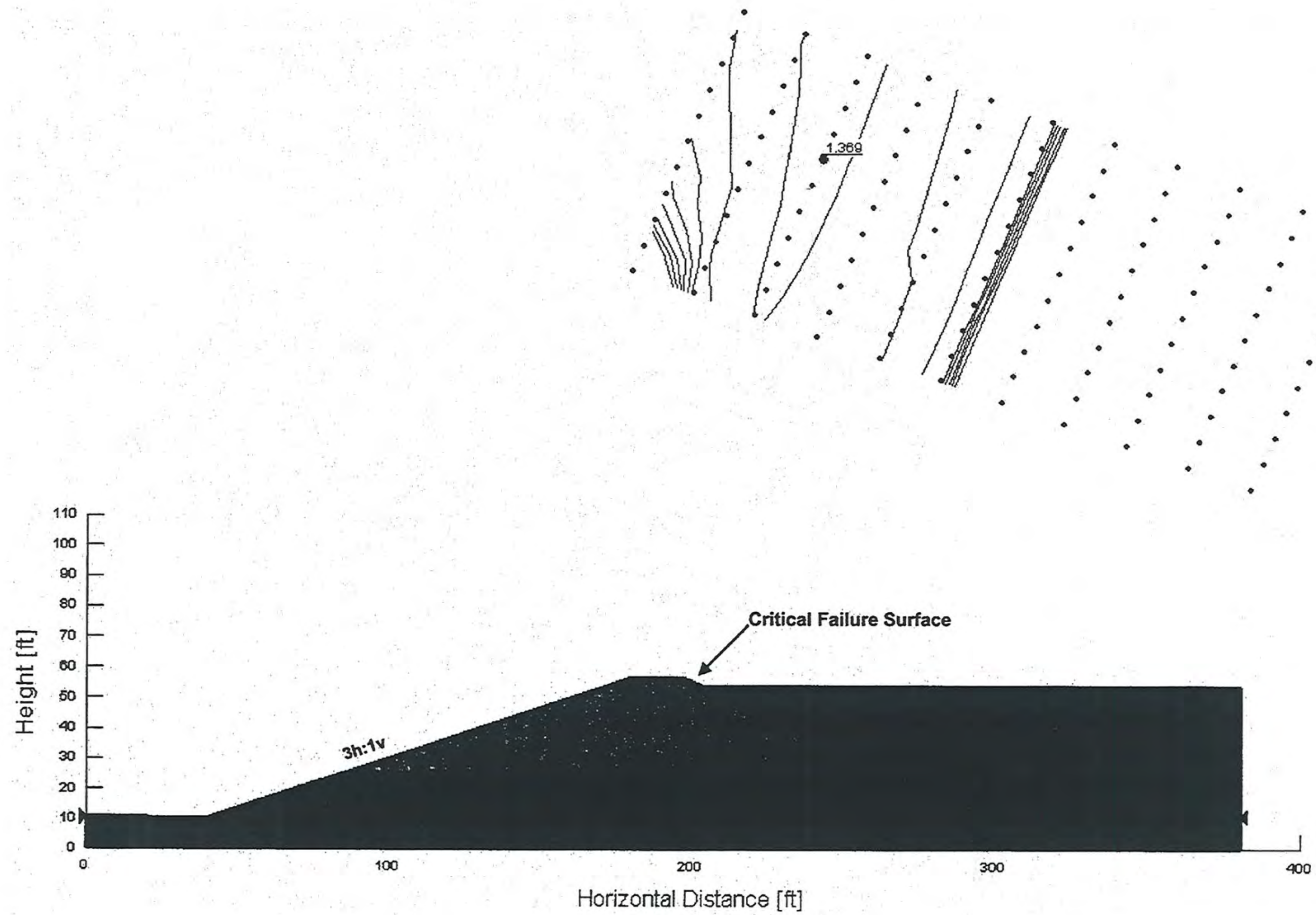


TetraTech, Inc.

FIGURE 4
Lined Alternative
Static Condition

International Uranium Corp.
Project: White Mesa (181413x)
06/01/06

E (7/8)



TetraTech, Inc.	FIGURE 5 Lined Alternative Seismic Condition	International Uranium Corp. Project: White Mesa (181413x) 06/01/06

E (8/8)

MFG, Inc.
A TETRA TECH COMPANY
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consulting
scientists and
engineers

July 13, 2006

Tetra Tech EM, Inc.
950 17th Street, 22nd Floor
Denver, Colorado 80202

MFG Project No. 181413x

Attn: Ms. JoAnn Tischler

Subject: Draft
Soil Property Verification and
Slope Stability Analyses
Earthen Embankment between Cells 4A and 4B,
IUC White Mesa Project
Blanding, Utah

Tetra Tech MFG prepared a technical memorandum dated June 7, 2006, and a letter dated June 9, 2006 describing slope stability analyses, assumptions, and recommendations for verification of soil properties for an earthen embankment at the International Uranium (USA) Corporation, White Mesa Project near Blanding, Utah.

On June 15, 2006, Tetra Tech drilled an exploratory boring in the embankment between Cell 4A and Cell 4B at the approximate location shown on Figure 1 (attached). Descriptions of soils encountered in the boring are shown on the Borehole log (also attached). The boring was drilled to a depth of 30 feet and sampled at 5 foot intervals using a 2 inch diameter California sampler driven into the soil by a 140 pound weight dropped 30 inches (a Standard Penetration Test, SPT). Samples were examined by a geotechnical engineer in our soils laboratory. Samples were selected and tested for moisture and density and Atterberg Limits to determine their classification and similarity to properties identified in previous geotechnical reports for the project. A triaxial test was performed to compare the angle of internal friction and cohesion of the in-place soil with the values determined by the original designers in 1981.

The moisture and density of the samples tested are shown in Table 1 below:

ATTACHMENT F (1/7)

Table 1. Soil Properties

Depth	Description	Wet Density (pcf)	Dry Density (pcf)	Moisture content (%)
10	Silty sand	136.5	125.0	9.2
20	Silty sand	140.5	126.3	11.3
25	Silty sand	134.7	122.6	9.9
-	Average	137.2	124.6	10.1

Atterberg limits tests indicate a liquid limit of 25, and a Plasticity Index of 13, with 50 percent silt and clay sized particles (passing the number 200 sieve). Triaxial testing indicated an effective angle of internal friction of 26.5 degrees and a drained cohesion of 957.5 psf.

These test results indicate although the samples were visually classified as silty sand, laboratory tests indicate the embankment soils tested are a very sandy clay rather than sand and silty sand as reported by others and assumed in our initial analysis.

We performed additional slope stability analyses using the following soil properties: an average moist unit weight of 137 pcf, an angle of internal friction of 26 degrees, and an effective cohesion of 900 psf. We calculated the minimum factors of safety shown in Table 2.

Table 2. Revised Minimum Factors of Safety

Condition	Calculated Minimum Factor of Safety
Unlined alternative, static, steady state	2.45
Unlined Alternative, 0.1g seismic	1.67
Lined Alternative, static	4.61
Lined Alternative, 0.1g seismic	3.21

Therefore the factors of safety calculated and presented in our June 2 Technical Memorandum are conservative. In fact, analyses using the measured soil properties indicate that the embankment exceeds typical minimum acceptable safety factors even in the event leakage were to occur from the liner and produce a saturated condition as shown in Figure 3 of our previous memorandum.

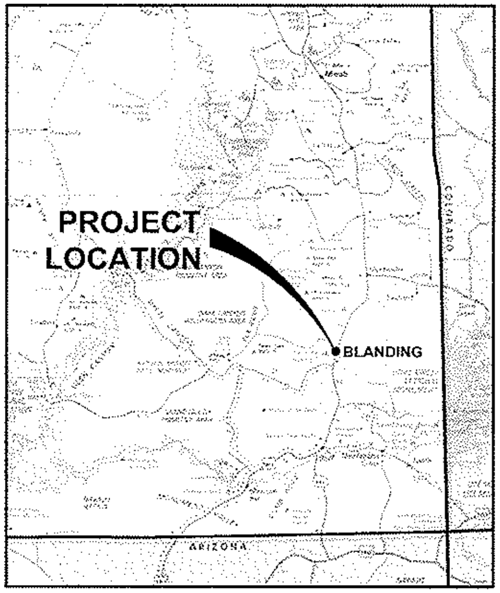
If you have any questions regarding our analysis, our previous correspondence, or this letter, please contact the undersigned.

Respectfully submitted,

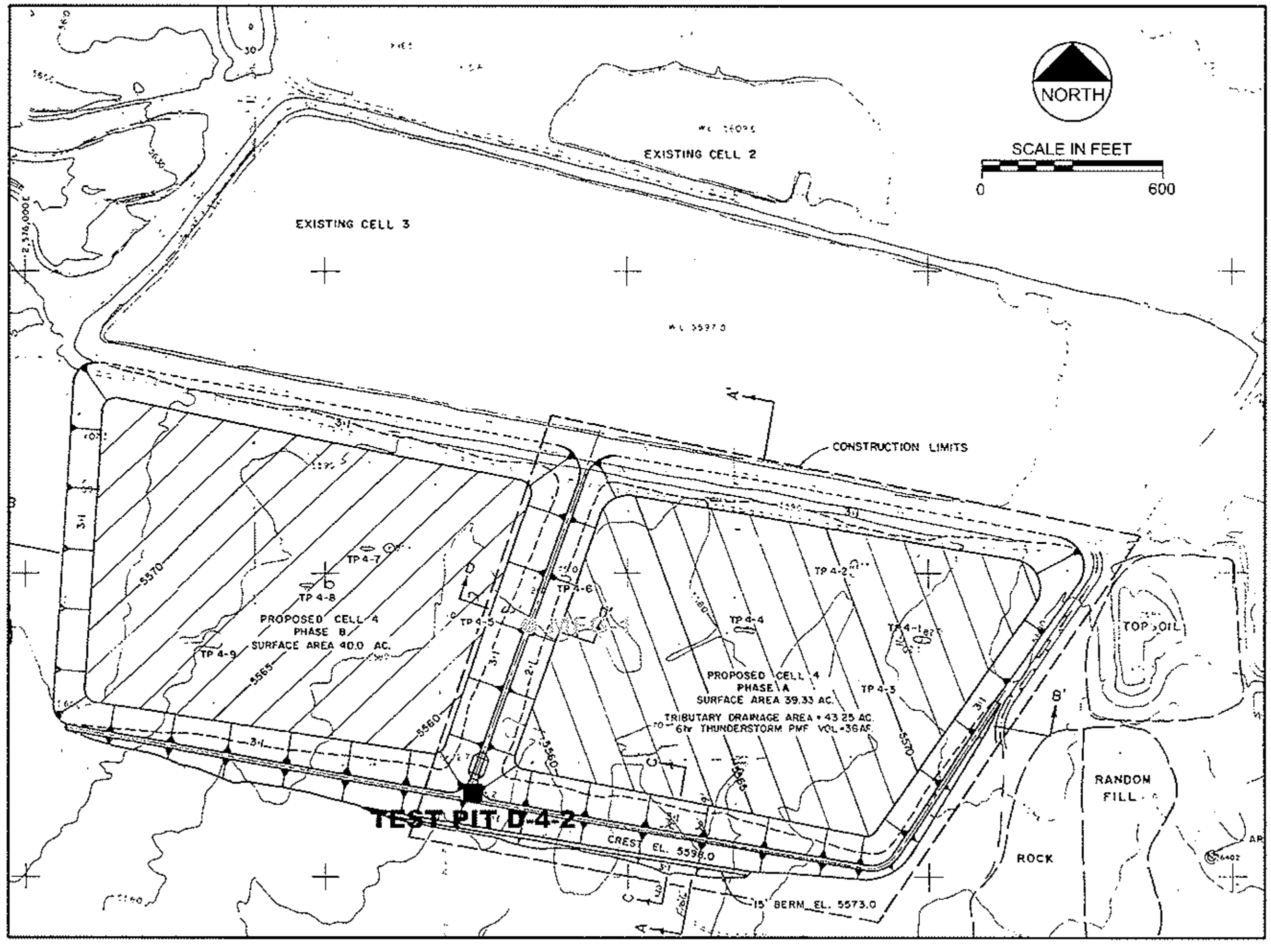
Tetratech MFG, Inc.

Thomas A. Chapel, CPG, PE
Senior Geotechnical Engineer

2 copies sent



VICINITY MAP



PROJECT AREA

4-INCH SOLID AUGER TO 30 FT. SAMPLE AT 5 FT. INTERVALS BACKFILL WITH BENTONITE

TETRA TECH, INC.

FIGURE 1
SITE LOCATION MAP

Date: JUNE 2006
Project: 181413X
File: LOCATION.DWG

F (4/7)

MFG, Inc.
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BOREHOLE LOG

DATE: 6/15/06

BOREHOLE NO.: **MFG-1**

PROJECT INFORMATION

PROJECT: WHITE MESA

PROJECT NO.: 181413X

CLIENT: TETRA TECH EMI

OWNER: INTERNATIONAL URANIUM (IUSA) CORPORATION

LOCATION: BLANDING, UTAH

BOREHOLE LOCATION

SEE FIGURE 1

FIELD INFORMATION

DATE & TIME ARRIVED: 6/15/06 9:00AM

BOREHOLE LOGGED BY: NMT

VISITORS: NONE

WEATHER: PARTLY CLOUDY, SLIGHT BREEZE, APPROX. 80°

DRILLING INFORMATION

DRILLING COMPANY: DA SMITH DRILLING

START TIME: 11:10AM

BORING DEPTH: APPROX. 31'　　BORING DIA.: 6"

DRILLING METHOD: CME 75 SOLID STEM AUGER

SAMPLING METHOD: 2-IN CA SAMPLES

TIME DRILLING COMPLETE: 12:50PM

BOREHOLE COMPLETION / ABANDONMENT INFORMATION

START TIME: 12:50PM　　COMPLETE TIME: 1:10PM

INSTRUMENTATION: NONE　　BACKFILL: BENTONITE

GROUNDWATER CONDITIONS

GROUNDWATER WAS NOT ENCOUNTERED DURING DRILLING

FOLLOWING FIELD WORK

TIME OF CLEAN-UP COMPLETE: 1:10PM　　TIME LEFT SITE: 1:50PM

NOTES:

F(5/7)

MFG, Inc. *consulting scientists and engineers*	**BOREHOLE LOG** **PROJECT:** *WHITE MESA* **PAGE:** *2 OF 3* **PROJECT NO.:** *181413X* **DATE:** *6/15/06*	**BOREHOLE NO.:** **MFG-1**

DEPTH (FT)	CORE RECOV.	DRIVE SAMPLES: SAMPLE TYPE	DRIVE SAMPLES: BLOWS (PER 6")	DRIVE SAMPLES: RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
0							**COAL COVER AT SURFACE (APPROX. 0.25')**
0–5.5							**SILTY CLAY (0 TO APPROX. 5.5')** SLIGHTLY MOIST, LIGHT OLIVE BROWN (2.5Y 5/3), VERY STIFF SILTY CLAY FILL, TRACE SAND, TRACE PEBBLES, WHITE PRECIPITATE, ZONES OF COLOR CHANGE TO RED (2.5YR 4/6). APPROX. 0.5' - MOIST.
5–6.5		CA B A	11 19 33	17"			**SILTY SAND (APPROX. 5.5' TO APPROX. 30')** SLIGHTLY MOIST, RED (2.5YR 5/6), VERY DENSE SILTY SAND, FINE TO MEDIUM GRAIN, TRACE TO SOME CLAY, WHITE PRECIPITATE. APPROX. 6.5' - SANDSTONE FRAGMENTS, DRY, PINK (5YR 8/3), VERY DENSE, MEDIUM CEMENTATION, FINE GRAIN.
10–11.5		CA B A	15 32 43	13"			
15–16.5		CA B A	13 18 36	18"			APPROX. 15' - ZONES OF SANDY CLAY VARIOUS COLORS, MOIST.
20							

F(6/7)

MFG, Inc. *consulting scientists and engineers*	**BOREHOLE LOG** **PROJECT:** *WHITE MESA* **PAGE:** *3 OF 3* **PROJECT NO.:** *181413X* **DATE:** *6/15/06*	**BOREHOLE NO.:** **MFG-1**

DEPTH (FT)	CORE RECOV.	DRIVE SAMPLES: SAMPLE TYPE	DRIVE SAMPLES: BLOWS (PER 6")	DRIVE SAMPLES: RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC	SOIL DESCRIPTION
20							**SILTY SAND (APPROX. 5.5' TO APPROX. 30')** SEE DESCRIPTION ON PREVIOUS PAGE.
20.5–21.5		CA B A	15 29 50/6"	18"			
24							APPROX. 24' - SLIGHTLY MOIST.
25–26.5		CA B A	12 13 20	13"			
30							**SANDSTONE (APPROX. 30' TO E.O.B.)** SLIGHTLY MOIST, PINK (2.5YR 8/3), VERY DENSE SANDSTONE, FINE TO MEDIUM CEMENTATION, FINE GRAIN.
30–31		CA B A	38 50/5"	13"			
31							E.O.B. = 31.0'

Depth scale: 20 – 40 ft.

F(7/7)

TRI/ENVIRONMENTAL, INC.

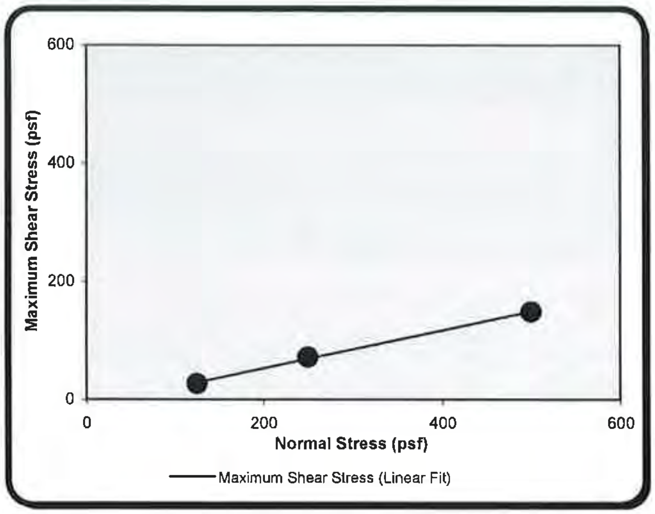
A Texas Research International Company

INTERFACE FRICTION TEST REPORT

Client: **Agru**
Project: Anne Steacy
Test Date: 7/5-7/5/05

TRI Log#: E2201-75-03
Test Method: ASTM D 5321

Tested Interface: Agru 60 mil Studliner vs. Agru 60 mil Smooth Geomembrane



Upper Box: Agru 60 mil smooth Geomembrane

Lower Box: Agru 60 mil Studliner

Interface Conditioning: Interface soaked and loading applied for a minimum of 3 hours prior to shear

Box Dimension: 12"x12"x4"

Test Condition: Wet

Shearing Rate: 0.2 inches/minute

Trial Number	1	2	3
Bearing Slide Resistance (lbs)	9	10	13
Normal Stress (psf)	125	250	500
Maximum Shear Stress (psf)	36	82	161
Corrected Shear Stre	27	72	148
Secant Angle (degrees)	12.1	16.0	16.5

RESULTS: Maximum Friction Angle and Y-intercept

Regression Friction Angle (degrees):		**16.2**		
Y-intercept or Regression Adhesion (psf):		**0**		
Regression Line:	Y=	0.290	* X +	0
Regression Coefficient (r squared):		0.986		

Note: The regression line includes the origin.

John M. Allen, E.I.T., 07/11/2005
Quality Review/Date

9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

ATTACHMENT G (1/4)

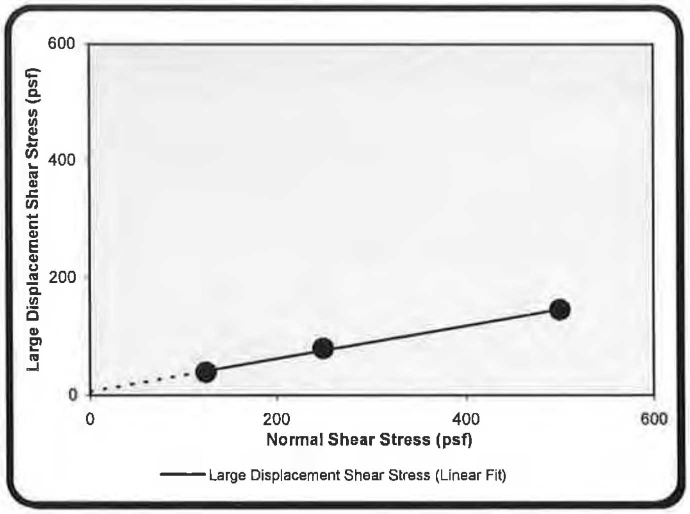
TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

INTERFACE FRICTION TEST REPORT

Client: **Agru**
Project: Anne Steacy
Test Date: 7/5-7/5/05

TRI Log#: E2201-75-03
Test Method: ASTM D 5321

Tested Interface: Agru 60 mil Studliner vs. Agru 60 mil Smooth Geomembrane



Upper Box: Agru 60 mil smooth Geomembrane

Lower Box: Agru 60 mil Studliner

Interface Conditioning: Interface soaked and loading applied for a minimum of 3 hours prior to shear

Box Dimension: 12"x12"x4"

Test Condition: Wet

Shearing Rate: 0.2 inches/minute

Trial Number	1	2	3
Bearing Slide Resistance (lbs)	9	10	13
Normal Stress (psf)	125	250	500
Large Displacment Shear Stress (psf)	48	90	158
Corrected Shear Stress (psf)	39	80	145
Secant Angle (degrees)	17.2	17.7	16.2

RESULTS: Large Displacement Friction Angle and Y-intercept at 3.5-in. of Displacement

Regression Friction Angle (degrees): 15.7
Y-intercept or Regression Adhesion (psf): 6

Regression Line: Y= 0.281 * X + 6
Regression Coefficient (r squared): 0.997

John M. Allen, E.I.T., 07/11/2005
Quality Review/Date

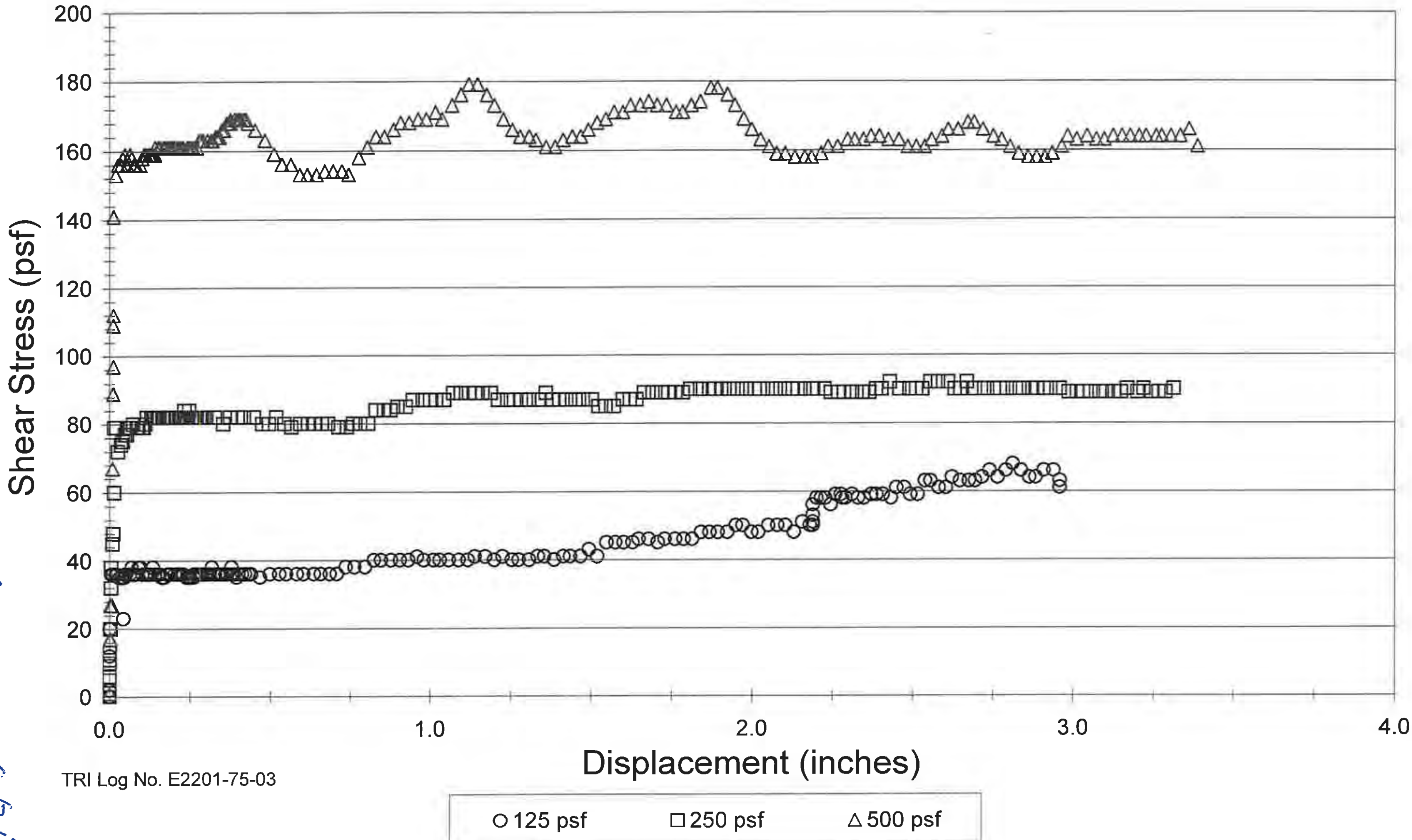
Large displacement shear stresses interperted at 2 inches of diplacement due to strain hardening effects.

9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

ATTACHMENT G (2/4)

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

AGRU INTERFACE FRICTION TEST
Agru 60 mil Smooth Geomembrane vs. Agru 60 mil Studliner



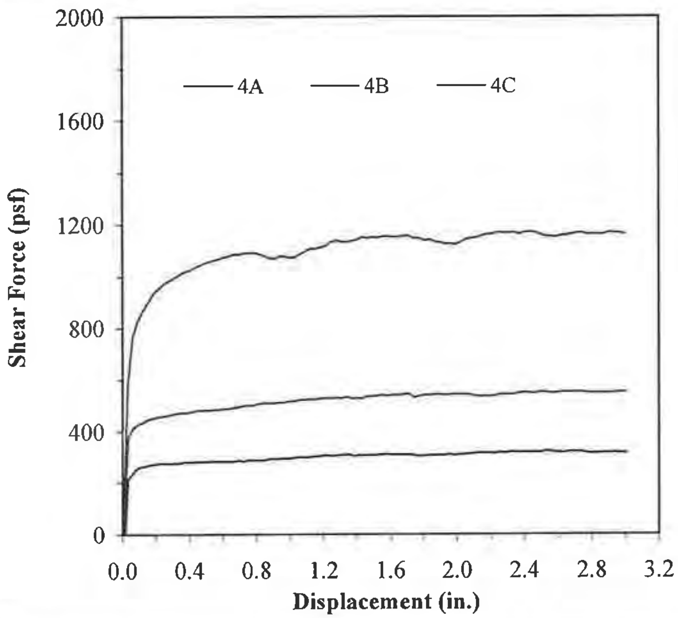
TRI Log No. E2201-75-03

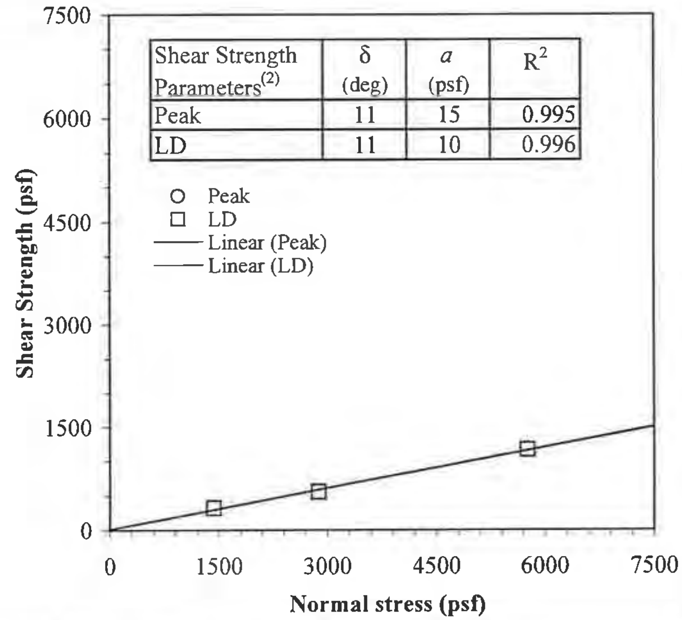
9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ FAX (512) 263-2558 □ 1-800-880-TEST

ATTACHMENT G (3/4)

GEOSYNTEC CONSULTANTS - DENISON MINES
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Steel plate with textured surafce
GSE GNS-300E geonet #131340947/
GSE 60-mil B/W smooth HDPE geomembrane #104152973 with white side up/
Lower Shear Box: Concrete sand





Shear Strength Parameters[2]	δ (deg)	a (psf)	R^2
Peak	11	15	0.995
LD	11	10	0.996

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	GCL Soaking Stress (psf)	GCL Soaking Time (hour)	Consolidation[1] Stress (psf)	Consolidation[1] Time (hour)	Subgrade Soil γ_d (pcf)	Subgrade Soil ω_i (%)	Subgrade Soil ω_f (%)	Cover Soil γ_d (pcf)	Cover Soil ω_i (%)	Cover Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_P (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
4A	12 x 12	1440	0.20	-	-	-	-	-	-	-	-	-	-	-	-	324	316	(1)
4B	12 x 12	2880	0.20	-	-	-	-	-	-	-	-	-	-	-	-	553	552	(1)
4C	12 x 12	5760	0.20	-	-	-	-	-	-	-	-	-	-	-	-	1172	1162	(1)

NOTES:
(1) Shear failure occurred at the interface between the geonet and white side of geomembrane.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

SGI TESTING SERVICES, LLC

DATE OF REPORT:	5/15/2010
FIGURE NO.	C-4
PROJECT NO.	SGI10027
DOCUMENT NO.	
FILE NO.	

APPENDIX G (4/4)

S10027-04.ds.xls

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF**	Project: **White Mesa Mill – Cell 5A & 5B**	Project/ Proposal No.: Task No.	**SC0634**

Title of Computations: **Spillway Capacity Calculations**

Computations by:	Signature	[signature]	12/18/12
	Printed Name	Rebecca Flynn, P.E.	Date
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature	[signature]	12/20/12
	Printed Name	Keaton Botelho, P.E.	Date
	Title	Project Engineer	
Computations Checked by:	Signature	[signature]	12/20/12
	Printed Name	Keaton Botelho, P.E.	Date
	Title	Project Engineer	
Computations backchecked by: (originator)	Signature	[signature]	12/18/12
	Printed Name	Rebecca Flynn, P.E.	Date
	Title	Project Engineer	
Approved by: (pm or designate)	Signature	[signature]	12/18/12
	Printed Name	Gregory T. Corcoran, P.E.	Date
	Title	Principal	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date: 12/18/12	Reviewed by:	G. Corcoran	Date: 12/18/12
Client: Energy Fuels	Project: White Mesa Mill- Cells 5A and 5B		Project/ Proposal No.:	SC0634	Task No.: 02

SPILLWAY CAPACITY CALCULATIONS

OBJECTIVE

The purpose of this calculation is to estimate the capacity of the spillway designed for Cells 5A and 5B. Cells 5A and 5B will be used for process liquids evaporation and disposal of tailings and by-products of the ore processing operations at the site. Initially, Cell 5A will contain excess runoff from the upstream Cells 2, 3, 4A, and 4B during the Probable Maximum Precipitation (PMP); 6 hour storm event. Following construction of Cell 5B, excessive runoff from the upstream Cells 2 through 5A will be contained in Cell 5B. The spillway between Cells 4B and 5A is located at the northeast corner of Cell 5A and is designed to pass excess runoff not retained in Cells 2 through 4B during the PMP event. The spillway between Cells 5A and 5B will be located in the southeast and southwest corners of Cells 5A and 5B, respectively, and is designed to pass excess runoff not retained in Cells 2 through 5A during the PMP event.

ASSUMPTIONS

The following assumptions were used for completion of this calculation:

- The watershed areas of the Cells are:

	Watershed Area
Cell 2	87 acre
Cell 3	83 acre
Cell 4A	42 acre
Cell 4B	44.5 acre
Cell 5A	42 acre
Cell 5B	42 acre

- The spillway conveying flows were designed with the following discharges:

Spillway	Flow
Cell2 to Cell 3	1283 cfs
Cell 3 to Cell 4A	1224 cfs
Cell 4A to Cell 4B	2507 cfs
Cell 4B to Cell 5A	*To Be Determined
Cell 5A to Cell 5B	*To Be Determined

Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	Energy Fuels	Project:	White Mesa Mill-Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

- Runoff from the Cells were calculated using a weighted average of the prior Cell's runoff:
  - The area weighted discharge (Q) for Cell 3 is: 2507 cfs/170ac = 14.75 cfs. Therefore, the design Q for Cell 4A is 14.75 cfs/ac * 42 acres = 620 cfs.
  - The area weighted Q for Cell 4B is: 14.75 cfs/acre*44.5 acres = 656 cfs
  - The area weighted Q for Cell 5A is: 14.75 cfs/acre*42 = 620 cfs

- During the PMP event after Cell 5A construction, Cells 2 through 4B are at capacity and the discharge passing through the 4B spillway is the sum of the four design flows: $Q_{Cell\ 2} + Q_{Cell\ 3} + Q_{cell\ 4A} + Q_{cell\ 4B}$ = 1283 cfs + 1224 cfs + 620 cfs + 649 cfs = **3,783 cfs.**
- During the PMP event after Cell 5B construction, Cells 2 through 5A are at capacity and the discharge passing through the 5A spillway is the sum of the five design flows: $Q_{Cell\ 2} + Q_{Cell\ 3} + Q_{cell\ 4A} + Q_{cell\ 4B} + Q_{cell\ 5A}$ = 1283 cfs + 1224 cfs + 620 cfs + 656 cfs + 620 cfs = **4,403 cfs.**
- The 5A spillway is designed with a bottom width of 40 feet, 10:1 (horizontal: vertical) side slopes, a channel slope of 2 percent, total depth of 5.5 feet (flow depth of 2.7 feet), and finished with smooth concrete (Manning's n of 0.015). (Attachment B)
- The 5B spillway is designed with a bottom width of 35 feet, 10:1 (horizontal: vertical) side slopes, a channel slope of 1.5 percent, total depth of 4 feet (flow depth of 3.2 feet), and finished with smooth concrete (Manning's n of 0.015). (Attachment B)

SPILLWAY CAPACITY CALCULATIONS

The spillway capacity is estimated using the Manning's equation:

$Q = (1.49/n)*R^{2/3}*S^{1/2}*A$

Where:

Q – Discharge (cfs),

n – Roughness Coefficient,

R – Hydraulic Radius (ft),

Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	Energy Fuels	Project:	White Mesa Mill- Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

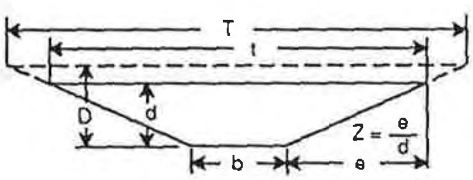
S – Channel Slope (ft/ft),
A – Flow Area (ft^2)

Cell 4B into Cell 5A

The top hinge of the spillway from Cell 4B to Cell 5A is at an elevation of 5598 ft msl. The lowest elevation around the crest of Cell 4B is 5596 ft msl and the wave run up factor is 0.77 ft (from the 10 January 1990 Drainage Report); therefore, a minimum of 2.77 ft of spillway freeboard (i.e. the top of liquid flow through the 4B to 5A spillway is 5595.23 ft msl) is necessary to prevent overtopping Cell 4B at the lowest point along the crest while allowing discharge of the runoff into Cell 5A. A discharge depth of 2.7 (i.e. the bottom of the spillway is at elevation 5592.53 ft msl) is calculated to verify that the design Q could pass the spillway with freeboard.

Figure 1 – Channel Dimensions for Trapezoidal Channels

Note: Freeboard = D–d for all selection



Cross-sectional area a	Wetted perimeter, p
$bd + Zd^2$	$b + 2d\sqrt{Z^2 + 1}$

Trapezoidal cross section

Discharge with Freeboard

n = 0.015
b = 40 ft
Z = 10
d = 2.7 ft (assumed depth of flow)
$A = (40 \times 2.7) + 10 \times 2.7^2 = 181\ ft^2$
$R = A/P$; $R = ((40 \times 2.7)+(10 \times 2.7^2))/(40+(2 \times 2.7)x(10^2+1)^{0.5}) = 1.92$ ft
S = 0.02
Qall = $(1.49/0.015) \times 1.92^{2/3} x 0.02^{1/2} \times 181$ = **3,924 cfs**

In summary, the Cell 4B into Cell 5A spillway will have a total depth of 5.5 ft (from elevation 5598 ft msl), a total top width of 150 ft, a bottom width of 40 ft, and a cross slope of 2 percent.

Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	Energy Fuels	Project:	White Mesa Mill-Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

Cell 5A into Cell 5B

The top hinge of the Cell 5A spillway is at an elevation between The capacity calculation for the spillway used the channel dimensions presented above and assumed a 0.77 ft freeboard corresponding to the wave run-up factor (from the 10 January 1990 Drainage Report). Therefore, a discharge depth of 3.23 ft is calculated to verify that the design Q could pass with spillway freeboard

Discharge with Freeboard

$n = 0.015$

$b = 35$ ft

$Z = 10$

$d = 3.23$ ft (assumed depth of flow)

$A = (35 \times 3.23) + 10 \times 3.23^2 = 217\ ft^2$

$R = A/P$; $R = ((35 \times 3.23)+(10 \times 3.23^2))/(35+(2 \times 3.23)\times(10^2+1)^{0.5}) = 2.18$ ft

$S = 0.015$

Qall = $(1.49/0.015) \times 2.18^{2/3} \times 0.015^{1/2} \times 217 =$ **4,440 cfs**

In summary, the Cell 5A into Cell 5B spillway will have a total depth of 4 ft, a total top width of 115 ft, a bottom width of 35 ft, and a cross slope of 1.5 percent.

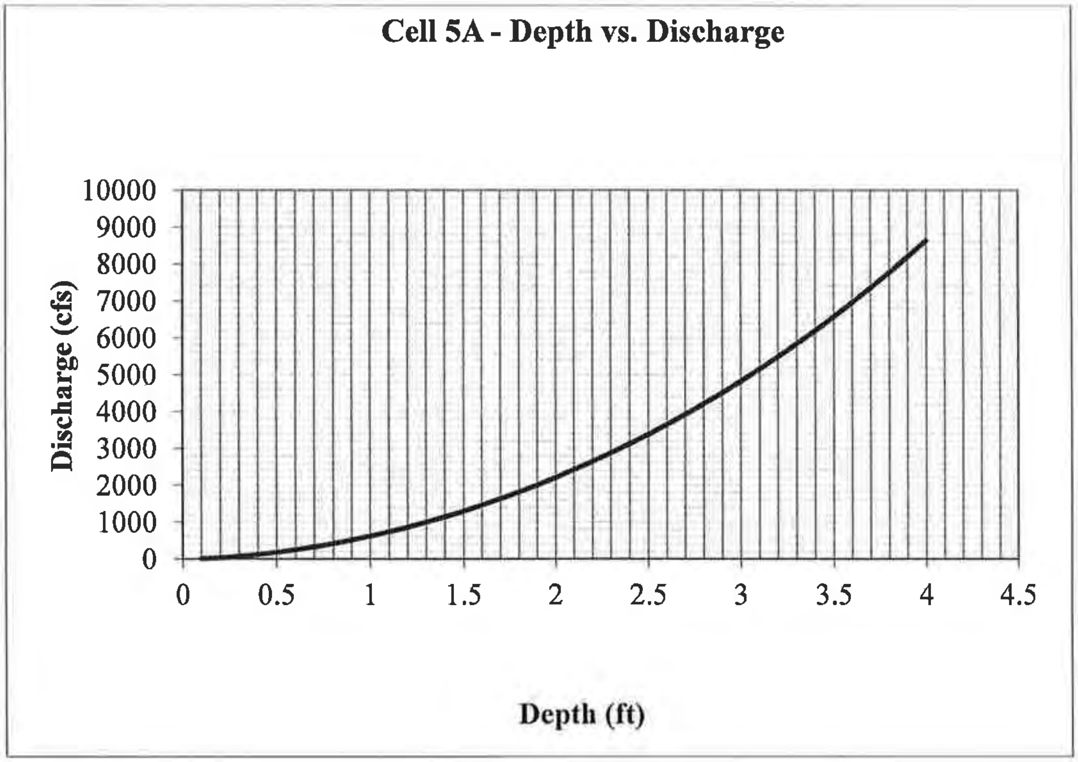
CONCLUSION

The allowable flows for the spillways, as designed, are estimated to be 3,924 cfs and 4,440 cfs (Cells 5A and 5B, respectively) which are greater than the flow rates for the PMP events, 3,783 cfs and 4,403 cfs for Cells 5A and 5B, respectively. Iterating on the discharge depth, the rating curve (Depth vs. Q) for the spillway is presented as Figures 2 and 3.

The spillway shown on Sheets 3B and 10 of the Construction Drawings show the Cell 5A to Cell 5B spillway with a top hinge elevation of 5585 ft msl. The lowest elevation around the crest of Cell 5A is 5588 ft msl. Accounting for the wave run up factor of 0.77 ft the top of liquid flow over the Cell 5A to Cell 5B spillway is at elevation 5587.23 ft msl. These elevations do not necessarily correspond to the capacity calculations presented herein. However; the spillway dimensions corresponding to the elevations on the Construction Drawings result in a spillway with greater capacity than the spillway designed in this calculation package.

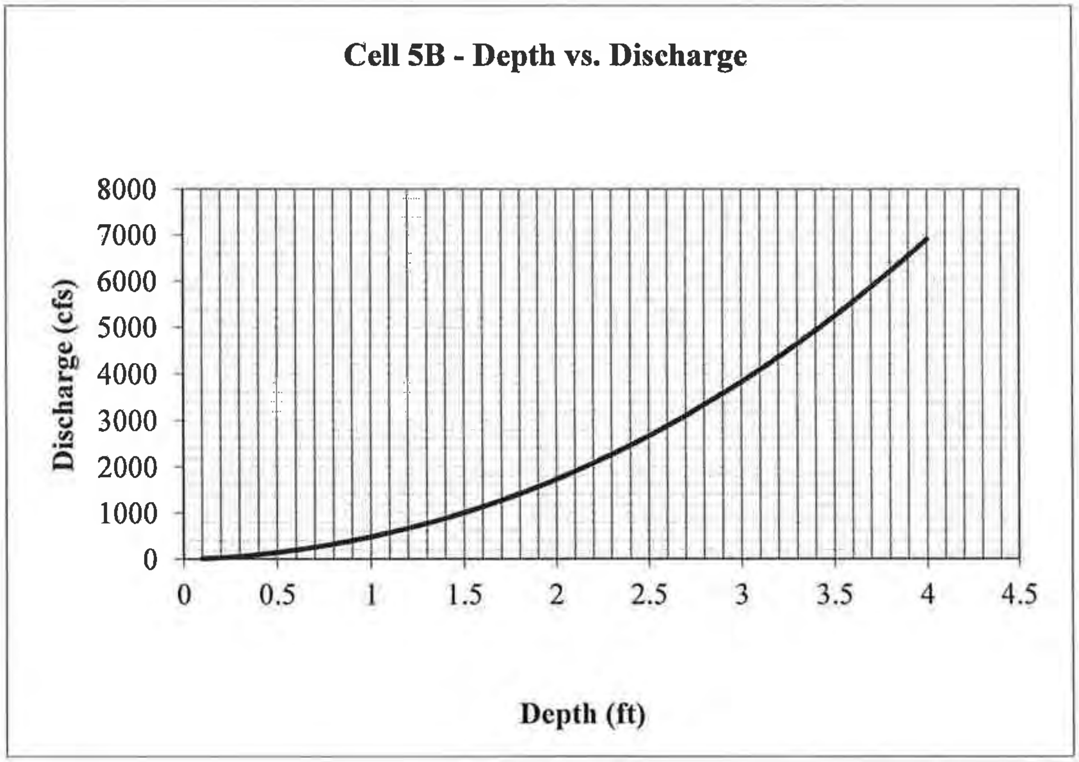
Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client:	Energy Fuels	Project:	White Mesa Mill-Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

Figure 2 – Rating Curve for Spillway 5A.



Written by:	R. Flynn	Date:	12/18/12	Reviewed by:	G. Corcoran	Date:	12/18/12
Client: Energy Fuels	Project:	White Mesa Mill-Cells 5A and 5B		Project/ Proposal No.:	SC0634	Task No.:	02

Figure 3 – Rating Curve for Spillway 5B



References

Mays, Larry W., "Water Resources Engineering, 2005 Edition," John Wiley & Sons, Inc, 2005.

Mays, Larry W., "Water Resources Engineering, 2005 Edition," John Wiley & Sons, Inc, 2005.

Table 5.1.1 Values of the Roughness Coefficient *n* *(continued)*
(Boldface figures are values generally recommended in design)

Type of channel and description	Minimum	Normal	Maximum
c. Concrete			
1. Trowel finish	0.011	**0.013**	0.015
2. Float finish	0.013	0.015	0.016
3. Finished, with gravel on bottom	0.015	0.017	0.020
4. Unfinished	0.014	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	—
8. On irregular excavated rock	0.022	0.027	—
d. Concrete bottom float finished with sides of			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry, plastered	0.016	0.020	0.024
4. Cement rubble masonry	0.020	0.025	0.030
5. Dry rubble or riprap	0.020	0.030	0.035
e. Gravel bottom with sides of			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
f. Brick			
1. Glazed	0.011	**0.013**	0.015
2. In cement mortar	0.012	**0.015**	0.018
g. Masonry			
1. Cemented rubble	0.017	0.025	0.030
2. Dry rubble	0.023	0.032	0.035
h. Dressed ashlar	0.013	0.015	0.017
i. Asphalt			
1. Smooth	0.013	0.013	—
2. Rough	0.016	0.016	—
j. Vegetal lining	0.030	—	0.500
C. Excavated or dredged			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	**0.022**	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140

AHC

Geosyntec consultants

COMPUTATION COVER SHEET

Client: **EF** Project: **White Mesa Mill – Cells 5A and 5B** Project/ Proposal No.: **SC0634** Task No. **02**

Title of Computations **Side Slope Riser Trench Stability Evaluation- Veneer Stability**

Computations by:	Signature		Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		Date 12/20/12
	Printed Name	Keaton Botelho, P.E.	
	Title	Project Engineer	
Computations Checked by:	Signature		Date 12/18/12
	Printed Name	Jay Griffin	
	Title	Senior Staff Engineer	
Computations backchecked by: (originator)	Signature		Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature		Date 12/18/12
	Printed Name	Gregory T Corcoran, P.E.	
	Title	Principal Engineer	

Approval notes: ______________________

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	11/14/12	Reviewed by:	G. Corcoran	Date:	12/10/12
Client:	EF	Project:	WMM- Cells 5A & 5B	Project/ Proposal No.:	SC0634	Task No.:	02

SIDE SLOPE RISER TRENCH STABILITY EVALUATION VENEER STABILITY OF GEOSYNTHETIC-SOIL LINED SLOPES

OBJECTIVE

To evaluate the tension developed within the geosynthetic-soil layered side slope riser trench liner system of the tailings pond liner system of the White Mesa Mill Cells 5A and 5B in Blanding, Utah.

SUMMARY OF RESULTS

The calculations suggest that the minimum peak geosynthetic interface friction angle of 23 degrees and no peak adhesion meets the requirement to prevent the development of tension in the geosynthetic components of the side slope riser trench liner system.

METHOD OF ANALYSIS

The stability analysis of the geosynthetic-soil layered systems was carried out using the approach outlined by Koerner and Soong [1998] (Attachment A). This approach calculates the driving force of an active soil wedge along a geosynthetic-soil layered side slope and compares it to the resisting force of the complementary passive soil wedge to evaluate the overall factor of safety against failure. The method presented by Koerner and Soong [1998] allows for the consideration of a uniform depth soil layer and the influence of dynamic equipment loading.

SIDE SLOPE RISER TRENCH LINER SYSTEM

The side slope liner system consists of, from top to bottom (Figure 1):

- 2 ft gravel;
- Cushion Geotextile;
- 60-mil HDPE Geomembrane, textured (primary);
- Cushion Geotextile;
- 60-mil HDPE Geomembrane, textured (secondary);
- Cushion Geotextile;

- 60-mil HDPE Geomembrane, textured (tertiary); and
- Prepared subgrade.

The critical side slope inclination is a maximum of 3.0H:1.0V. The maximum height of the side slope riser trench is 46 vertical feet in the southeast corner of Cell 5B and 46 feet in the southwest corner of Cell 5A.

MATERIAL PARAMETERS

Based on a review of potential liner interfaces, the likely critical interface has been identified as the textured HDPE geomembrane and non-woven geotextile. Based on laboratory test data of material similar to that intended for the site, this interface is assumed to have ashear strength of approximately 28 degrees and no adhesion (Attachment B).

Geosynthetic Interface:

The geosynthetic interface friction angle was varied to evaluate the minimum allowable value to obtain no tension at a minimum factor of safety value of 1.3. A literature review was performed to evaluate if the calculated minimum allowable interface friction value is achievable in addition to laboratory testing performed on the material anticipated for this project.

REVIEW OF REPORTED INTERFACE STRENGTHS

The following values for the interface friction between the geosynthetic and soil components of the liner system represent values reported in the literature and as reported with laboratory test results:

Gravel (GP)	38	NAVFAC(1), 0 psf cohesion (Attachment C)
NW geotextile to Textured HDPE	28	Cell 4B CQA Report (Attachment B)
Textured HDPE to Sand Subgrade	33	4th GRI Seminar (Attachment D)

1. NAVFAC (1986) lists typical shear strength values for various compacted soils. To be conservative, a value of phi = 32 degree was used.

DESIGN CRITERION

For the geosynthetic-soil lined slopes of the Cell 5A and 5B liner systems, it was desired to evaluate inclination which would introduce no geosynthetic tension. Subsequently, zero geosynthetic tension was established as the design criterion for veneer stability of the geosynthetic-soil lined side slopes.

In consideration of the significance of no tension in the geosynthetic liner system and consistent with current practice, Geosyntec will adopt a factor of safety (FS) equal to or greater than 1.3 for veneer stability.

ANALYSIS

According to the Koerner and Soong approach, a soil veneer on a side slope is stable when the resultant driving force on the passive wedge (E_P) is equal to or less than the resultant resistant force on the active wedge (E_A). The following equations represent the resultant resistance and active forces, respectively:

$$E_A = \frac{FS(W_A - N_A \cos\beta) - (N_A \tan\delta + C_a)\sin\beta}{\sin\beta(FS)}$$ (Attachment A, 2 of 6)

$$E_P = \frac{C + W_P \tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi}$$ (Attachment A, 2 of 6)

The variables will be defined in a subsequent section.

By setting E_A=E_P, the resulting equation may be arranged in the form of the quadratic equation $ax^2+bx+c=0$. Considering FS as the variable of interest, the resulting equation is as follows:

$$a(FS)^2 + b(FS) + c = 0$$ (Attachment A, 2 of 6)

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The factor of safety may be obtained from the solution of the following equation:

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$ (Attachment A, 2 of 6)

Where the constants are defined, as in Attachment A, 6 of 6:

$$a = (W_A - N_A \cos\beta)\cos\beta \quad (1)$$

$$b = -[(W_A - N_A \cos\beta)\sin\beta\tan\phi + (N_A \tan\delta + C_a)\sin\beta\cos\beta + \sin\beta(C + W_P \tan\phi)] \quad (2)$$

$$c = (N_A \tan\delta + C_a)\sin^2\beta\tan\phi \quad (3)$$

In which the variables are indicated on Figure 1 and defined as follows:

$$C = \frac{c \cdot h}{\sin\beta} \quad (4)$$ (Attachment A, 2 of 6)

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right) \quad (5)$$ (Attachment A, 2 of 6)

$$W_A = \gamma \cdot h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right) \quad (6)$$ (Attachment A, 2 of 6)

$$N_A = W_A \cos\beta \quad (7)$$ (Attachment A, 2 of 6)

$$W_P = \frac{\gamma \cdot h^2}{\sin 2\beta} \quad (8)$$ (Attachment A, 2 of 6)

β = soil slope angle beneath the geomembrane, **18.4°** for 3H:1V slope
δ = minimum interface friction angle of side slope liner system, **23°**
ϕ = friction angle of gravel, **32°**
γ = unit weight of the gravel, **135 pcf**
C = cohesive force along the failure plane of the passive wedge
c = cohesion of the gravel, **0 psf**

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C_a = adhesive force
c_a = adhesion between the sand and the geomembrane, **0 psf**
h = thickness of the gravel, **2 feet**
L = length of slope measured along the geomembrane beneath gravel, **145.5 feet**
N_A = effective force normal to the failure plane of the active wedge
W_A = total weight of the active wedge
W_P = total weight of the passive wedge

Substituting the variables and solving equations (4)-(8), above:

$$C = \frac{c \cdot h}{\sin\beta} = \frac{0 \cdot 2}{\sin(26.6)} = \mathbf{0\ lbs/ft} \qquad (4)$$

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right) = 0\left(126.5 - \frac{2}{\sin 18.4}\right) = \mathbf{0\ lbs/ft} \qquad (5)$$

$$W_A = \gamma \cdot h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right) = 135 \cdot 2^2\left(\frac{145.5}{2} - \frac{1}{\sin 18.4} - \frac{\tan 18.4}{2}\right) = \mathbf{37{,}481\ \ lbs/ft} \qquad (6)$$

$$N_A = W_A \cos\beta = 37{,}481 \cdot \cos 18.4 = \mathbf{35{,}565\ lbs/ft} \qquad (7)$$

$$W_P = \frac{\gamma \cdot h^2}{\sin 2\beta} = \mathbf{901\ lbs/ft} \qquad (8)$$

Next, substituting the solutions to equations (4)-(8) into equations (1)-(3):

a= (37,481 – 35,565 · cos18.4) cos (18.4) = **3,543 lbs/ft** (1)

b= -[(37,481 – 35,565 · cos 18.4) sin 18.4 tan 32
+ (35,565 tan 23 + 0) sin 18.4 cos 18.4
+ sin 18.4 (0 + 901 tan 32)] = **-5,435 lbs/ft** (2)

c = (35,565 tan 23 + 0) $\sin^2$ 18.4 tan 32 = **940 lbs/ft** (3)

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Finally, inserting the solutions to (1), (2) and (3) and solving the following equation:

$$FS = \frac{-b+\sqrt{b^2-4ac}}{2a} = \frac{-(-5435)+\sqrt{(-5435)^2-4\cdot 3543\cdot 940}}{2\cdot 3543} = \mathbf{1.33}$$

Therefore, the factor of safety for the veneer stability of the drainage aggregate layer on a sideslope composite liner system is 1.33. This factor of safety satisfies the stability criterion of 1.3, as previously described.

RESULTS AND CONCLUSIONS

The results suggest that the proposed side slope riser trench liner system satisfies the design criteria of no geosynthetic tension development:

Soil Cover Layer Inclination (H:V)	Equipment Loading	Tension FS
3.0H:1V	NONE	1.33

Results of veneer stability analyses presented herein indicate that the interface friction angle (residual) of 28 degrees with no apparent peak cohesion textured geomembrane to sand subgrade interface meets the static factor of safety that satisfies that design criteria of no tension in the geosynthetic liner system.

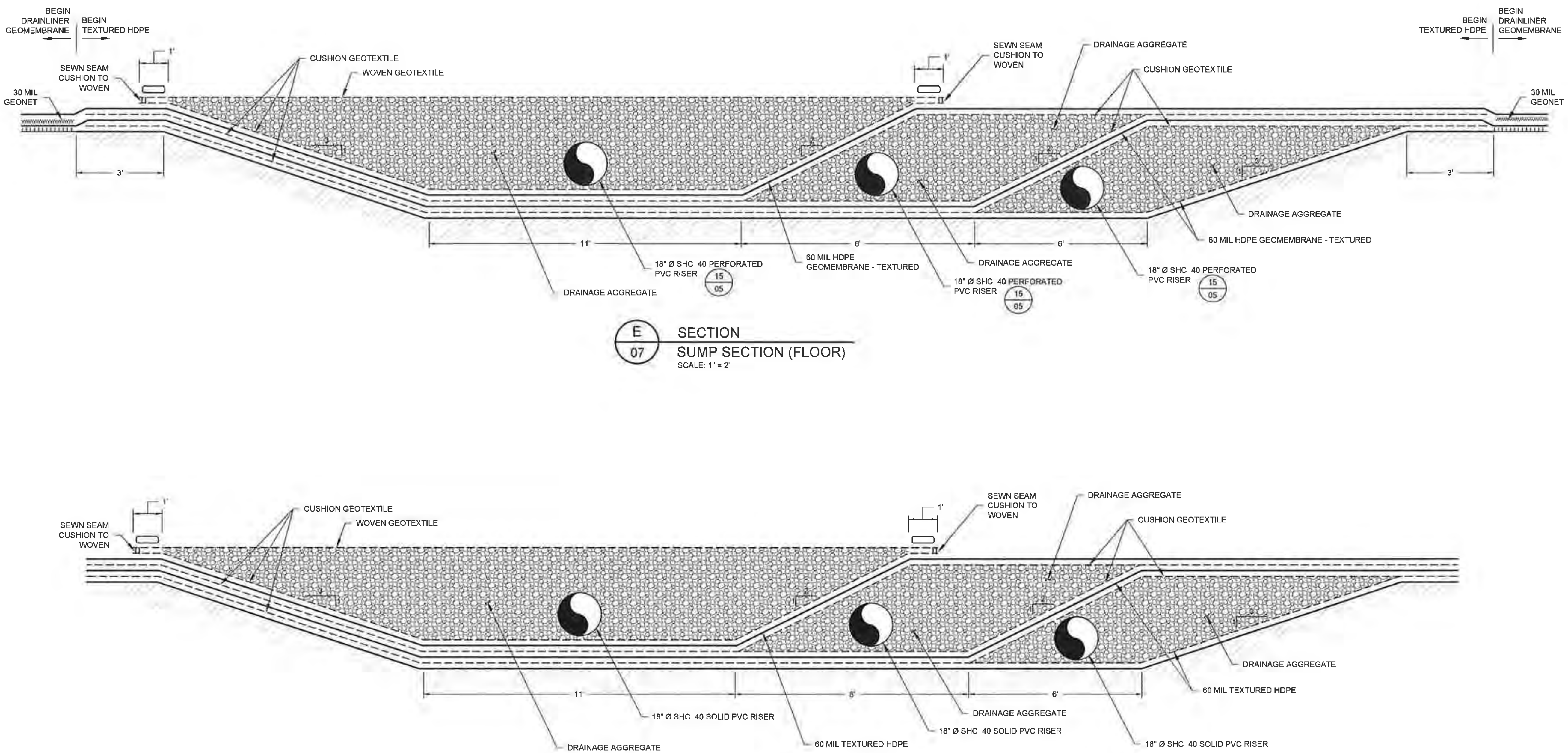
REFERENCES

Abramson, Lee, Lee, Thomas, Sharma, Sunil, Boyce, Glenn (2002), "Slope Stability and Stabilization Methods." (*Attachment B*)

Koerner, R. K. and Soong, T.Y., [1998], "Analysis and Design of Veneer Cover Soils", Proceedings of the Sixth International Conference on Geosynthetics, Atlanta, Georgia, Vol. I, 1998. *(Attachment A)*

NAVFAC (1982), "Foundations and Earth Structures, Design Manual - 7.2," Department of Navy, Naval Facilities Engineering Command, May 1982 *(Attachment C)*

Proceedings of the 4th GRI Seminar on the Topic of Landfill Closures. GRI – Dec 14, 1990. (*Attachment D*)



E
07
SECTION
SUMP SECTION (FLOOR)
SCALE: 1" = 2'

F
07
SECTION
SUMP SECTION (SLOPE)
SCALE: 1" = 2'

FIGURE 1

NOTES:

1. PREPARED SUBGRADE AT CELL BASE SHALL CONSIST OF AT LEAST 6-INCHES OF COMPACTED FILL OVERLYING SANDSTONE AS PER SECTIONS 02200 AND 02220 OF THE TECHNICAL SPECIFICATIONS
2. DETAILS ARE SHOWN TO SCALE INDICATED EXCEPT FOR THE GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. SOIL THICKNESSES ARE MINIMUMS
3. WOVEN GEOTEXTILE SHALL BE PROPEX 200 ST, SKAPS W 200, OR APPROVED EQUAL (WOVEN SLIT FILM, AOS = 40, FLOW RATE = 4 GPM/SF, GRAB STRENGTH = 200 LBS, PUNCTURE = 100 LBS)

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
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Energy Fuels Resources (USA) Inc

TITLE: DETAILS & SECTIONS IV

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL, BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION UNLESS SEALED

SIGNATURE

DATE

DESIGN BY	GTC	DATE	JANUARY 2013
DRAWN BY	MMC	PROJECT NO	SC0634
CHECKED BY	RBF	FILE	SC0634-05-07
REVIEWED BY	GTC	DRAWING NO	08 OF 12
APPROVED BY	GTC		

- The issue of appropriate normal stress is greatly complicated if gas pressures are generated in the underlying waste. These gas pressures will counteract some (or all) of the gravitational stress of the cover soil. The resulting shear strength, and subsequent stability, can be significantly decreased. See Liu et al (1997) for insight into this possibility.
- Shear rates necessary to attain drained conditions (if this is the desired situation) are extremely slow, requiring long testing times.
- Deformations necessary to attain residual strengths require large relative movement of the two respective halves of the shear box. So as not to travel over the edges of the opposing shear box sections, devices should have the lower shear box significantly longer than 300 mm. However, with a lower shear box longer than the upper traveling section, new surface is constantly being added to the shearing plane. This influence is not clear in the material's response or in the subsequent behavior.
- The attainment of a true residual strength is difficult to achieve. ASTM D5321 states that one should "run the test until the applied shear force remains constant with increasing displacement". Many commercially available shear boxes have insufficient travel to reach this condition.
- The ring torsion shearing apparatus is an alternative device to determine true residual strength values, but is not without its own problems. Some outstanding issues are the small specimen size, nonuniform shear rates along the width of the specimen, anisotropic shearing with some geosynthetics and no standardized testing protocol. See Stark and Poeppel (1994) for information and data using this alternative test method.

2.3 Various Types of Loadings

There are a large variety of slope stability problems that may be encountered in analyzing and/or designing final covers of engineered landfills, abandoned dumps and remediation sites as well as leachate collection soils covering geomembranes beneath the waste. Perhaps the most common situation is a uniformly thick cover soil on a geomembrane placed over the soil subgrade at a given and constant slope angle. This "standard" problem will be analyzed in the next section. A variation of this problem will include equipment loads used during placement of cover soil on the geomembrane. This problem will be solved with equipment moving up the slope and then moving down the slope.

Unfortunately, cover soil slides have occurred and it is felt that the majority of the slides have been associated with seepage forces. Indeed, drainage above a geomembrane (or other barrier material) in the cover soil cross section must be accommodated to avoid the possibility of seepage forces. A section will be devoted to this class of slope stability problems.

Lastly, the possibility of seismic forces exists in earthquake prone locations. If an earthquake occurs in the vicinity of an engineered landfill, abandoned dump or remediation site, the seismic wave travels through the solid waste mass reaching the upper surface of the cover. It then decouples from the cover soil materials, producing a horizontal force which must be appropriately analyzed. A section will be devoted to the seismic aspects of cover soil slope analysis as well.

All of the above actions are destabilizing forces tending to cause slope instability. Fortunately, there are a number of actions that can be taken to increase the stability of slopes.

Other than geometrically redesigning the slope with a flatter slope angle or shorter slope length, a designer can add soil mass at the toe of the slope thereby enhancing stability. Both toe berms and tapered soil covers are available options and will be analyzed accordingly. Alternatively, the designer can always use geogrids or high strength geotextiles within the cover soil acting as reinforcement materials. This technique is usually referred to as veneer reinforcement. Cases of both intentional and nonintentional veneer reinforcement will be presented.

Thus it is seen that a number of strategies influence slope stability. Each will be described in the sections to follow. First, the basic gravitational problem will be presented followed by those additional loading situations which tend to decrease slope stability. Second, various actions that can be taken by the designer to increase slope stability will be presented. The summary will contrast the FS-values obtained in the similarly crafted numeric examples.

3 SITUATIONS CAUSING DESTABILIZATION OF SLOPES

This section treats the standard veneer slope stability problem and then superimposes upon it a number of situations, all of which tend to destabilize slopes. Included are gravitational, construction equipment, seepage and seismic forces. Each will be illustrated by a design graph and a numeric example.

3.1 Cover Soil (Gravitational) Forces

Figure 3 illustrates the common situation of a *finite* length, uniformly thick cover soil placed over a liner material at a slope angle "β". It includes a passive wedge at the toe and has a tension crack of the crest. The analysis that follows is after Koerner and Hwu (1991), but comparable analyses are available from Giroud and Beech (1989), McKelvey and Deutsch (1991), Ling and Leshchinsky (1997) and others.

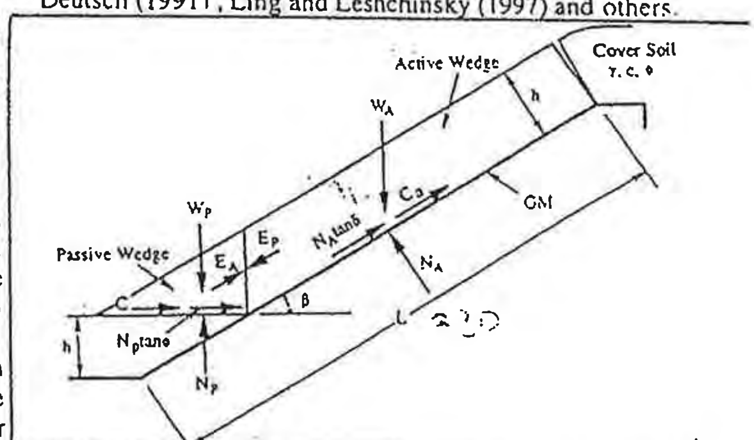

Figure 3. Limit equilibrium forces involved in a finite length slope analysis for a uniformly thick cover soil.

Attachment A 1/6

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...ne symbols used in Figure 3 are defined below.

W_A = total weight of the active wedge
W_P = total weight of the passive wedge
N_A = effective force normal to the failure plane of the active wedge
N_P = effective force normal to the failure plane of the passive wedge
γ = unit weight of the cover soil
h = thickness of the cover soil
L = length of slope measured along the geomembrane
β = soil slope angle beneath the geomembrane
ϕ = friction angle of the cover soil
δ = interface friction angle between cover soil and geomembrane
C_a = adhesive force between cover soil of the active wedge and the geomembrane
c_a = adhesion between cover soil of the active wedge and the geomembrane
C = cohesive force along the failure plane of the passive wedge
c = cohesion of the cover soil
E_A = interwedge force acting on the active wedge from the passive wedge
E_P = interwedge force acting on the passive wedge from the active wedge
FS = factor of safety against cover soil sliding on the geomembrane

The expression for determining the factor of safety can be derived as follows:

Considering the active wedge,

$$W_A = \gamma h^2\left(\frac{L}{h} - \frac{1}{\sin\beta} - \frac{\tan\beta}{2}\right) \quad (3)$$

$$N_A = W_A \cos\beta \quad (4)$$

$$C_a = c_a\left(L - \frac{h}{\sin\beta}\right) \quad (5)$$

By balancing the forces in the vertical direction, the following formulation results:

$$E_A \sin\beta = W_A - N_A \cos\beta - \frac{N_A \tan\delta + C_a}{FS}\sin\beta \quad (6)$$

Hence the interwedge force acting on the active wedge is:

$$E_A = \frac{(FS)(W_A - N_A\cos\beta) - (N_A\tan\delta + C_a)\sin\beta}{\sin\beta(FS)} \quad (7)$$

The passive wedge can be considered in a similar manner:

$$W_P = \frac{\gamma h^2}{\sin 2\beta} \quad (8)$$

$$N_P = W_P + E_P \sin\beta \quad (9)$$

$$C = \frac{(c)(h)}{\sin\beta} \quad (10)$$

By balancing the forces in the horizontal direction, the following formulation results:

$$E_P \cos\beta = \frac{C + N_P \tan\phi}{FS} \quad (11)$$

Hence the interwedge force acting on the passive wedge is:

$$E_P = \frac{C + W_P \tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi} \quad (12)$$

By setting $E_A = E_P$, the resulting equation can be arranged in the form of the quadratic equation $ax^2 + bx + c = 0$ which in our case, using FS-values, is:

$$a(FS)^2 + b(FS) + c = 0 \quad (13)$$

where

$$a = (W_A - N_A\cos\beta)\cos\beta$$

$$b = -[(W_A - N_A\cos\beta)\sin\beta\tan\phi + (N_A\tan\delta + C_a)\sin\beta\cos\beta + \sin\beta(C + W_P\tan\phi)]$$

$$c = (N_A\tan\delta + C_a)\sin^2\beta\tan\phi \quad (14)$$

The resulting FS-value is then obtained from the solution of the quadratic equation:

$$FS = \frac{-b + \sqrt{b^2 - 4ac}}{2a} \quad (15)$$

When the calculated FS-value falls below 1.0, sliding of the cover soil on the geomembrane is to be anticipated. Thus a value of greater than 1.0 must be targeted as being the minimum factor of safety. How much greater than 1.0 the FS-value should be, is a design and/or regulatory issue. The issue of minimum allowable FS-values under different conditions will be assessed at the end of the paper. In order to better illustrate the implications of Eqs. 13, 14 and 15, typical design curves for various FS-values as a function of slope angle and interface friction angle are given in Figure 4. Note that the curves are developed specifically for the variables stated in the legend of the figure. Example 1 illustrates the use of the curves in what will be the standard example to which other examples will be compared.

Example 1:
Given a 30 m long slope with a uniformly thick 300 mm cover soil at a unit weight of 18 kN/m³. The soil has a friction angle of 30 deg. and zero cohesion, i.e., it is a sand. The cover soil is placed directly on a geomembrane as shown in Figure 3. Direct shear testing has resulted in a interface friction angle between the cover soil and geomembrane of 22 deg. with zero adhesion. What is the FS-value at a slope angle of 3(H)-to-1(V), i.e., 18.4 deg?

Attachment A 2/6

Solution:

Substituting Eq. 14 into Eq. 15 and solving for the FS-value results in the following which is seen to be in agreement with the curves of Figure 4.

$$\left.\begin{array}{l} a = 14.7\,\text{kN/m} \\ b = -21.3\,\text{kN/m} \\ c = 3.5\,\text{kN/m} \end{array}\right\} \text{FS} = 1.25$$

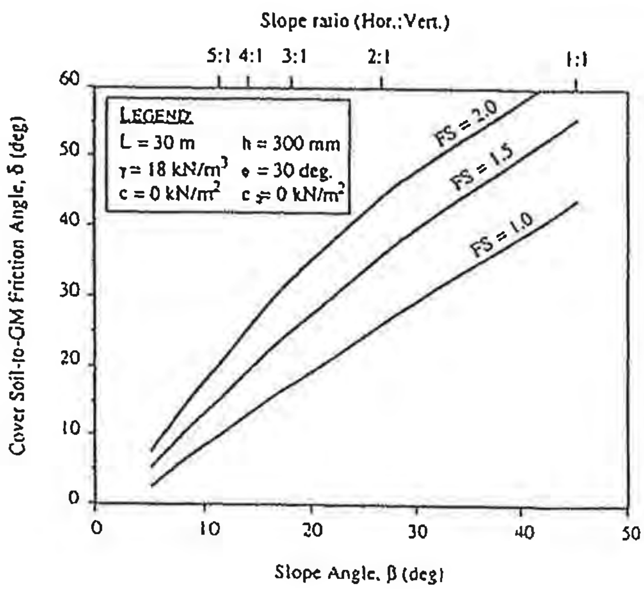


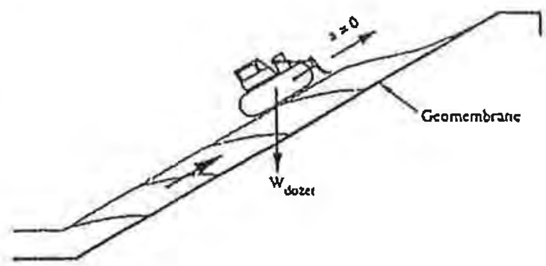
Figure 4. Design curves for stability of uniform thickness cohesionless cover soils on linear failure planes for various global factors-of-safety.

Comment:
In general, this is too low of a value for a final cover soil factor-of-safety and a redesign is necessary. While there are many possible options of changing the geometry of the situation, the example will be revisited later in this section using toe berms, tapered cover soil thickness and veneer reinforcement. Furthermore, this general problem will be used throughout the main body of this paper for comparison purposes to other cover soil slope stability situations.

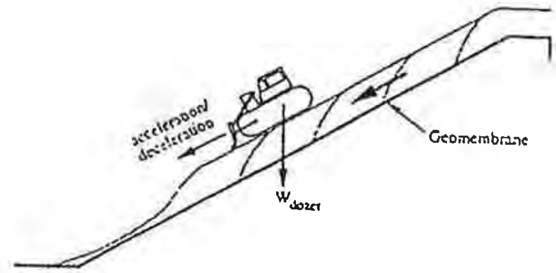
3.2 Tracked Construction Equipment Forces

The placement of cover soil on a slope with a relatively low shear strength inclusion (like a geomembrane) should always be from the toe upward to the crest. Figure 5a shows the recommended method. In so doing, the gravitational forces of the cover soil and live load of the construction equipment are compacting previously placed soil and working with an ever present passive wedge and stable lower-portion beneath the active wedge. While it is necessary to specify low ground pressure equipment to place the soil, the reduction of the FS-value for this situation of equipment working up the slope will be seen to be relatively small.

For soil placement down the slope, however, a stability analysis cannot rely on toe buttressing and also a dynamic stress should be included in the calculation. These conditions decrease the FS-value and in some cases to a great extent. Figure 5b shows this procedure. Unless absolutely necessary, it is not recommended to place cover soil on a slope in this manner. If it is necessary, the design must consider the unsupported soil mass and the dynamic force of the specific type of construction equipment and its manner of operation.



(a) Equipment backfilling up slope
(the recommended method)



(b) Equipment backfilling down slope
(method is not recommended)

Figure 5. Construction equipment placing cover soil on slopes containing geosynthetics.

For the first case of a bulldozer pushing cover soil up from the toe of the slope to the crest, the analysis uses the free body diagram of Figure 6a. The analysis uses a specific piece of tracked construction equipment (like a bulldozer characterized by its ground contact pressure) and dissipates this force or stress through the cover soil thickness to the surface of the geomembrane. A Boussinesq analysis is used, see Poulos and Davis (1974). This results in an equipment force per unit width as follows:

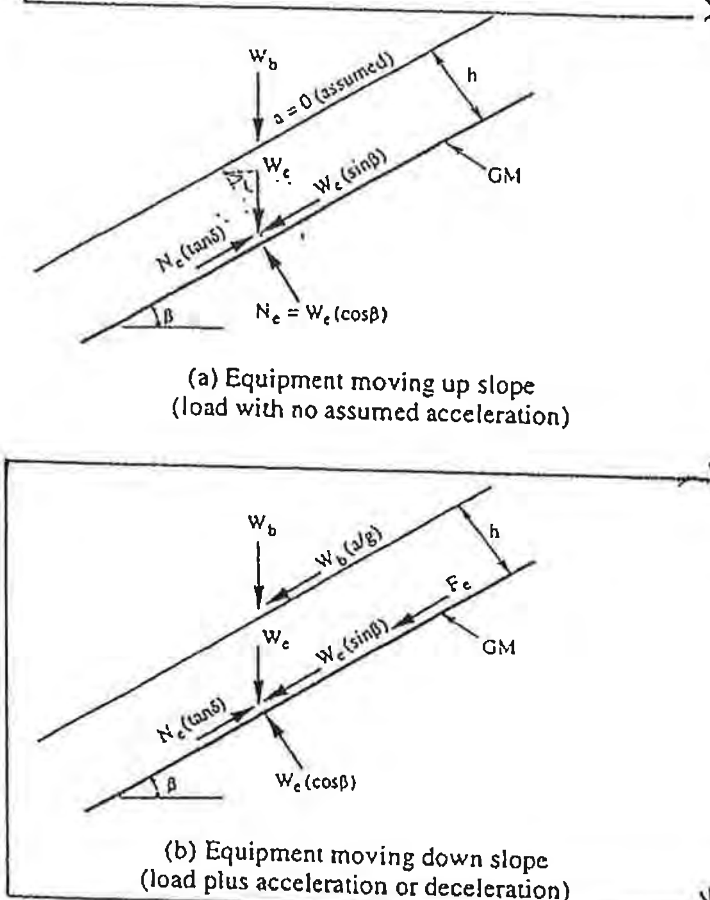
$$W_e = q w I \qquad (16)$$

where

W_e = equivalent equipment force per unit width at the geomembrane interface
q = $W_b / (2 \times w \times b)$

Attachment A 3/6

W_b = actual weight of equipment (e.g., a bulldozer)
w = length of equipment track
b = width of equipment track
I = influence factor at the geomembrane interface see Figure 7



(a) Equipment moving up slope
(load with no assumed acceleration)

(b) Equipment moving down slope
(load plus acceleration or deceleration)

Figure 6. Additional (to gravitational forces) limit equilibrium forces due to construction equipment moving on cover soil (see Figure 3 for the gravitational soil force to which the above forces are added).

Upon determining the additional equipment force at the cover soil-to-geomembrane interface, the analysis proceeds as described in Section 3.1 for gravitational forces only. In essence, the equipment moving up the slope adds an additional term, W_e, to the W_A-force in Eq. 3. Note, however, that this involves the generation of a resisting force as well. Thus, the net effect of increasing the driving force as well as the resisting force is somewhat neutralized insofar as the resulting FS-value is concerned. It should also be noted that no acceleration/deceleration forces are included in this analysis which is somewhat optimistic. Using these concepts (the same equations used in Section 3.1 are used here), typical design curves for various FS-values as a function of equivalent ground contact equipment pressures and cover soil thicknesses are given in Figure 8. Note that the curves are developed specifically for the variables stated in the legend. Example 2a illustrates the use of the formulation.

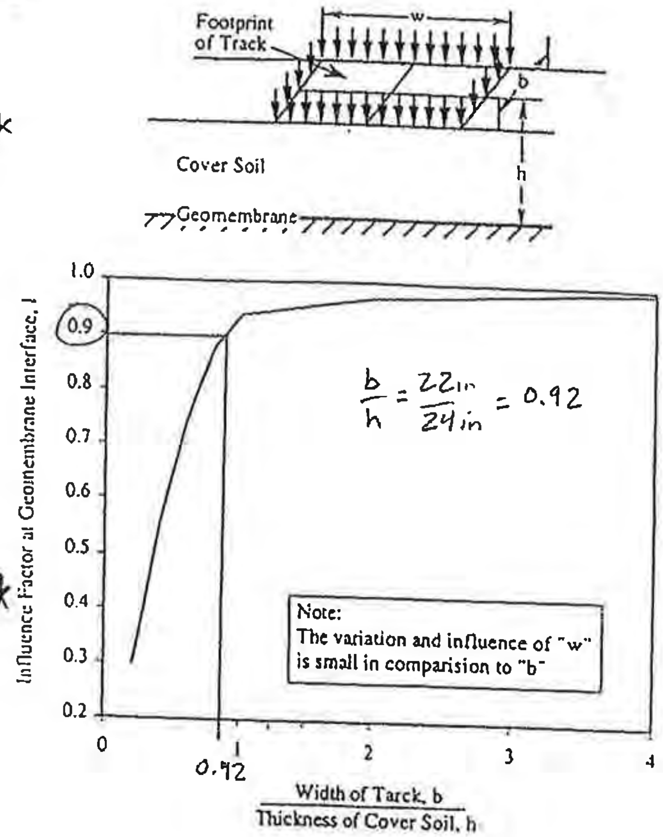


Figure 7. Values of influence factor, "I", for use in Eq. 16 to dissipate surface force of tracked equipment through the cover soil to the geomembrane interface, after Poulos and Davis (1974).

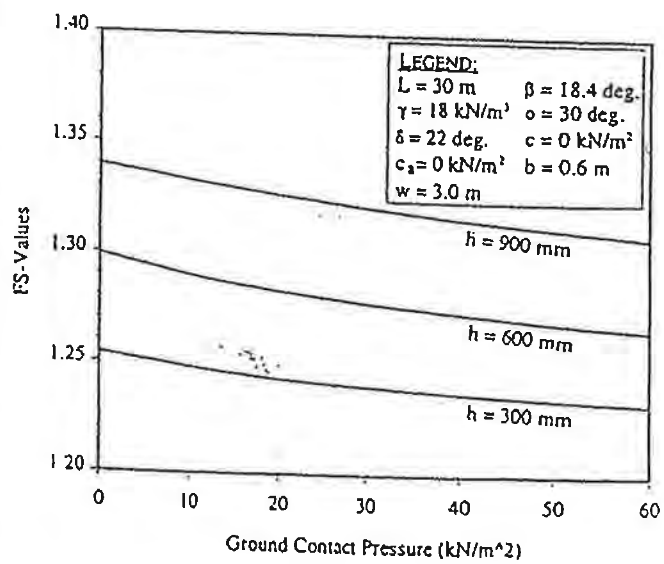


Figure 8. Design curves for stability of different thickness of cover soil for various values of tracked ground contact pressure construction equipment.

Attachment A 4/6

Example 2a:

Given 30 m long slope with uniform cover soil of 300 mm thickness at a unit weight of 18 kN/m³. The soil has a friction angle of 30 deg. and zero cohesion, i.e., it is a sand. It is placed on the slope using a bulldozer moving from the toe of the slope up to the crest. The bulldozer has a ground pressure of 30 kN/m² and tracks that are 3.0 m long and 0.6 m wide. The cover soil to geomembrane friction angle is 22 deg. with zero adhesion. What is the FS-value at a slope angle of 3(H)-to-1(V), i.e., 18.4 deg.

Solution:

This problem follows Example 1 exactly except for the addition of the bulldozer moving up the slope. Using the additional equipment load Eq. 16, substituted into Eqs. 14 and 15 results in the following.

$$\left.\begin{aligned} a &= 73.1\,\text{kN/m} \\ b &= -104.3\,\text{kN/m} \\ c &= 17.0\,\text{kN/m} \end{aligned}\right\} FS = 1.24$$

Comment:

While the resulting FS-value is low, the result is best assessed by comparing it to Example 1, i.e., the same problem except without the bulldozer. It is seen that the FS-value has only decreased from 1.25 to 1.24. Thus, in general, a low ground contact pressure bulldozer placing cover soil up the slope with negligible acceleration/deceleration forces does not significantly decrease the factor-of-safety.

For the second case of a bulldozer pushing cover soil down from the crest of the slope to the toe as shown in Figure 5b, the analysis uses the force diagram of Figure 6b. While the weight of the equipment is treated as just described, the lack of a passive wedge along with an additional force due to acceleration (or deceleration) of the equipment significantly changes the resulting FS-values. This analysis again uses a specific piece of construction equipment operated in a specific manner. It produces a force parallel to the slope equivalent to W_b (a/g), where W_b = the weight of the bulldozer, a = acceleration of the bulldozer and g = acceleration due to gravity. Its magnitude is equipment operator dependent and related to both the equipment speed and time to reach such a speed, see Figure 9. A similar behavior will be seen for deceleration.

The acceleration of the bulldozer, coupled with an influence factor "I" from Figure 7, results in the dynamic force per unit width at the cover soil to geomembrane interface, "F_e". The relationship is as follows:

$$F_e = W_e\left(\frac{a}{g}\right) \quad (17)$$

where

F_e = dynamic force per unit width parallel to the slope at the geomembrane interface,

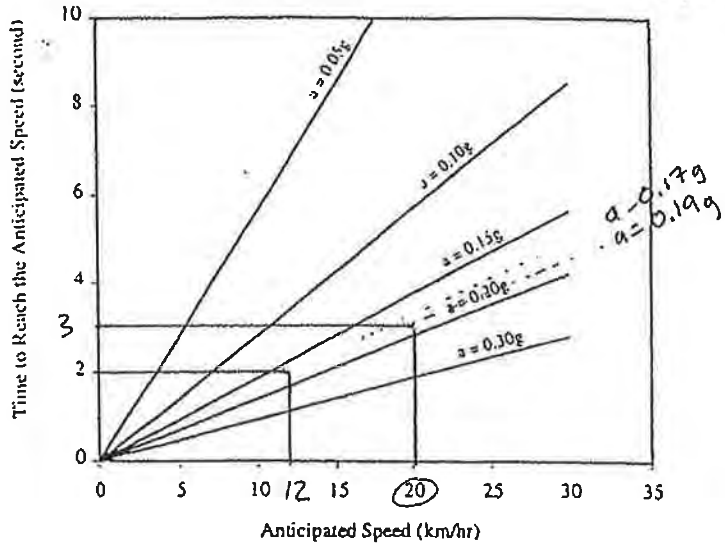


Figure 9. Graphic relationship of construction equipment speed and rise time to obtain equipment acceleration.

W_e = equivalent equipment (bulldozer) force per unit width at geomembrane interface, recall Eq. 16.

β = soil slope angle beneath geomembrane

a = acceleration of the bulldozer

g = acceleration due to gravity

Using these concepts, the new force parallel to the cover soil surface is dissipated through the thickness of the cover soil to the interface of the geomembrane. Again, a Boussinesq analysis is used, see Poulos and Davis (1974). The expression for determining the FS-value can now be derived as follows:

Considering the active wedge, and balancing the forces in the direction parallel to the slope, the following formulation results:

$$E_A + \frac{(N_e + N_A)\tan\delta + C_a}{FS} = (W_A + W_e)\sin\beta + F_e \quad (18)$$

where

N_e = effective equipment force normal to the failure plane of the active wedge

$= W_e \cos\beta \quad (19)$

Note that all the other symbols have been previously defined.

The interwedge force acting on the active wedge can now be expressed as:

$$E_A = \frac{(FS)\left[(W_A + W_e)\sin\beta + F_e\right]}{FS} - \frac{\left[(N_e + N_A)\tan\delta + C_a\right]}{FS} \quad (20)$$

The passive wedge can be treated in a similar manner. The following formulation of the interwedge force acting on the passive wedge results:

Attachment A 5/6

GSC 5/11/01 GTC 5/11/01 (3)

$$E_P = \frac{C + W_P \tan\phi}{\cos\beta(FS) - \sin\beta\tan\phi} \quad (21)$$

By setting $E_A = E_P$, the following equation can be arranged in the form of Eq. 13 in which the "a", "b" and "c" terms are as follows:

$$a = \left[(W_A + W_e)\sin\beta + F_e\right]\cos\beta$$

$$b = -\left\{\left[(N_e + N_A)\tan\delta + C_a\right]\cos\beta + \left[(W_A + W_e)\sin\beta + F_e\right]\sin\beta\tan\phi + (C + W_P\tan\phi)\right\}$$

$$c = \left[(N_e + N_A)\tan\delta + C_a\right]\sin\beta\tan\phi \quad (22)$$

Finally, the resulting FS-value can be obtained using Eq. 15. Using these concepts, typical design curves for various FS-values as a function of equipment ground contact pressure and equipment acceleration can be developed, see Figure 10. Note that the curves are developed specifically for the variables stated in the legend. Example 2b illustrates the use of the formulation.

Example 2b:

Given a 30 m long slope with uniform cover soil of 300 mm thickness at a unit weight of 18 kN/m³. The soil has a friction angle of 30 deg. and zero cohesion, i.e., it is a sand. It is placed on the slope using a bulldozer moving from the crest of the slope down to the toe. The bulldozer has a ground contact pressure of 30 kN/m² and tracks that are 3.0 m long and 0.6 m wide. The estimated equipment speed is 20 km/hr and the time to reach this speed is 3.0 sec. The cover soil to geomembrane friction angle is 22 deg. with zero adhesion. What is the FS-value at a slope angle of 3(H)-to-1(V), i.e., 18.4 deg.

Solution:

Using the design curves of Figure 10 along with Eqs. 22 substituted into Eq. 15 the solution can be obtained:

- From Figure 9 at 20 km/hr and 3.0 sec. the bulldozer's acceleration is 0.19g.
- From Eq. 22 substituted into Eq. 15 we obtain

$$\left.\begin{aligned} a &= 88.8\,\text{kN/m} \\ b &= -107.3\,\text{kN/m} \\ c &= 17.0\,\text{kN/m} \end{aligned}\right\} \quad FS = 1.03$$

Comment:

This problem solution can now be compared to the previous two examples:

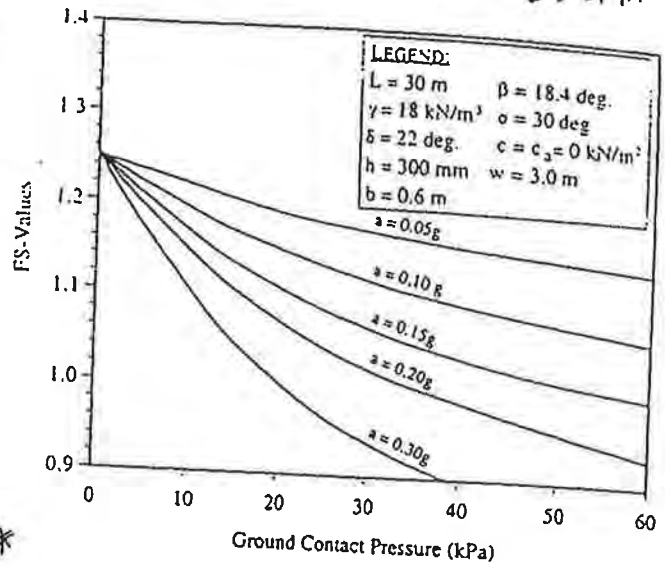


Figure 10. Design curves for stability of different construction equipment ground contact pressure for various equipment accelerations.

Ex. 1:	cover soil alone with no bulldozer loading	FS = 1.25
Ex. 2a:	cover soil plus bulldozer moving up slope	FS = 1.24
Ex. 2b:	cover soil plus bulldozer moving down slope	FS = 1.03

The inherent danger of a bulldozer moving down the slope is readily apparent. Note, that the same result comes about by the bulldozer decelerating instead of accelerating. The sharp breaking action of the bulldozer is arguable the more severe condition due to the extremely short times involved when stopping forward motion. Clearly, only in unavoidable situations should the cover soil placement equipment be allowed to work down the slope. If it is unavoidable, an analysis should be made of the specific stability situation and the construction specifications should reflect the exact conditions made in the design. The maximum allowable weight and ground contact pressure of the equipment should be stated along with suggested operator movement of the cover soil placement operations. Truck traffic on the slopes can also give as high, or even higher, stresses and should be avoided unless adequately designed. Additional detail is given in McKelvey (1994). The issue of access ramps is a unique subset of this example and one which deserves focused attention due to the high loads and decelerations that often occur.

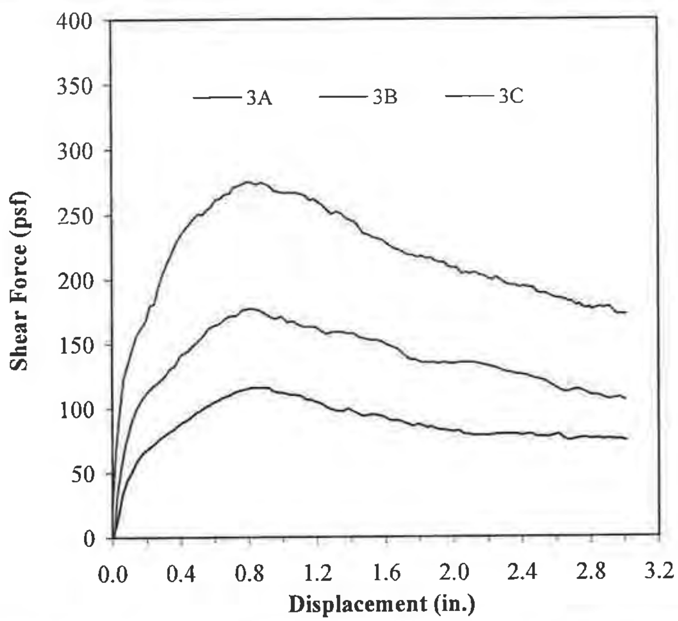
3.3 Consideration of Seepage Forces

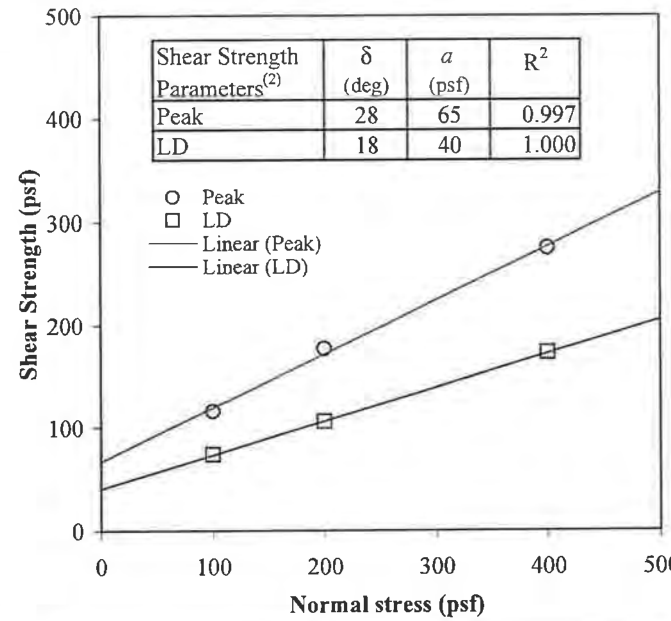
The previous sections presented the general problem of slope stability analysis of cover soils placed on slopes under different conditions. The tacit assumption throughout was that either permeable soil or a drainage layer was placed above the barrier layer with adequate flow capacity to efficiently remove permeating water safely way from the cross section. The amount of water to be removed is obviously a site specific situation. Note that in extremely

Attachment A 6

GEOSYNTEC CONSULTANTS - DENISON MINES – Cell 4B
INTERFACE DIRECT SHEAR TESTING (ASTM D 5321)

Upper Shear Box: Concrete sand
SKAPS GE116 nonwoven geotextile with non heat-treated side down/
GSE 60-mil B/W textured HDPE geomembrane #104152824 with white side up/
Lower Shear Box: Concrete sand





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	GCL Soaking Stress (psf)	GCL Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Subgrade Soil γ_d (pcf)	Subgrade Soil ω_i (%)	Subgrade Soil ω_f (%)	Cover Soil γ_d (pcf)	Cover Soil ω_i (%)	Cover Soil ω_f (%)	GCL ω_i (%)	GCL ω_f (%)	Shear Stress τ_P (psf)	Shear Stress τ_{LD} (psf)	Failure Mode
3A	12 x 12	100	0.2	-	-	-	-	-	-	-	-	-	-	-	-	116	74	(1)
3B	12 x 12	200	0.2	-	-	-	-	-	-	-	-	-	-	-	-	177	106	(1)
3C	12 x 12	400	0.2	-	-	-	-	-	-	-	-	-	-	-	-	275	173	(1)

NOTES:
(1) Shear failure occurred at the interface between the non heat-treated side of geotextile and white side of geomembrane.
(2) The reported total-stress parameters of friction angle and adhesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The large-displacement (LD) shear strength was calculated using the shear force measured at the end of the test.

SGI TESTING SERVICES, LLC

DATE OF REPORT:	5/24/2010
FIGURE NO.	C-3
PROJECT NO.	SGI10027
DOCUMENT NO.	
FILE NO.	

ATTACHMENT B(1/1)

S10027-03.ds.xls

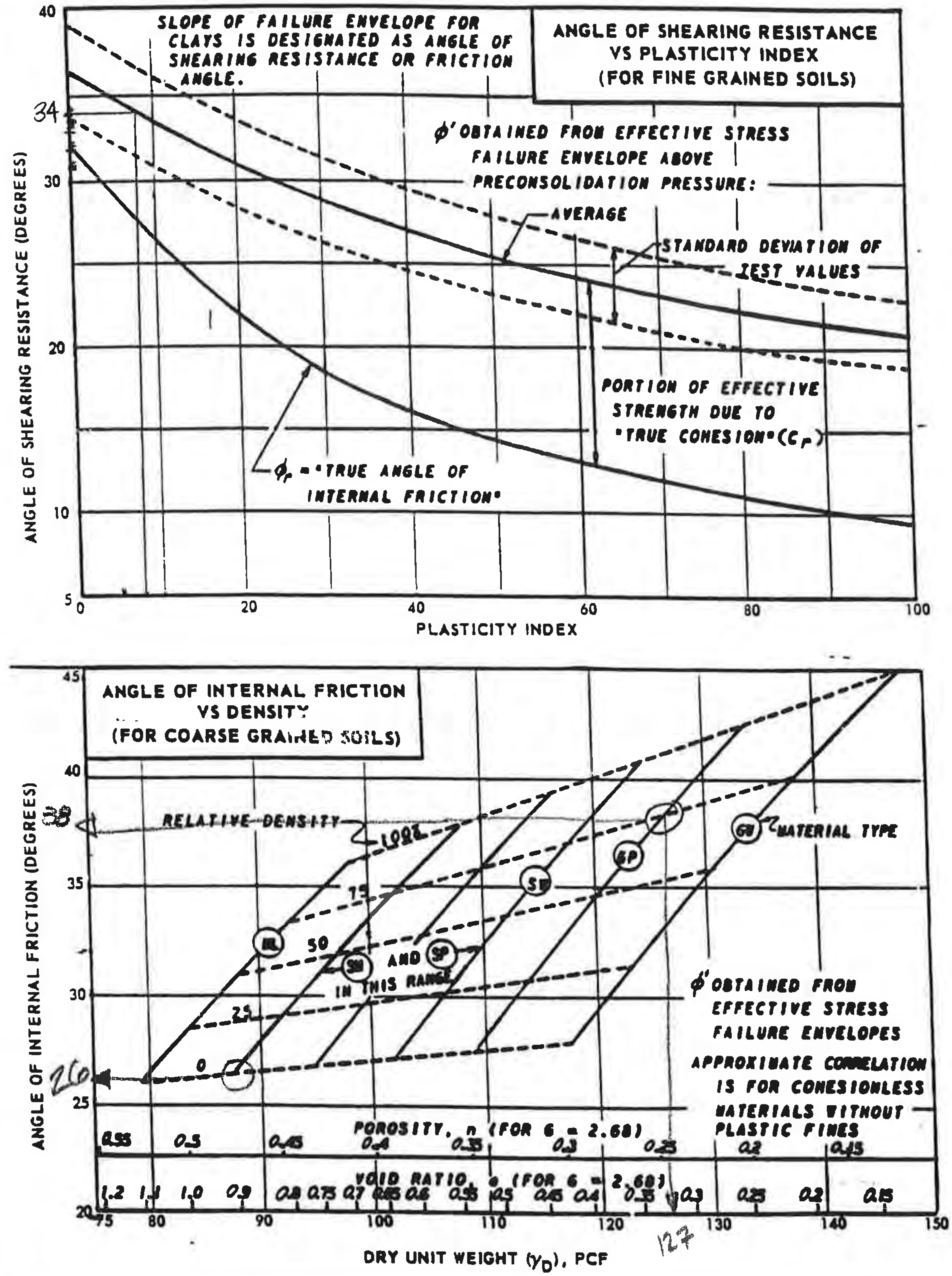


FIGURE 3-7

Correlations of Strength Characteristics

NAVFAC DM7-03, 1986

ATTACHMENT C (1/1)

FROM - PROCEEDINGS OF THE 4th GRI SEMINAR ON THE TOPIC OF LANDFILL CLOSURES

GRI - DEC. 14, 1990

TABLE 6
TMI COEFFICIENT OF FRICTION TEST RESULTS

GEONET VS. GEOSYNTHETICS INTERFACE FRICTION

NONWOVEN, NEEDLEPUNCHED	20°
NONWOVEN, HEATBONDED	17°
MONOFILAMENT	14°
MULTIFILAMENT	20°
SLIT FILM	14°
HDPE - SMOOTH	16°
HDPE - ROUGH	18°
CSPE	24°
VLDPE	20°
PVC	17°

GEOTEXTILE VS. GEOMEMBRANE INTERFACE FRICTION

GEOTEXTILE INTERFACE	HDPE	HDPE (ROUGH)	PVC	CSPE	VLDPE
WOVEN, SLIT FILM	18°	17°	23°	25°	22°
WOVEN, MONOFILAMENT	21°	14°	22°	23°	22°
WOVEN, MULTIFILAMENT	21°	25°	29°	27°	22°
NONWOVEN, HEATBONDED	23°	23°	19°	23°	19°
NONWOVEN, NEEDLEPUNCHED	19°	34°	22°	21°	20°

Attachment D 1/1

Geosyntec
consultants

COMPUTATION COVER SHEET

Client: **EF** Project: **White Mesa Mill – Cells 5A and 5B** Project/ Proposal No.: **SC0634** Task No. **02**

Title of Computations **ANALYSIS OF SLIMES DRAIN**

Computations by:	Signature		Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Assumptions and Procedures Checked by: (peer reviewer)	Signature		Date 12/13/12
	Printed Name	Gregory T. Corcoran, P.E.	
	Title	Principal	
Computations Checked by:	Signature		Date 12/10/12
	Printed Name	Jay Griffin	
	Title	Senior Staff Engineer	
Computations backchecked by: (originator)	Signature		Date 12/18/12
	Printed Name	Rebecca Flynn, P.E.	
	Title	Project Engineer	
Approved by: (pm or designate)	Signature		Date 12/13/12
	Printed Name	Gregory T. Corcoran, P.E.	
	Title	Principal	

Approval notes:

Revisions (number and initial all revisions)

No.	Sheet	Date	By	Checked by	Approval

Written by:	R. Flynn	Date:	11/11/12	Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	White Mesa Mill – Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

PURPOSE AND METHOD OF ANALYSIS

The purpose of this calculation package is to demonstrate that the proposed "slimes drain system" will dewater the tailings at the site within a reasonable time.

Fluid flow rate in porous media will be evaluated using Darcy's law.

ASSUMPTIONS

- This project involves the construction of two 42 acre triple lined tailings cells (Cells 5A and 5B) that are approximately 46 feet deep at their deepest point (Cell 5B) and 28 feet deep at the shallowest point with an average depth of 37 feet. The liquids level in the cell will be kept a minimum of 3 feet below the top of the berm (free-board). Therefore, the maximum depth of liquid in the cell will be 43 feet at the start of dewatering with an average and minimum depth of liquid of 34 and 25 feet, respectively.
- The cell will be filled with -28 mesh (US No. 30 sieve) tailings, largely consisting of fine sands and silts, with some clay. Results of grinding test sieve analyses, which are reported based on Tyler Mesh sieve sizes, are presented in Table 1. The grinding test data report is presented in Attachment A. Sieve to Tyler Mesh conversions are presented in Attachment B.
- The tailings will be placed within the cell in a slurry form under the surface of the free liquid contained within the cell. This placement methodology is anticipated to result in a low density (no compaction) soil structure. Therefore, saturated hydraulic conductivity and total porosity are anticipated to be higher than similar soils that are compacted.
- Based on the grinding report (Attachment A), tailings are comprised of approximately 6% medium sand, 49% fine sand, and 45% silt and clay size particles (Table 1).
- Based on the gradation of the tailings (Table 1) from the grinding report (Attachment A), the tailings would be classified as silty sand (SM) by the unified soil classification system (USCS). According to the Hydrologic Evaluation of Landfill Performance (HELP) Model Engineering Documentation (Attachment C), **low density** SM soils would exhibit saturated hydraulic

conductivities of between 1.7×10^{-3} cm/sec and 5.2×10^{-4} cm/sec and **low density** silt (ML) and sandy clay (SC) would exhibit saturated hydraulic conductivities of between 3.7×10^{-4} cm/sec and 1.2×10^{-4} cm/sec. The geomean of these two groups of soils, which are gradationally similar to the tailings, is 4.74×10^{-4} cm/sec (Table 2). According to Cedergren (Attachment D), under a normal stress of 2 tons per square foot (approximate normal stress on deeper tailings in the cell), medium sand, fine sand, silt, and silty clay would exhibit a saturated hydraulic conductivities of approximately 2×10^{-2} cm/sec, 1×10^{-2} cm/sec, 1×10^{-4} cm/sec 5×10^{-7} cm/sec, respectively. The geomean of these three soil types, which are gradationally similar to the tailings, is 3.31×10^{-4} cm/sec. The more conservative, lower hydraulic conductivity of 3.31×10^{-4} cm/sec, will be used in this analysis.

- Based on the gradation of the tailings from the grinding report, the tailings would be classified as silty sand (SM) by the unified soil classification system (USCS). According to the HELP Model Engineering Documentation (Attachment C), **low density** SM soils would exhibit drainable porosity of between 0.251 and 0.332 and **low density** silt (ML) and sandy clay (SC) would exhibit drainable porosity of between 0.154 and 0.231. The average of these two groups of soils, which are gradationally similar to the tailings, is 0.253 (Table 2). According to the HELP Model Engineering Documentation, medium sand, fine sand, silt, and silty clay would exhibit drainable porosity values of 0.35, 0.29, 0.14, and 0.11, respectively. The average of these three soil types, where are gradationally similar to the tailings, is 0.22. Since the average drainable porosity of 0.22 corresponds to the lower hydraulic conductivity (higher density, lower permeability, lower porosity) selected above, this value will be used in this analysis.
- The permeability of the tailings is isotropic.
- Darcy's law will be used to compute water flow velocities.
- The proposed slimes drain system will consist of a series of strip drains (geotextile wrapped HDPE core, 1" thick, 12" wide, with a transmissivity of 29 (gal/min/ft), which connect to a perforated 4" diameter PVC header pipe that is bedded in drainage aggregate and wrapped in a woven geotextile. The PVC pipe will convey the liquid to the sump for removal.

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- The slimes drain spacing will be 50' and will be continuous across the base of the cell (Figure 1).

CALCULATIONS

The flow geometry for the maximum depth of liquid within the cell is illustrated on Figure 2 and used to compute the emptying time for the proposed slimes drain system.

Calculate the flow into a unit length of strip drain for the various hydraulic gradient conditions.

At the start of cell dewatering, the maximum depth of liquid will vary between 25 feet at the shallow end and 43 feet at the deep end, with an average depth of approximately 34 feet. As the water level drops within the cell, the length of the longest flow path and the associated hydraulic gradient will continually change with time.

The total volume to be drained by a unit length of strip, Q, can be calculated using Darcy's law as follows:

$Q = kiA$

where:

k = hydraulic conductivity of tailings = $3.31\text{x}10^{-4}$ cm/sec = $6.51\text{x}10^{-4}$ ft/min

i = gradient along flowpath = $\frac{dh}{dl} = \frac{43}{49.7} = 0.87$ (see Figure 2)

A = area of strip drain where flow will pass =1.17 ft^2/ft (see Figure 3)

$$Q = (6.57 \times 10^{-4} \frac{ft}{\text{min}})(0.87)(1.17\ ft^2)$$

$$Q = 6.69x10^{-4} \frac{ft^3}{\text{min}} \times 7.48 \frac{gal}{ft^3} = 5.0x10^{-3} \frac{gal}{\text{min}}$$

For each one foot incremental drop in fluid elevation within the cell, the total volume to be drained by a unit length of strip drain is as follows:

V = 1 ft unit length x 1ft depth x 50 ft width x 0.22 (drainable porosity) = 11 ft^3 of free liquid

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Therefore, the time to drain the first one foot of liquid within the cell can be estimated as follows:

$t = V/Q = 11\ ft^3 / 6.69x10^{-4}\ ft^3/min = 16{,}731$ minutes = 11.62 days

Tables 3, 4, and 5 depict the calculations for the maximum (43 feet), average (34 feet), and minimum (25 feet) cell liquid depth, respectively. The results of the maximum depth calculations indicate that the proposed slimes drain system will allow the tailings contained in Cell 5B to drain within approximately 5.63 years.

Calculate the design flow rate of the strip drains.

For this calculation we will assume that the strip drains have a flow rate of 29 gallon per minute per foot (Attachment E, GDE Multi-Flow, 2006), a width of 12" and that flow is occurring under a gradient of 0.01. The assumed gradient of 0.01 is less than the actual gradient, which is between 0.011 and 0.014; therefore, this estimate is conservative.

Design Flow rate of strip drains:

$$q = \Theta i$$

where:

q = flowrate per unit width

$$i = \frac{dh}{dl} = 0.01$$

Θ = transmissivity = 29 gpm/ft

To account for detrimental effects on the geonet such as chemical clogging, biological clogging, installation defects, and creep, partial factors of safety were used to reduce the strip drain transmissivity. Using recommended partial factor of safety values from Koerner (1999) (Attachment F, 2/4), the reduced transmissivity is calculated as follows:

$$\Theta_{allow} = \Theta_{ult}\left[\frac{1}{FS_{IN} \times FS_{CR} \times FS_{CC} \times FS_{BC}}\right]$$

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where:

Θ_{allow} = allowable flow

$\Theta_{ultimate}$ = calculated value of flow

FS_{IN} = factor of safety for installation, 1.5 (CQA performed during installation)

FS_{CR} = factor of safety for creep, 2.0

FS_{CC} = factor of safety for chemical clogging, 2.0

FS_{BC} = factor of safety for biological clogging, 1.0 (low pH precludes biological activity)

The factors of safety are used to calculate the allowable transmissivity:

$$\Theta_{allow} = 29\frac{gpm}{ft}\left[\frac{1}{1.5 \times 2.0 \times 2.0 \times 1.0}\right] = 4.83\frac{gpm}{ft}$$

Using this transmissivity value, the average factor of safety for flow in the strip composite is estimated to be as follows:

$$FS = \frac{Q_D}{Q_R} = \frac{4.83\ gpm}{0.0049\ gpm} = 986 \quad \text{(Acceptable)}$$

The average allowable flow rate is much larger than the average maximum flow rate, even with the built-in partial factors of safety. Furthermore, as indicated on Tables 3, 4, and 5, the calculated flow rate within the strip drain decreases with time, which further increases the factor of safety.

Calculate the minimum required AOS and permittivity for filtration geotextile component of strip drain

The geotextile serves as a filter between the strip composite core and the tailings material. The geotextile minimizes fine particles of the tailings material from migrating into the strip composite, yet allows water to penetrate. Migration of fine particles would have the adverse effect of decreasing the transmissivity of the strip composite layer.

To be conservative in these calculations, the tailings material soil is assumed to consist of more than 20 percent clay.

The retention requirements for geotextiles can be evaluated using the chart entitled "Soil Retention Criteria for Steady-State Flow Conditions" developed by Luettich et al., (1991) (Attachment G, 1/3). This chart uses soil properties to evaluate the required apparent opening size (AOS or O_{95}) of the geotextile. Using the Soil Retention Chart, the AOS of the filter fabrics shall be:

$O_{95} < 0.21$ mm, which corresponds to sieve No. 70.

The permeability of the filter fabric must be evaluated to allow flow through the filter fabric. The following equation can be used to evaluate the minimum allowable geotextile permeability:

$k_g > i_s k_s$ (Luettich et al. (1991), Att. G, 2/3)

where: k_g = permeability of geotextile (cm/s)
i_s = hydraulic gradient (dimensionless)
k_s = permeability of the tailings material (cm/s)

Hydraulic Gradient, i: Attachment G, page 3/3 from Luettich et al. (1991) lists typical hydraulic gradients for various geotextile drainage applications. In this attachment, a hydraulic gradient of 10 for liquid impoundment applications is recommended.

Soil Permeability, k_s: A permeability of 3.31×10^{-4} cm/s was assumed for the tailings material, as previously defined.

Therefore,

$k_g > \quad i_s k_s = (10)(3.31\text{x}10^{-4} \text{ cm/s})$
$k_g > \quad 3.31 \times 10^{-3}$ cm/s

Koerner (1999) suggests applying partial factors of safety to the ultimate flow capacity of the geotextile to account for clogging of the geotextile. Using recommendations given in Table 2.12 on p. 150 of Koerner (1999) (Attachment F, 1/4), the following partial safety values were applied:

soil clogging and blinding: 10 (5 – 10)

creep reduction of voids:	2.0 (1.5 – 2.0)
intrusion into voids:	1.2 (1.0 – 1.2)
chemical clogging:	1.5 (1.2 – 1.5)
biological clogging (low pH precludes biological activity):	1.0 (2 – 10)

Therefore,

$k_g >$ $(3.31 \times 10^{-3})(10)(2)(1.2)(1.5)(1)$

$k_g >$ 0.12 cm/s

The thickness of a typical nonwoven needled punched 4 oz/yd^2 (135 g/m^2) geotextile is approximately 40 mils (0.10 cm), see Attachment H. Dividing the permeability by the thickness of the geotextile results in a required minimum permittivity of 1.2 sec^{-1}. The geotextile used in this project has a permittivity of 2.0 sec^{-1}, which is greater than the required permittivity.

Check Pipe Flow Rate

Based on calculations from previous sections, the maximum daily flow rate to the sump is estimated to be 148 gpm (0.33 cfs) (Table 3). The capacity of the pipe is calculated based on Manning's equation for gravity flow as follows:

$$Q = \frac{1.486}{n} R_h^{2/3} S^{1/2} A$$

Where

n = 0.010 (Koerner (1999), Attachment F, 4/4)
S = Slope of liner (ft/ft) = 1.75 %
R_h = hydraulic radius, ft
Q = flow rate, cubic feet per second, ft^3/s
A = flow area, ft^2

Assuming 4-inch pipe:

A = π D^2/4 = 12.6 sq. inches = 0.088 ft^2
R_h = Area (π D^2/4)/Wetted Perimeter (π D)
= D/4 = 1 in = 0.083 ft

$$Q = \frac{1.486}{0.010} 0.083^{2/3} 0.0175^{1/2} 0.088 \text{ ft}^2 = 0.33 \frac{\text{ft}^3}{s} = 147\ gpm$$

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Since 147 gpm is less than the maximum required 148 gpm, this calculation shows that the 4-inch diameter slimes drain pipe is the limiting factor for dewatering the tailings in the early phase of dewatering (high flow rates). However, it does not mean that the pipe will be unable to handle this flow, but rather the pipe will require additional time to drain. The additional time needed is computed in the following section.

Effect of Maximum Pipe Capacity on Drainage Time

The maximum capacity of the pipe is 147 gpm, as computed above. Assuming the cell's total lateral length of strip drain is approximately 30,120 feet, the flow rate, per foot of strip drain is calculated to be:

$$\text{Flow Rate} = \frac{147\ gallon}{\min} * \frac{60\min}{1\ hr} * \frac{24\ hr}{1\ day} * \frac{1 ft^3}{7.48\ gallon} * \frac{1}{30{,}120 feet} = 0.94 \frac{ft^3}{day}$$

The time needed to de-water first layer is:

$$Time = \frac{Volume}{Drain\ \ length\ \times flow\ rate} = \frac{(50\ x\ 1\ x\ 1\ x\ 0.22)\ ft^3}{1\ ft \times 0.94\ \frac{ft^3}{day}} = 11.70\ days$$

The difference between the maximum daily flow rate drainage time (11.62 days) and the maximum daily flow the pipe is able to deliver (11.70 days) is negligible. Therefore, the cell will take an estimated 5.63 years to drain.

Effect of Precipitation on Drainage Time

To account for the effect of precipitation added to the tailings cell, the HELP Model was used to estimate the average annual leakage through a 3 foot thick (tailings above the liquid) layer of silty sand material (Attachment I). HELP Model default parameters were used along with a maximum 16 inch evaporative zone (conservative for dry climate) and weather data from Grand Junction, Colorado. The model was performed for a 10 year period and included precipitation events ranging from 5.83 to 10.36 inches per year.

The results of this analysis suggest that a maximum average annual percolation through the 3 foot soil layer above the liquid will be approximately 12 ft^3 per acre or 504 ft^3 (3,770 gal.) for the entire Cell 5B area of 42 acres.

Written by:	R. Flynn	Date:	11/11/12	Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	White Mesa Mill – Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

The average flow rate during Cell 5B dewatering, as calculated from Table 3 is equal to 83 gpm (119,520 gallon/day).

The time required to drain the additional volume of precipitation in the tailings is computed using the following equation:

$$Time = \frac{Volume}{FlowRate} = \frac{3{,}770\ gal}{119{,}520\,\frac{gal}{day}} = 0.03\ days$$

The additional time that the pond will require to empty due to precipitation is insignificant. Therefore, the total estimated time to dewater Cell 5B is 5.63 years.

REFERENCES

Cedergren, H.R., "Seepage, Drainage, and Flow Nets," 3rd Ed., John Wiley & Sons, Inc., 1989
(Attachment D)

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(Attachment E)

Hydrologic Evaluation of Landfill Performance Model, Engineering Documentation for Version 3, EPA, 1994.
(Attachment C)

Koerner, R. M., "Designing With Geosynthetics," 4th Ed., Prentice Hall, 1999.
(Attachment F)

Luettich, S.M., Giroud, J.P., and Bachus, R.C., (1991), "Geotextile Filter Design Manual, report prepared for Nicolon Corporation, Norcross, GA.
(Attachment G)

Amoco Fabrics and Fibers Company, (1991), "*Amoco Waste Related Geotextiles.*"
(Attachment H)

Written by:	R. Flynn	Date:	11/11/12	Reviewed by:	G. Corcoran	Date:	12/13/12
Client:	EF	Project:	White Mesa Mill – Cells 5A and 5B	Project/ Proposal No.:	SC0634	Task No.:	02

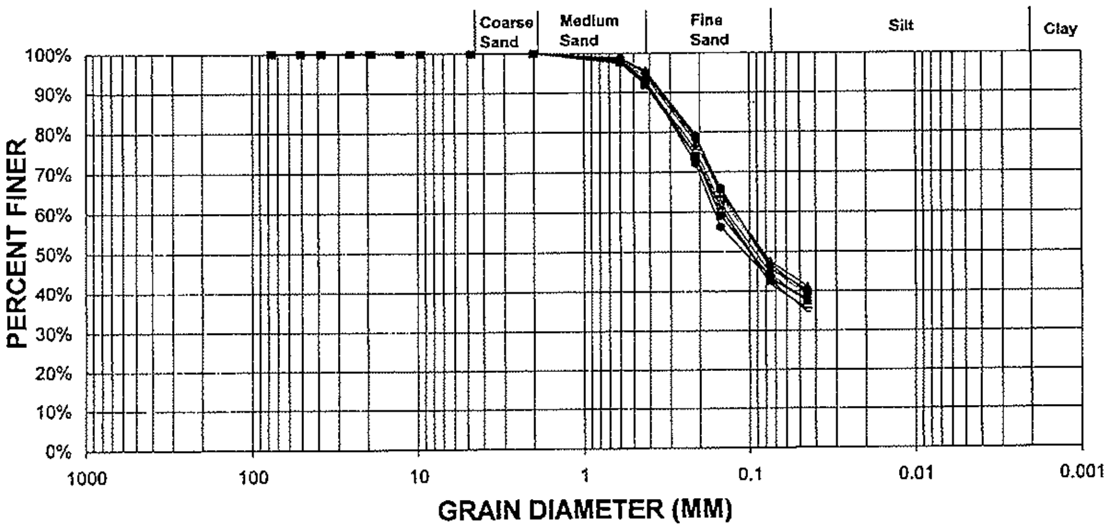
Amoco Fabrics and Fibers Company, (1991), "*Amoco Waste Related Geotextiles.*" *(Attachment H)*

Table 1
DSM Screen Undersize Gradation

SIEVE ANALYSIS

		Grinding Test 1			Grinding Test 2A			Grinding Test 2B			Grinding Test 3A			Grinding Test 3B		
Sieve No.	Diameter (mm)	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer
3 in.	76.2	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
2 in.	50.8	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 1/2 in.	38.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 in.	25.4	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/4 in.	19.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1/2 in.	12.7	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/8 in.	9.530	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 4	4.750	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 10	2.000	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 30	0.600	1.2	1.2%	98.8%	2.0	2.0%	98.0%	1.7	1.7%	98.3%	2.4	2.4%	97.6%	1.9	1.9%	98.1%
No. 40	0.425	4.6	4.6%	95.4%	7.3	7.3%	92.7%	6.0	6.0%	94.0%	8.1	8.1%	91.9%	6.9	6.9%	93.1%
No. 70	0.212	20.8	20.8%	79.2%	24.5	24.5%	75.5%	22.6	22.6%	77.4%	26.2	26.2%	73.8%	27.9	27.9%	72.1%
No. 100	0.150	34.8	34.8%	65.2%	38.1	38.1%	61.9%	35.5	35.5%	64.5%	41.0	41.0%	59.0%	43.9	43.9%	56.1%
No. 200	0.075	53.4	53.4%	46.6%	55.7	55.7%	44.3%	52.5	52.5%	47.5%	56.6	56.6%	43.4%	57.4	57.4%	42.6%
No. 325	0.045	60.5	60.5%	39.5%	62.7	62.7%	37.3%	58.8	58.8%	41.2%	62.5	62.5%	37.5%	61.9	61.9%	38.1%
Pan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		Grinding Test 6A			Grinding Test 6B			Grinding Test 4A			Grinding Test 4B		
Sieve No.	Diameter (mm)	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer	Wt. Retained (grams)	% Retained	% Finer
3 in.	76.2	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
2 in.	50.8	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 1/2 in.	38.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1 in.	25.4	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/4 in.	19.1	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
1/2 in.	12.7	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
3/8 in.	9.530	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 4	4.750	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 10	2.000	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%	0.0	0.0%	100.0%
No. 30	0.600	1.3	1.3%	98.7%	1.0	1.0%	99.0%	2.7	2.7%	97.3%	2.7	2.7%	97.3%
No. 40	0.425	5.2	5.2%	94.8%	4.7	4.7%	95.3%	7.6	7.6%	92.4%	7.3	7.3%	92.7%
No. 70	0.212	21.7	21.7%	78.3%	21.4	21.4%	78.6%	26.2	26.2%	73.8%	25.9	25.9%	74.1%
No. 100	0.150	34.1	34.1%	65.9%	35.9	35.9%	64.1%	38.7	38.7%	61.3%	39.2	39.2%	60.8%
No. 200	0.075	54.4	54.4%	45.6%	54.4	54.4%	45.6%	57.3	57.3%	42.7%	58.3	58.3%	41.7%
No. 325	0.045	59.7	59.7%	40.3%	61.1	61.1%	38.9%	65.4	65.4%	34.6%	64.6	64.6%	35.4%
Pan	-	-	-	-	-	-	-	-	-	-	-	-	-



Average

Med Sand	6.4%
Fine Sand	49.1%
Silt	44.4%

%FINER = 100 - Σ%RETAINED

5/12/2007

Table 2
Tailings Parameters

Soil	Permeability[1] (cm/sec)	Drainable Porosity[2] (vol./vol.)
med sand	2.00E-02	0.35
fine sand	1.00E-02	0.29
silt	1.00E-04	0.14
silty clay	6.00E-07	0.11
average	7.53E-03	0.22
geomean	3.31E-04	0.20

Soil	Permeability[3] (cm/sec)	Drainable Porosity[3] (vol./vol.)
SM (LS)	1.70E-03	0.332
SM (LFS)	1.00E-03	0.326
SM (SL)	7.20E-04	0.263
SM (FSL)	5.20E-04	0.251
ML (L)	3.70E-04	0.231
ML (SiL)	1.90E-04	0.217
SC (SCL)	1.20E-04	0.154
average	6.60E-04	0.253
geomean	4.74E-04	0.246

Notes:

(1) Source - "Seepage, Drainage, and Flow Nets", Cedergren, H. R., 1989.

(2) Source - The Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3, EPA, 1994 - Figure 2 - Soil texture vs. Moisture Retention.

(3) Source - The Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3, EPA, 1994 - Table 1 - Low Density Soil Characteristics.

TABLE 3
White Mesa Mill
Cell 5B Slimes Drain
Maximum Liquid Depth

Permeability (cm/sec)	Permeability (ft/min)	Drainage Path Length (ft.)	Thickness (VF)	Q (cfm/ft)	Volume of Liquid (CF/ft)	Time to Dewater (min/VF/ft)	Time to Dewater (days/VF/ft)	Total Flow Rate (gpm)	Volume Removed (gal)	Pipe Limitation (days)
3.31E-04	6.51E-04	49.7	43	6.57E-04	11	16,731	11.62	148.14	2,478,439	0.08
3.31E-04	6.51E-04	49.2	42	6.49E-04	11	16,957	11.78	146.16	2,478,439	
3.31E-04	6.51E-04	48.6	41	6.41E-04	11	17,158	11.92	144.44	2,478,439	
3.31E-04	6.51E-04	48.1	40	6.32E-04	11	17,406	12.09	142.39	2,478,439	
3.31E-04	6.51E-04	47.6	39	6.23E-04	11	17,667	12.27	140.28	2,478,439	
3.31E-04	6.51E-04	47.1	38	6.13E-04	11	17,942	12.46	138.14	2,478,439	
3.31E-04	6.51E-04	46.7	37	6.02E-04	11	18,270	12.69	135.66	2,478,439	
3.31E-04	6.51E-04	46.3	36	5.91E-04	11	18,617	12.93	133.13	2,478,439	
3.31E-04	6.51E-04	45.9	35	5.79E-04	11	18,983	13.18	130.56	2,478,439	
3.31E-04	6.51E-04	45.5	34	5.68E-04	11	19,371	13.45	127.94	2,478,439	
3.31E-04	6.51E-04	45.1	33	5.56E-04	11	19,783	13.74	125.28	2,478,439	
3.31E-04	6.51E-04	44.8	32	5.43E-04	11	20,265	14.07	122.30	2,478,439	
3.31E-04	6.51E-04	44.5	31	5.29E-04	11	20,779	14.43	119.28	2,478,439	
3.31E-04	6.51E-04	44.3	30	5.15E-04	11	21,375	14.84	115.95	2,478,439	
3.31E-04	6.51E-04	44.0	29	5.01E-04	11	21,962	15.25	112.85	2,478,439	
3.31E-04	6.51E-04	43.8	28	4.86E-04	11	22,643	15.72	109.46	2,478,439	
3.31E-04	6.51E-04	43.7	27	4.70E-04	11	23,428	16.27	105.79	2,478,439	
3.31E-04	6.51E-04	43.5	26	4.54E-04	11	24,218	16.82	102.34	2,478,439	
3.31E-04	6.51E-04	43.4	25	4.38E-04	11	25,129	17.45	98.63	2,478,439	
3.31E-04	6.51E-04	43.3	24	4.21E-04	11	26,116	18.14	94.90	2,478,439	
3.31E-04	6.51E-04	43.3	23	4.04E-04	11	27,251	18.92	90.95	2,478,439	
3.31E-04	6.51E-04	43.2	22	3.87E-04	11	28,424	19.74	87.20	2,478,439	
3.31E-04	6.51E-04	43.2	21	3.69E-04	11	29,778	20.68	83.23	2,478,439	
3.31E-04	6.51E-04	43.3	20	3.51E-04	11	31,339	21.76	79.09	2,478,439	
3.31E-04	6.51E-04	43.3	19	3.33E-04	11	32,988	22.91	75.13	2,478,439	
3.31E-04	6.51E-04	43.4	18	3.15E-04	11	34,901	24.24	71.01	2,478,439	
3.31E-04	6.51E-04	43.6	17	2.96E-04	11	37,125	25.78	66.76	2,478,439	
3.31E-04	6.51E-04	43.7	16	2.78E-04	11	39,535	27.46	62.69	2,478,439	
3.31E-04	6.51E-04	43.9	15	2.60E-04	11	42,364	29.42	58.50	2,478,439	
3.31E-04	6.51E-04	44.1	14	2.41E-04	11	45,597	31.66	54.36	2,478,439	
3.31E-04	6.51E-04	44.4	13	2.22E-04	11	49,438	34.33	50.13	2,478,439	
3.31E-04	6.51E-04	44.7	12	2.04E-04	11	53,920	37.44	45.96	2,478,439	
3.31E-04	6.51E-04	45.0	11	1.86E-04	11	59,217	41.12	41.85	2,478,439	
3.31E-04	6.51E-04	45.3	10	1.68E-04	11	65,573	45.54	37.80	2,478,439	
3.31E-04	6.51E-04	45.7	9	1.50E-04	11	73,502	51.04	33.72	2,478,439	
3.31E-04	6.51E-04	46.0	8	1.32E-04	11	83,233	57.80	29.78	2,478,439	
3.31E-04	6.51E-04	46.5	7	1.14E-04	11	96,157	66.78	25.77	2,478,439	
3.31E-04	6.51E-04	46.9	6	9.72E-05	11	113,148	78.58	21.90	2,478,439	
3.31E-04	6.51E-04	47.4	5	8.02E-05	11	137,225	95.30	18.06	2,478,439	
3.31E-04	6.51E-04	47.8	4	6.36E-05	11	172,979	120.12	14.33	2,478,439	
3.31E-04	6.51E-04	48.3	3	4.72E-05	11	233,051	161.84	10.63	2,478,439	
3.31E-04	6.51E-04	48.9	2	3.11E-05	11	353,919	245.78	7.00	2,478,439	
3.31E-04	6.51E-04	49.4	1	1.54E-05	11	715,076	496.58	3.47	2,478,439	
						days	**2,055.93**		**96,659,131**	**0.08**
						years	**5.63**			

Average Soil Porosity	0.22	
Geomean Soil Permeability	3.31E-04	cm/sec
Distance Between Drains	50	ft
Thickness of Unit	1	ft
Maximum Depth	43	ft
Length of Strip Drain	30,120	ft

TABLE 4
White Mesa Mill
Cell 5B Slimes Drain
Average Liquid Depth

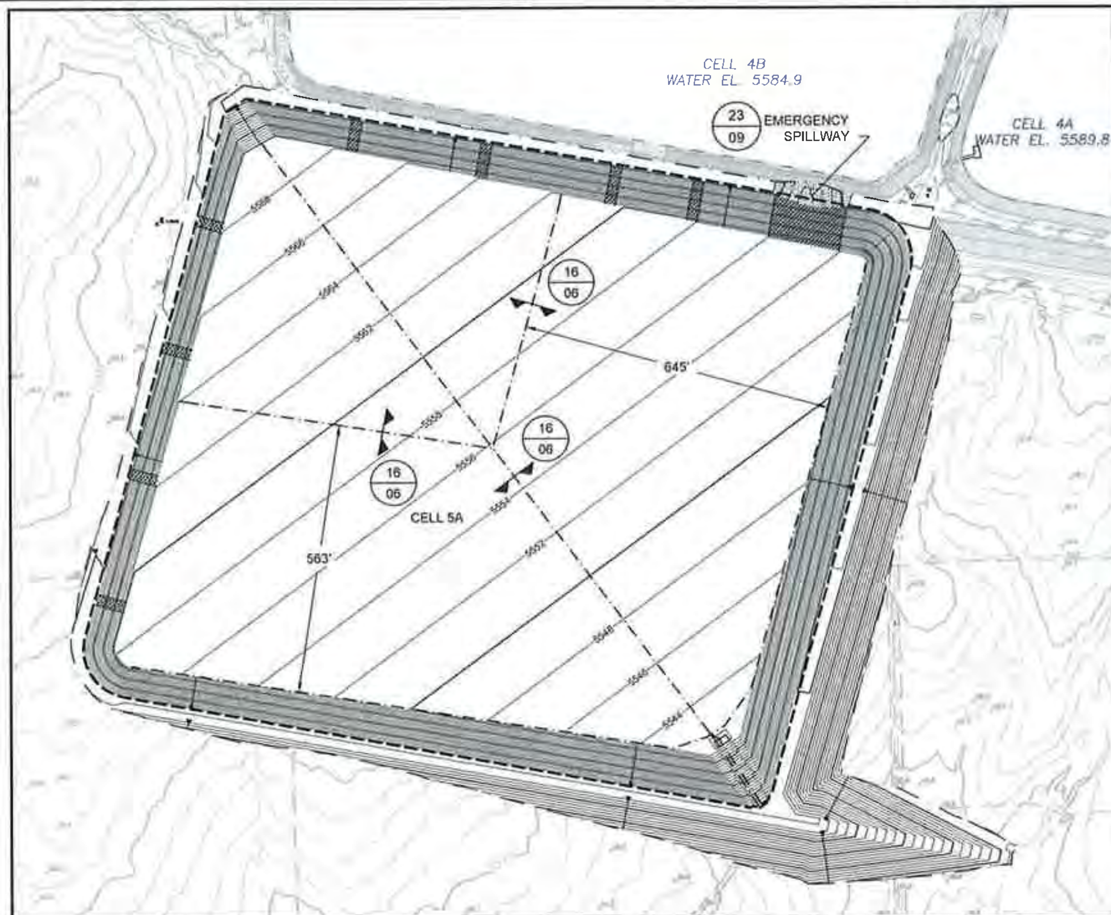
Permeability (cm/sec)	Permeability (ft/min)	Drainage Path Length (ft.)	Thickness (VF)	Q (cfm/ft)	Volume of Liquid (CF/ft)	Time to Dewater (min/VF/ft)	Time to Dewater (days/VF/ft)	Total Flow Rate (gpm)	Volume Removed (gal)
3.31E-04	6.51E-04	42.2	34	6.12E-04	11	17,966	12.48	137.95	2,478,439
3.31E-04	6.51E-04	41.8	33	6.00E-04	11	18,335	12.73	135.17	2,478,439
3.31E-04	6.51E-04	41.5	32	5.86E-04	11	18,773	13.04	132.02	2,478,439
3.31E-04	6.51E-04	41.2	31	5.72E-04	11	19,238	13.36	128.83	2,478,439
3.31E-04	6.51E-04	41.0	30	5.56E-04	11	19,783	13.74	125.28	2,478,439
3.31E-04	6.51E-04	40.8	29	5.40E-04	11	20,365	14.14	121.70	2,478,439
3.31E-04	6.51E-04	40.6	28	5.24E-04	11	20,989	14.58	118.08	2,478,439
3.31E-04	6.51E-04	40.5	27	5.07E-04	11	21,713	15.08	114.15	2,478,439
3.31E-04	6.51E-04	40.4	26	4.89E-04	11	22,492	15.62	110.19	2,478,439
3.31E-04	6.51E-04	40.3	25	4.71E-04	11	23,334	16.20	106.22	2,478,439
3.31E-04	6.51E-04	40.3	24	4.53E-04	11	24,306	16.88	101.97	2,478,439
3.31E-04	6.51E-04	40.3	23	4.34E-04	11	25,363	17.61	97.72	2,478,439
3.31E-04	6.51E-04	40.3	22	4.15E-04	11	26,516	18.41	93.47	2,478,439
3.31E-04	6.51E-04	40.4	21	3.95E-04	11	27,848	19.34	89.00	2,478,439
3.31E-04	6.51E-04	40.6	20	3.74E-04	11	29,385	20.41	84.34	2,478,439
3.31E-04	6.51E-04	40.7	19	3.55E-04	11	31,007	21.53	79.93	2,478,439
3.31E-04	6.51E-04	40.9	18	3.34E-04	11	32,891	22.84	75.35	2,478,439
3.31E-04	6.51E-04	41.2	17	3.14E-04	11	35,081	24.36	70.65	2,478,439
3.31E-04	6.51E-04	41.4	16	2.94E-04	11	37,455	26.01	66.17	2,478,439
3.31E-04	6.51E-04	41.8	15	2.73E-04	11	40,338	28.01	61.44	2,478,439
3.31E-04	6.51E-04	42.1	14	2.53E-04	11	43,529	30.23	56.94	2,478,439
3.31E-04	6.51E-04	42.5	13	2.32E-04	11	47,323	32.86	52.37	2,478,439
3.31E-04	6.51E-04	42.9	12	2.13E-04	11	51,749	35.94	47.89	2,478,439
3.31E-04	6.51E-04	43.3	11	1.93E-04	11	56,980	39.57	43.50	2,478,439
3.31E-04	6.51E-04	43.8	10	1.73E-04	11	63,402	44.03	39.09	2,478,439
3.31E-04	6.51E-04	44.3	9	1.54E-04	11	71,250	49.48	34.78	2,478,439
3.31E-04	6.51E-04	44.8	8	1.36E-04	11	81,061	56.29	30.57	2,478,439
3.31E-04	6.51E-04	45.4	7	1.17E-04	11	93,882	65.20	26.40	2,478,439
3.31E-04	6.51E-04	46.0	6	9.91E-05	11	110,977	77.07	22.33	2,478,439
3.31E-04	6.51E-04	46.6	5	8.15E-05	11	134,909	93.69	18.37	2,478,439
3.31E-04	6.51E-04	47.2	4	6.44E-05	11	170,808	118.62	14.51	2,478,439
3.31E-04	6.51E-04	47.9	3	4.76E-05	11	231,121	160.50	10.72	2,478,439
3.31E-04	6.51E-04	48.6	2	3.13E-05	11	351,748	244.27	7.05	2,478,439
3.31E-04	6.51E-04	49.3	1	1.54E-05	11	713,629	495.58	3.47	2,478,439
						days	**1,899.68**		**76,831,617**
						years	**5.20**		

Average Soil Porosity	0.22	
Geomean Soil Permeability	3.31E-04	cm/sec
Distance Between Drains	50	ft
Thickness of Unit	1	ft
Average Depth	34	ft
Length of Strip Drain	30,120	ft

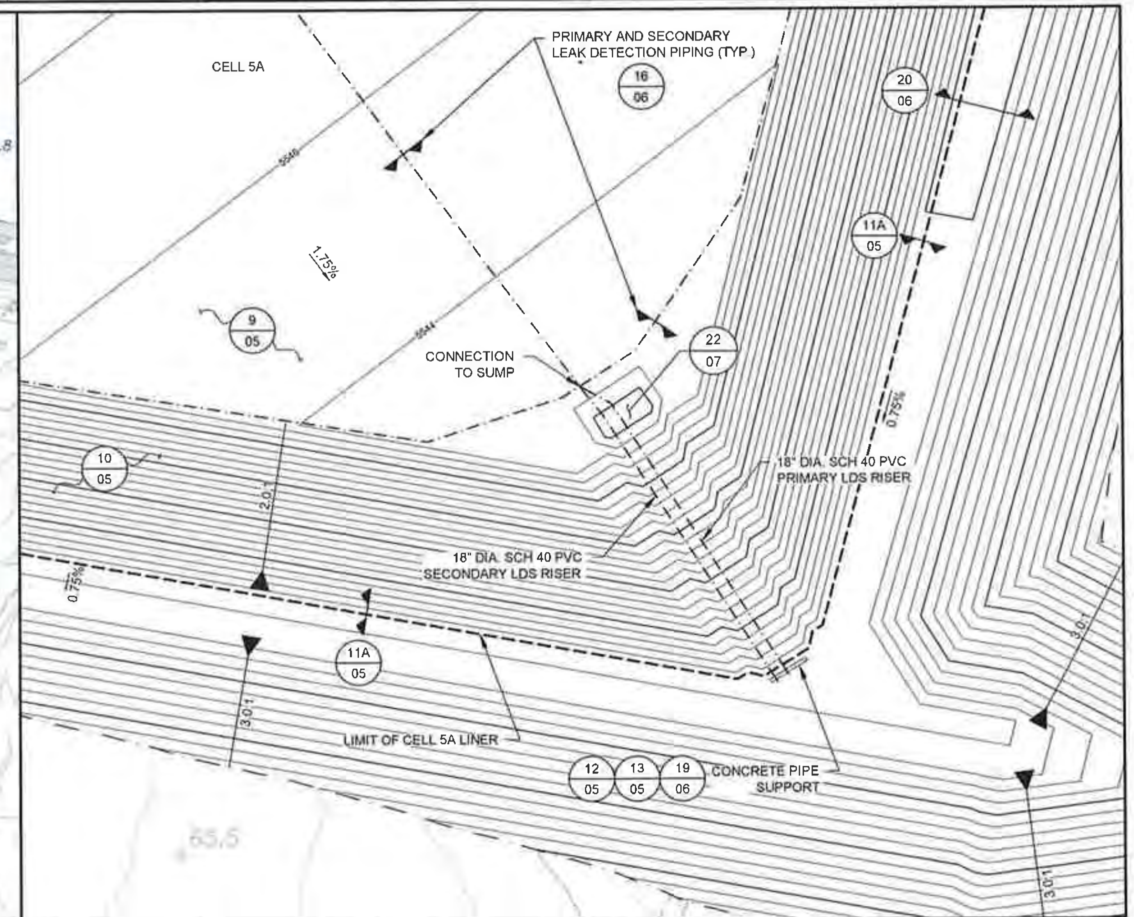
TABLE 5
White Mesa Mill
Cell 5B Slimes Drain
Minimum Liquid Depth

Permeability (cm/sec)	Permeability (ft/min)	Drainage Path Length (ft.)	Thickness (VF)	Q (cfm/ft)	Volume of Liquid (CF/ft)	Time to Dewater (min/VF/ft)	Time to Dewater (days/VF/ft)	Total Flow Rate (gpm)	Volume Removed (gal)
3.31E-04	6.51E-04	35.4	25	5.37E-04	11	20,497	14.23	120.92	2,478,439
3.31E-04	6.51E-04	35.4	24	5.15E-04	11	21,351	14.83	116.08	2,478,439
3.31E-04	6.51E-04	35.5	23	4.92E-04	11	22,342	15.52	110.93	2,478,439
3.31E-04	6.51E-04	35.6	22	4.70E-04	11	23,424	16.27	105.81	2,478,439
3.31E-04	6.51E-04	35.8	21	4.46E-04	11	24,677	17.14	100.44	2,478,439
3.31E-04	6.51E-04	36.1	20	4.21E-04	11	26,128	18.14	94.86	2,478,439
3.31E-04	6.51E-04	36.4	19	3.97E-04	11	27,731	19.26	89.37	2,478,439
3.31E-04	6.51E-04	36.7	18	3.73E-04	11	29,513	20.50	83.98	2,478,439
3.31E-04	6.51E-04	37.1	17	3.48E-04	11	31,590	21.94	78.46	2,478,439
3.31E-04	6.51E-04	37.6	16	3.23E-04	11	34,017	23.62	72.86	2,478,439
3.31E-04	6.51E-04	38.1	15	2.99E-04	11	36,767	25.53	67.41	2,478,439
3.31E-04	6.51E-04	38.6	14	2.76E-04	11	39,910	27.72	62.10	2,478,439
3.31E-04	6.51E-04	39.2	13	2.52E-04	11	43,648	30.31	56.78	2,478,439
3.31E-04	6.51E-04	39.8	12	2.29E-04	11	48,010	33.34	51.62	2,478,439
3.31E-04	6.51E-04	40.5	11	2.06E-04	11	53,295	37.01	46.50	2,478,439
3.31E-04	6.51E-04	41.2	10	1.84E-04	11	59,638	41.42	41.56	2,478,439
3.31E-04	6.51E-04	42.0	9	1.63E-04	11	67,551	46.91	36.69	2,478,439
3.31E-04	6.51E-04	42.8	8	1.42E-04	11	77,442	53.78	32.00	2,478,439
3.31E-04	6.51E-04	43.6	7	1.22E-04	11	90,160	62.61	27.49	2,478,439
3.31E-04	6.51E-04	44.4	6	1.03E-04	11	107,117	74.39	23.14	2,478,439
3.31E-04	6.51E-04	45.3	5	8.39E-05	11	131,146	91.07	18.90	2,478,439
3.31E-04	6.51E-04	46.2	4	6.58E-05	11	167,189	116.10	14.82	2,478,439
3.31E-04	6.51E-04	47.1	3	4.84E-05	11	227,261	157.82	10.91	2,478,439
3.31E-04	6.51E-04	48.0	2	3.17E-05	11	347,406	241.25	7.13	2,478,439
3.31E-04	6.51E-04	49.0	1	1.55E-05	11	709,286	492.56	3.49	2,478,439
						days	**1,713.26**		**57,004,103**
						years	**4.69**		

Average Soil Porosity	0.22	
Geomean Soil Permeability	3.31E-04	cm/sec
Distance Between Drains	50	ft
Thickness of Unit	1	ft
Minimum Depth	25	ft
Length of Strip Drain	30,120	ft



1 / 04A PLAN
CELL 5A LEAK DETECTION SYSTEM
SCALE: 1" = 200'



3 / 04A DETAIL
CELL 5A LEAK DETECTION SYSTEM
SCALE: 1" = 50'

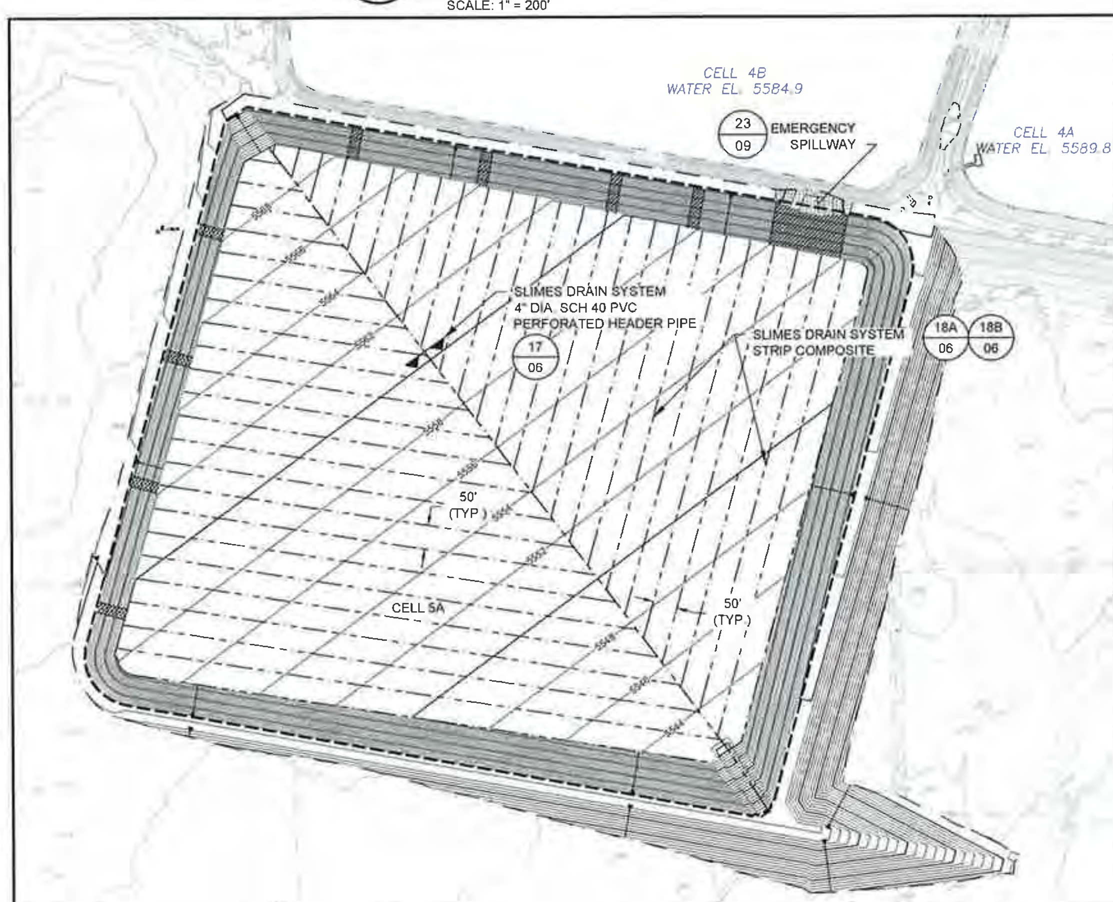
12/05 13/05 19/06

LEGEND

- JUNE 2011 EXISTING GROUND MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- 5602 — PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- LIMIT OF LINER SYSTEM
- PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- SPLASH PAD 21/06

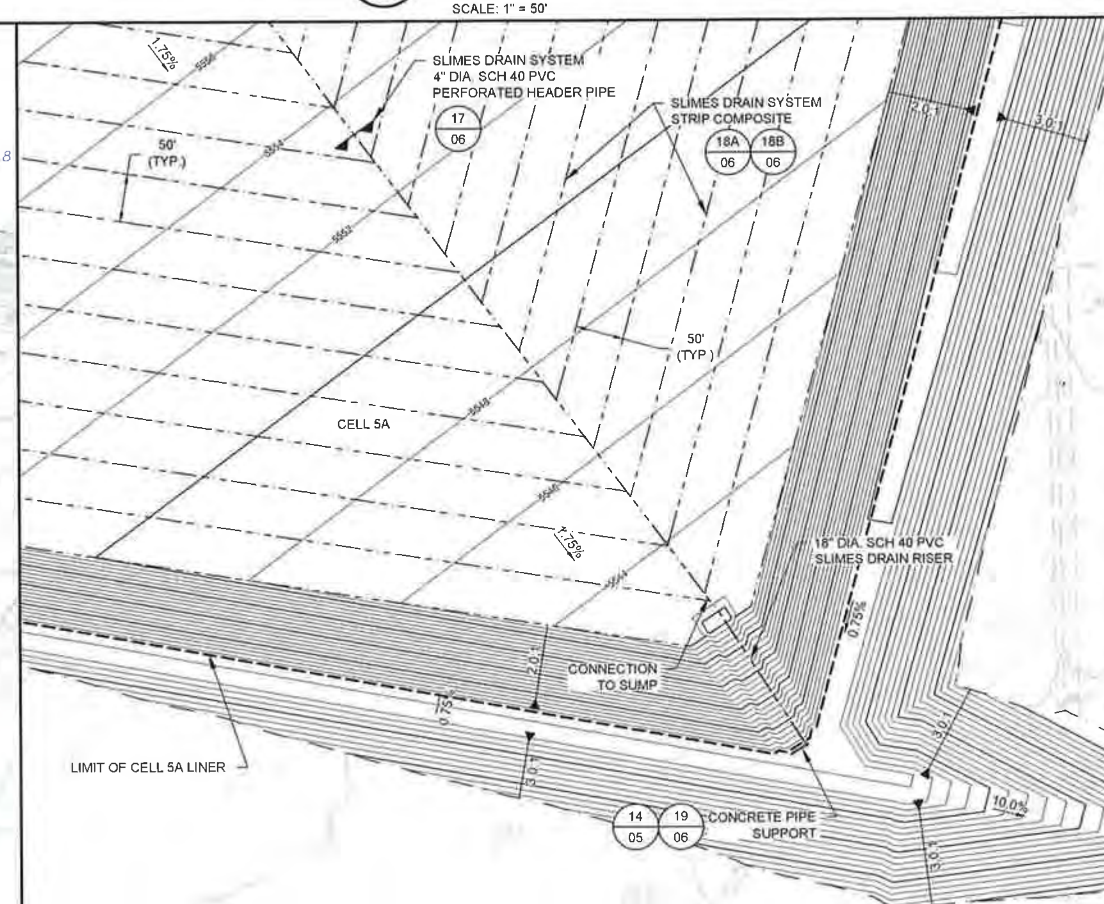
NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011 THIS INFORMATION WAS PROVIDED BE ENERGY FUELS RESOURCES (USA) INC
2. CONTRACTOR SHALL SEGREGATE TOPSOIL, SOIL AND ROCK MATERIALS INTO SEPARATE STOCKPILES IN STOCKPILE AREA AS DIRECTED BY THE CONSTRUCTION MANAGER. CONTRACTOR SHALL NOT STOCKPILE OVER DELINEATED ARCHEOLOGICAL SITES UNLESS DIRECTED OTHERWISE BY THE CONSTRUCTION MANAGER
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT



2 / 04A PLAN
CELL 5A SLIMES DRAIN SYSTEM
SCALE: 1" = 200'

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



4 / 04A DETAIL
CELL 5A SLIMES DRAIN SYSTEM
SCALE: 1" = 100'

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

FIGURE 1A

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE 858 674 6559

Energy Fuels Resources (USA) Inc

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5A

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL, BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION UNLESS SEALED

SIGNATURE
DATE

DESIGN BY	GTC	DATE	JANUARY 2013
DRAWN BY	MMC	PROJECT NO	SC0634
CHECKED BY	RBF	FILE	SC0634 - 03A-04B
REVIEWED BY	GTC	DRAWING NO	04A OF 12
APPROVED BY	GTC		

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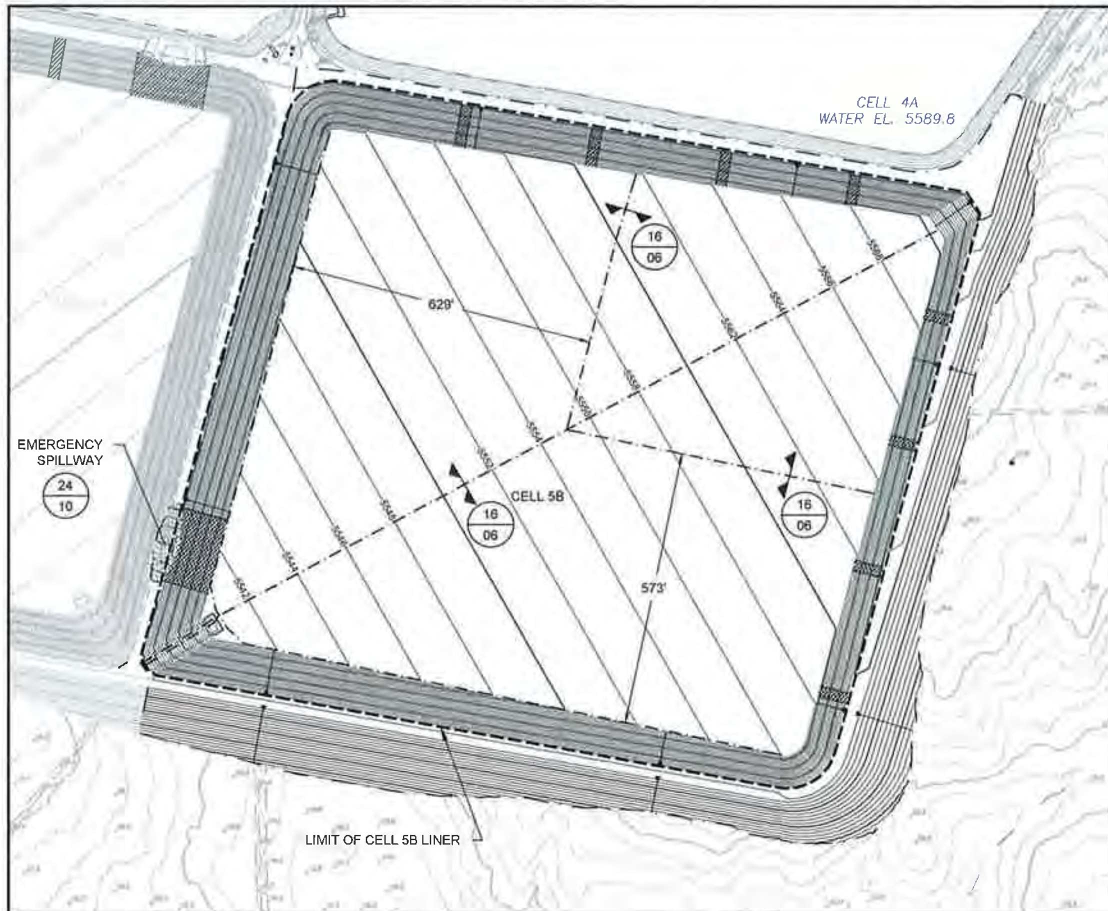
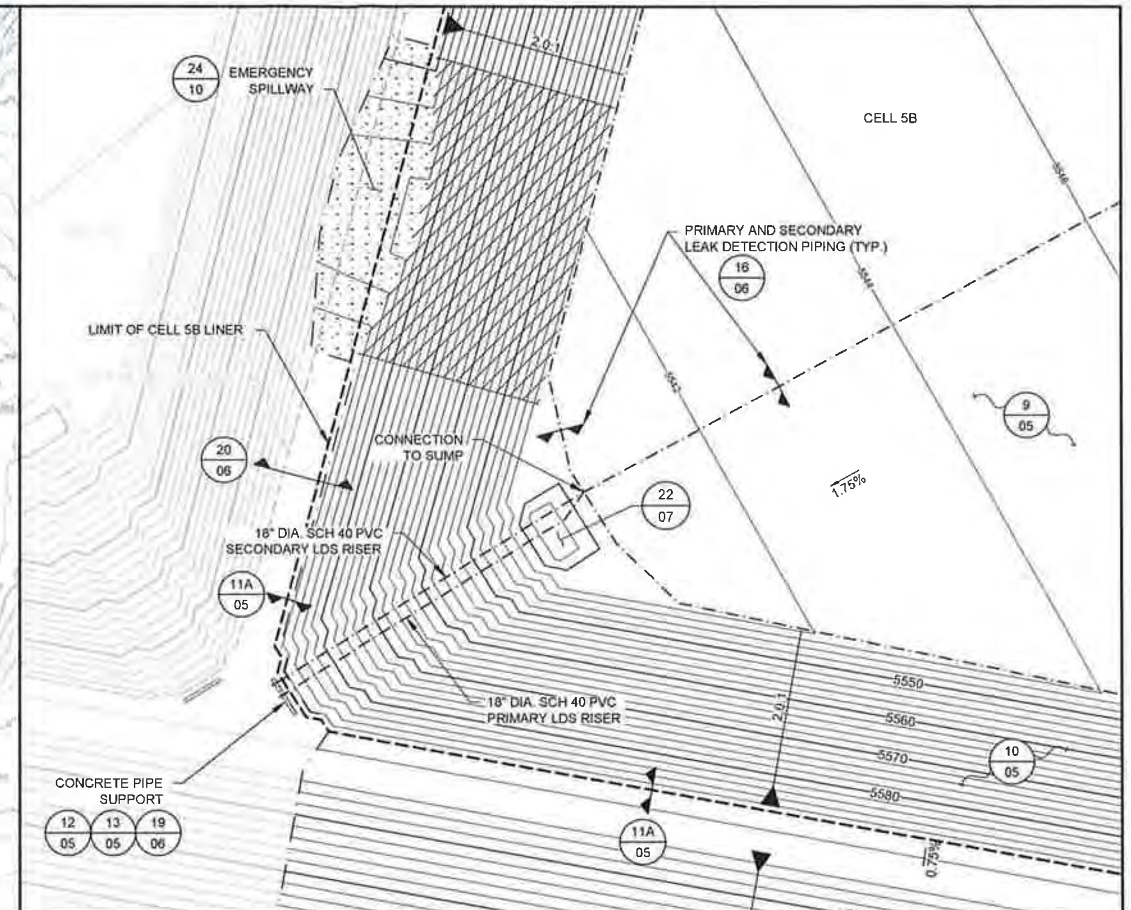


21
04B
PLAN
CELL 5B LEAK DETECTION SYSTEM
SCALE: 1" = 200'



6
04B
DETAIL
CELL 5B LEAK DETECTION SYSTEM
SCALE: 1" = 50'

LEGEND

- JUNE 2011 EXISTING GROUND / CELL 5A GRADING MAJOR CONTOUR (10')
- JUNE 2011 EXISTING GROUND / CELL 5A GRADING MINOR CONTOUR (2')
- EXISTING DIRT ROAD
- EXISTING FENCE
- 5600 — PROPOSED GRADING MAJOR CONTOUR (10')
- 5602 — PROPOSED GRADING MINOR CONTOUR (2')
- PROPOSED GRADING LIMIT
- LIMIT OF LINER SYSTEM
- PRIMARY AND SECONDARY LEAK DETECTION SYSTEM PIPING
- SLIMES DRAIN SYSTEM PIPING
- SLIMES DRAIN SYSTEM STRIP COMPOSITE AND SAND BAGS
- SPLASH PAD (21/06)

NOTES

1. EXISTING SITE FEATURE AND PHOTOGRAMMETRIC TOPOGRAPHIC CONTOURS BASED UPON A SURVEY CONDUCTED ON JUNE 29, 2011. THIS INFORMATION WAS PROVIDED BE ENERGY FUELS RESOURCES (USA) INC.
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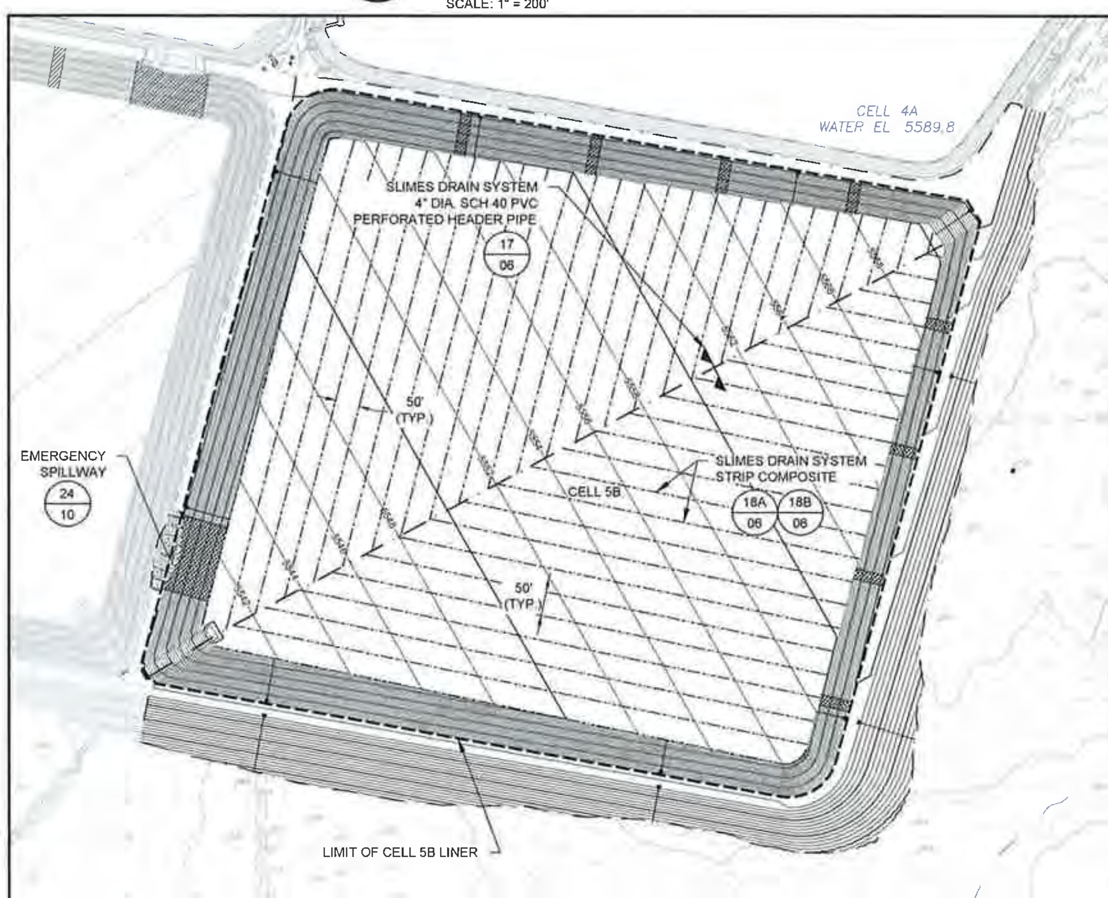
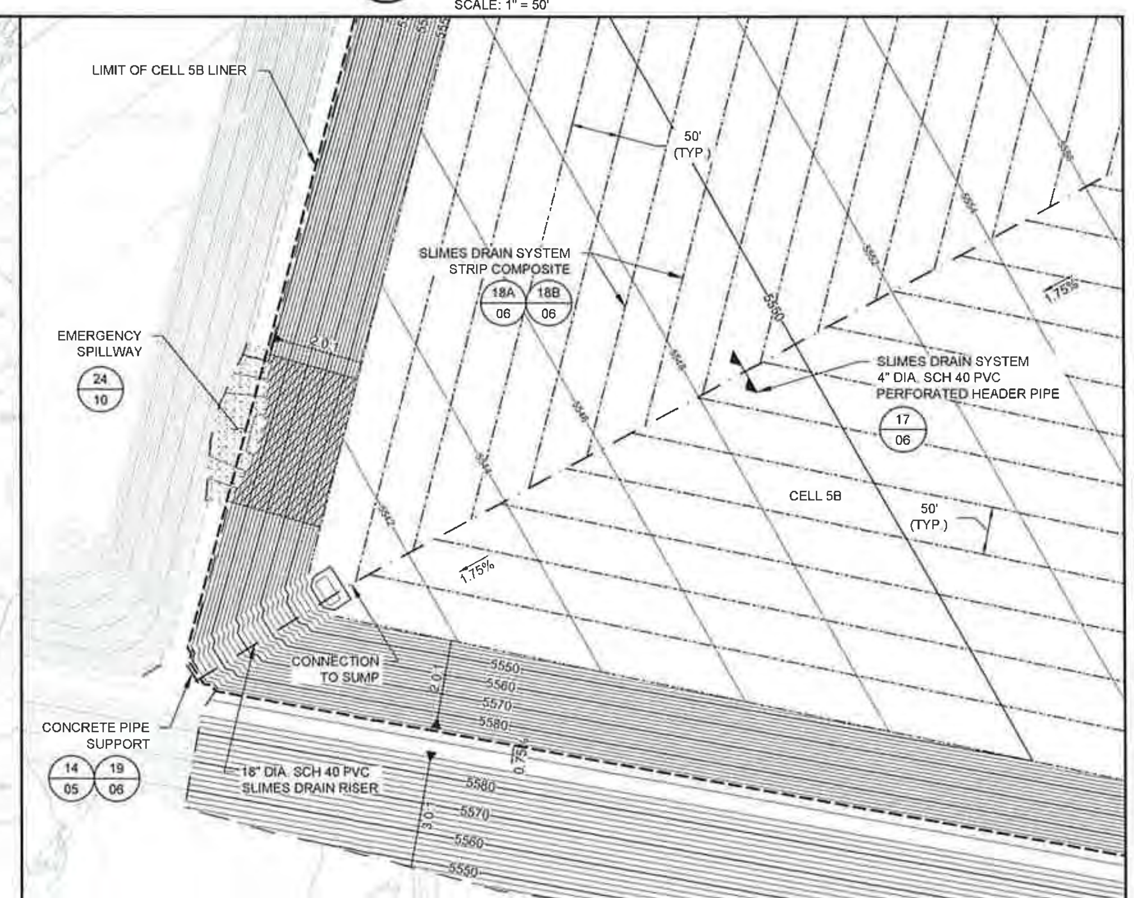
3. STOCKPILE TO BE CONSTRUCTED AT SLOPES NO STEEPER THAN 2H:1V AND A MINIMUM OF 20 FT FROM THE CREST OF THE SLOPE. STOCKPILE WITHIN 100 FT OF CREST OF SLOPE SHALL NOT EXCEED 20 FT IN HEIGHT.



7
04B
PLAN
CELL 5B SLIMES DRAIN SYSTEM
SCALE: 1" = 200'

SCALE IS BASED ON 22" X 34" NON-REDUCED SHEET SIZE (BORDER = 21" X 32")



8
04B
DETAIL
CELL 5B SLIMES DRAIN SYSTEM
SCALE: 1" = 100'

PERMIT LEVEL DESIGN
NOT FOR CONSTRUCTION

FIGURE 1B

REV	DATE	DESCRIPTION	DRN	APP

Geosyntec consultants
10875 RANCHO BERNARDO RD, SUITE 200
SAN DIEGO, CA 92127
PHONE: 858 674 6559

Energy Fuels Resources (USA) Inc

TITLE: PIPE LAYOUT PLAN AND DETAILS - CELL 5B

PROJECT: CONSTRUCTION OF CELLS 5A AND 5B

SITE: WHITE MESA MILL, BLANDING, UTAH

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION UNLESS SEALED

SIGNATURE

DATE

DESIGN BY	GTC	DATE	JANUARY 2013
DRAWN BY	MMC	PROJECT NO.	SC0634
CHECKED BY	RBF	FILE	SC0634 - 03A-04B
REVIEWED BY	GTC	DRAWING NO.	04B OF 12
APPROVED BY	GTC		

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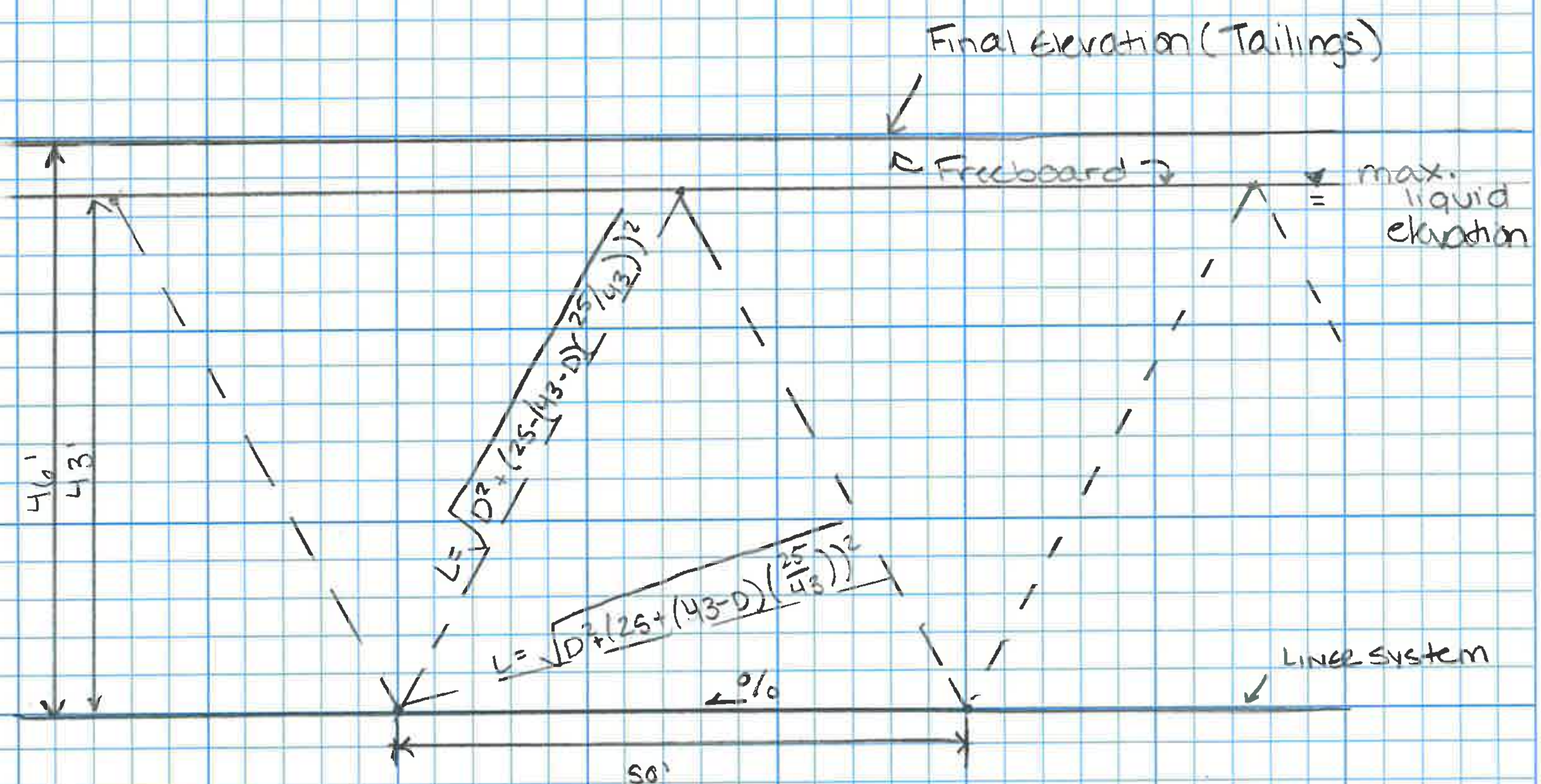
Geosyntec consultants

Page ___ of ___

Written by: ______ Date: __/__/__ (DD MM YY) Reviewed by: ______ Date: __/__/__ (DD MM YY)

Client: ______ Project: ______ Project/Proposal No. ______ Task No. ______

Maximum Depth Flow Geometry



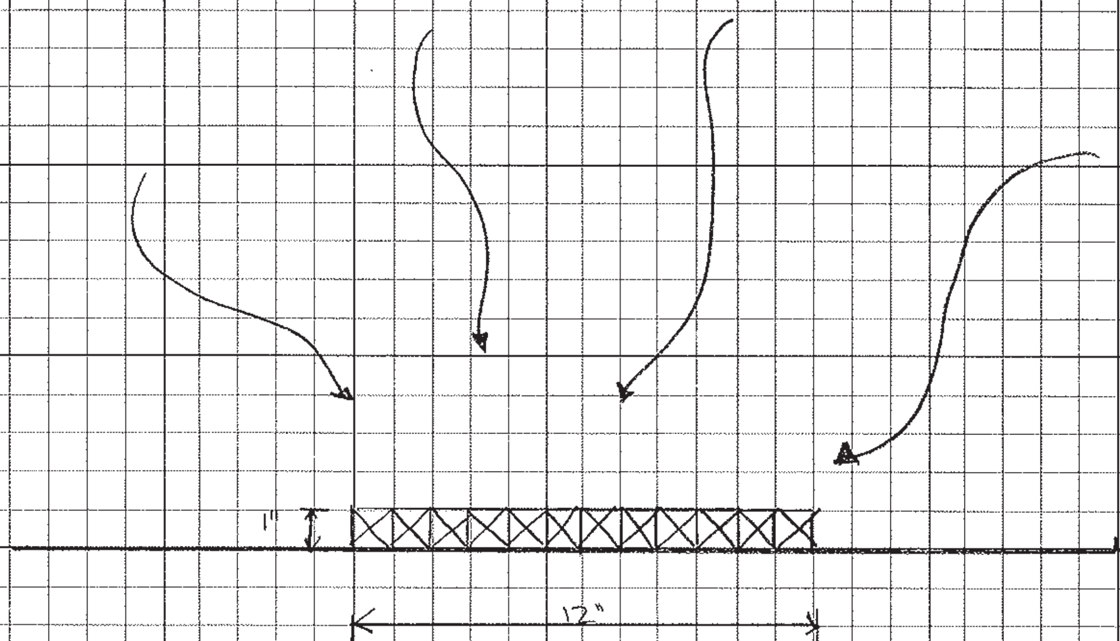
Examples:

$D = 43' \rightarrow L = \sqrt{43^2 + (25 - (43-43)(25/43))^2} = 49.7'$

$D = 10' \rightarrow L = \sqrt{10^2 + (25 - (43-10)(25/43))^2} = 45.3'$

FIGURE 2

Geosyntec consultants



FLOW AREA - STRIP COMPOSITE

$$A = \frac{14"}{12"/1} = 1.17 \text{ ft}^2/\text{ft}$$

FIGURE 3

EXHIBIT 1

SAMPLE DESCRIPTION AND PREPARATION

CSMRI Sample 1

Sponsor's Designation of Sample: Run-of-mine.

Date Received at Institute: June 5, 1978.

Sample Weight: 100,520 lb.

Sample Container: Two truckloads.

Sample Description: Mine ore -- estimate 5% +10-in. material. Largest boulder -- 48 in. x 24 in. x 14 in. Only two or three rocks were greater than 36 in.

Method of Preparation: All +10-in. material broken to -10 in. by sledgehammer and jackhammer. The sample was screened at 6 in. and 1-1/2 in. with the +6 in. fraction, put in barrels, and the -1/2 in. fraction piled. The -6 in. +1-1/2 in. material was screened at 4 in. and 1-1/2 in. with the -6 in. +4 in. and -4 in. +1-1/2 in. fractions barreled. The additional -1-1/2 in. fraction was piled with the previous -1-1/2 in. fraction. A screen size analysis of the entire quantity of mill feed material is presented in Exhibit 3. A summary screen size analysis of the ore is as follows:

Screen Product in.		Weight %
Head (calculated)		100.00
-10	+6	2.92
-6	+4	9.48
-4	+1-1/2	15.30
-1-1/2		72.30

EXHIBIT 1

CSMRI Sample 2

Sponsor's Designation of Sample:	Crushed ore.
Date Received at Institute:	June 5, 1978.
Sample Weight:	47,380 lb.
Sample Container:	One truckload.
Sample Description:	Ore previously crushed to -3 in., maximum particles approximately 2-1/2 in.
Method of Preparation:	The ore was used as received.

EXHIBIT 2

GRINDING TESTS

Grinding Test 1, Autogenous

Date:	June 13, 1978
Feed Rate, stph:	2
Ore:	Run-of-mine
DSM Screen, in. width:	12
DSM Screen Opening, mm:	1.27
Measured Mill Power Tare (empty mill), kw:	2.06
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Meter Reading watt-hr	Mill-Bearing Oil Temp. °F	Ore Feed Rate (as received)(1) -1-1/2 in. lb/hr	-4 in. +1-1/2 in. lb/hr	-6 in. +4 in. lb/hr	-10 in. +6 in. lb/hr	Mill Discharge Solids %	Mill Discharge Solids lb/hr	Sweco Screen Oversize Solids %	Sweco Screen Oversize Solids lb/hr	DSM Screen Overflow Solids %	DSM Screen Overflow Solids lb/hr	DSM Screen Underflow Solids %	DSM Screen Underflow Solids lb/hr	Mill Water Meter %	Mill Water Rate lb/hr	Mill Load Volume %	Remarks
0910	0	--	--	104	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Start mill.
0915	5	12.2	12,964	--	3,150	612	380	116	63	8,335	--	--	--	--	--	--(2)	90	2,858	--	--
1005	55	8.7	--	--	2,880	612	380	116	62	--	90	506	60	3,348	57	2,616(2)	90	2,858	--	--
1030	80	6.8	--	105	2,835	612	380	116	69	--	90	304	70	3,591	58	710(2)	90	2,858	--	--
1100	110	6.5	12,977	106	2,993	612	380	116	66	--	--	--	69	4,223	58	679(2)	80	2,540	--	Mill down, elevator plugged.
1135	145	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Start mill.
1142	145	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1150	153	6.2	--	109	2,993	612	380	116	69	12,420	90	1,114	70	5,544	56	2,583	--	--	--	--
1230	193	6.0	12,988	111	2,903	612	380	116	64	10,829	90	405	69	6,955	60	4,388	75	2,382	--	--
1300	223	6.2	--	112	3,319	612	380	116	65	11,232	90	365	70	6,048	60	3,861	81	2,572	--	--
1345	238	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Pump plugged. DSM feed.
1400	253	6.4	--	112	3,128	612	380	116	65	11,700	90	122	69	3,229	60	3,996	80	2,540	--	Sample
1415	268	6.3	13,004	112	2,970	612	380	116	65	9,945	90	547	71	3,515	59	2,907	79	2,509	15	Sample.
Average					3,019	612	380	116	65	10,744	90	480	69	4,557	59	3,547	83	2,640		

(1) Moisture: -1-1/2 in., 2.8%; -4 in. +1-1/2 in., 1.0%; -6 in. +4 in., 0.8%; -10 in. +6 in., 0.7%. Average dry ore feed rate: -1-1/2 in., 2,934.5 lb/hr; -4 in. +1-1/2 in., 605.9 lb/hr; -6 in. +4 in., 376.8 lb/hr; -10 in. +6 in., 115.0 lb/hr; total, 4,032.2 lb/hr, 2.016 dry stph. Mill volume end of test: 15%.

(2) Excluded from average.

Feed Rate, stph dry:	2.016
Ball Charge:	None
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Instantaneous Gross Power (meter reading) kwhr	Instantaneous Corrected Power (from input-output curve) kwhr	Power Consumption Gross kwhr/st	Power Consumption Net kwhr/st	Circulating Load Weight % of Feed(1)	Mill Discharge Solids %	Remarks
0910	0	--	--	--	--	--	--	--	--
0915	5	12.2	4.25	2.64	1.31	1.01	--	63	--
1005	55	8.7	5.96	4.25	2.11	1.81	--	62	--
1030	80	6.8	7.62	5.80	2.88	2.58	--	69	--
1100	110	6.5	7.97	6.10	3.03	2.73	--	66	--
1135	145	--	--	--	--	--	--	--	Unplug bucket elevator.
1150	153	6.2	8.36	6.47	3.21	2.91(2)	162.0	69	--
1230	193	6.0	8.64	6.73	3.34	3.04(2)	183.0	64	--
1300	223	6.2	8.36	6.47	3.21	2.91(2)	145.0	65	--
1345	238	--	--	--	--	--	--	--	Unplug DSM feed pump.
1400(3)	253	6.4	8.10	6.23	2.09	2.79(2)	79.0	65	--
1415(3)	268	6.3	8.23	6.35	3.15	2.85(2)	100.0	65	--
Average						2.90	133.8		

(1) Calculated: Sum of Sweco oversize and DSM oversize as percentage of dry mill feed.
(2) Average for power (last five readings): 2.90 kwhr/st.
(3) Sample run.

EXHIBIT 2

Grinding Test 1 -- continued

Procedure: Sample was wet screened on a 325M screen, products dried, and the +325M material dry screened using a Ro-Tap for 30 min.

Test Product	Screen Size Analysis DSM Screen Undersize
Sample Time:	1415
Sample Weight, g:	4,630.5
Screen Product (Tyler) Mesh	Weight %
Head (calculated)	100.0
+28	1.2
-28 +35	3.4
-35 +65	16.2
-65 +100	14.0
-100 +200	18.6
-200 +325	7.1
-325	39.5

US Sieve

GTC 5/10/07

No. 30
No. 40
No. 70
No. 100
No. 200
No. 325

EXHIBIT 2

Grinding Test 2

Date:	June 14, 1978
Feed Rate, stph:	2.0
Ore:	Run-of-mine
Ball Charge:	Total: 301.8 lb; 2% mill volume
-1-1/2 in. +1 in. Balls, lb:	114.5
-2 in. +1-1/2 in. Balls, lb:	151.3
3 in. Balls, lb:	36.0
DSM Screen, in. width:	12
DSM Screen Openings, mm:	1.27
Measured Mill Power Tare (empty mill), kw:	2.06
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Meter Reading watt-hr	Mill-Bearing Oil Temp. °F	Ore Feed Rate (as received)(1) -1-1/2 in. lb/hr	-4 in. +1-1/2 in. lb/hr	-6 in. +4 in. lb/hr	-10 in. +6 in. lb/hr	Mill Discharge Solids %	Mill Discharge Solids lb/hr	Sweco Screen Oversize Solids %	Sweco Screen Oversize Solids lb/hr	DSM Screen Overflow Solids %	DSM Screen Overflow Solids lb/hr	DSM Screen Underflow Solids %	DSM Screen Underflow Solids lb/hr	Mill Water Meter %	Mill Water Rate lb/hr	Mill Load Volume %	Remarks
1040	0	8.7	13,004	102	--	612	380	116	--	--	--	--	--	--	--	--	95	3,017	-	Start mill.
1110	30	5.2	--	104	--	612	380	116	--	--	--	--	--	--	--	--	83	2,636	-	--
1130	50	5.3	--	106	3,060	612	380	116	62	8,147	50	248	74	1,565	54	2,989(2)	84	2,668	-	--
1200	80	5.0	--	108	2,846	612	380	116	63	6,577	67	653	71	1,150	--	--	82	2,604	-	--
1230	110	4.8	13,023	111	3,105	612	380	116	64	8,467	64	605	73	1,281	--	--	82	2,604	-	--
1300	140	4.8	--	112	3,139	612	380	116	63	6,917	62	391	73	2,102	57	3,694	81	2,572	-	--
1330	170	4.8	--	113	3,263	612	380	116	66	8,494	63	595	69	3,571	56	3,881	81	2,572	-	--
1400	200	4.9	--	113	2,981	612	380	116	66	9,029	64	624	71	2,939	58	3,680	81	2,572	-	--
1415	215	5.0	--	113	2,869	612	380	116	66	10,098	64	547	70	3,119	58	3,811	79	2,509	-	Sample.
1430	230	5.0	13,044	113	2,993	612	380	116	65	8,483	64	557	71	3,259	57	3,565	79	2,509	9	Sample. End of test.
Average					3,032	612	380	116	65	8,277	62	528	72	2,373	57	3,726	83	2,626		

(1) Moisture: -1-1/2 in., 2.8%; -4 in. +1-1/2 in., 1.0%; -6 in. +4 in., 0.8%; -10 in. +6 in., 0.7%. Average dry ore feed rate: -1-1/2 in., 2,947.0 lb/hr; -4 in. +1-1/2 in., 605.9 lb/hr; -6 in. +4 in., 376.8 lb/hr; -10 in. +6 in., 115.0 lb/hr; total: 4,044.7 lb/hr, 2.022 dry stph. Mill volume end of test: 9%.

(2) Excluded from average.

Feed Rate, stph dry:	2.022
Ball Charge:	301.8 lb, 2% mill volume
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Instantaneous Gross Power (meter reading) kwhr	Instantaneous Corrected Power (from input-output curve) kwhr	Power Consumption Gross kwh/st	Power Consumption Net kwh/st	Circulating Load Weight % of Feed(1)	Mill Discharge Solids %
1040	0	8.7	5.96	4.22	2.09	1.79	--	--
1110	30	5.2	9.97	7.93	3.92	3.63	--	--
1130	50	5.3	9.78	7.78	3.85	3.55	--	62
1200	80	5.0	10.36	8.25	4.08	3.78	--	63
1230	110	4.8	10.80	8.63	4.27	3.97	--	64
1300	140	4.8	10.80	8.63	4.27	3.97	59.0(4)	63
1330	170	4.8	10.80	8.63	4.27	3.97	95.0	66
1400	200	4.9	10.58	8.44	4.17	3.88	87.0	66
1415(3)	215	5.0	10.36	8.25	4.08	3.78(2)	92.0	66
1430(3)	230	5.0	10.36	8.25	4.08	3.78(2)	93.0	65
Average						3.78	91.8	

(1) Calculated: Sum of Sweco oversize and DSM oversize as a percentage of dry mill feed.

(2) Average for power (last two readings): 3.78 kwhr/st.

(3) Sample run.

(4) Omitted from average.

EXHIBIT 2

Grinding Test 2 -- continued

Procedure: Samples were wet screened on a 325M screen, products dried, and the +325M material dry screened using a Ro-Tap for 30 min.

	Screen Size Analysis								
Test Product	Mill Discharge		Sweco Screen Oversize		DSM Screen Oversize		DSM Screen Undersize		Circulating Load
Sample Time	1415	1430	1415	1430	1415	1430	1415	1430	
Sample Weight, g:	1,058.8	1,206.6	669.3	979.0	915.6	1,106.8	888.1	932.3	
Screen Product (Tyler) Mesh	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %
Head (calculated)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
+28	23.8	21.6	65.5	71.8	40.4	37.6	2.0	1.7	43.4
-28 +35	6.8	6.4	2.5	1.6	8.4	9.9	5.3	4.3	8.1
-35 +65	13.5	13.3	4.2	3.6	8.8	12.0	17.2	16.6	9.4
-65 +100	9.4	10.2	3.2	3.0	4.7	7.6	13.6	12.9	5.7
-100 +200	11.9	13.4	5.0	5.0	7.3	10.3	17.6	17.0	8.3
-200 +325	4.2	5.9	3.0	2.1	1.6	4.7	7.0	6.3	3.1
-325	30.4	29.2	16.6	12.9	28.8	17.9	37.3	41.2	22.0

EXHIBIT 2

Grinding Test 3

Date:	June 15, 1978
Feed Rate, stph:	3.0
Ore:	Run-of-mine
Ball Charge:	Total: 301.8 lb, 2% mill volume
-1-1/2 in. +1 in. Balls, lb:	114.5
-2 in. +1-1/2 in. Balls, lb:	151.3
3 in. Balls, lb:	36.0
DSM Screen, in. width:	12
DSM Screen Openings, mm:	1.27
Measured Mill Power Tare (empty mill), kw:	2.06
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Meter Reading watt-hr	Mill-Bearing Oil Temp. °F	Ore Feed Rate (as received)(1) -1-1/2 in. lb/hr	Ore Feed Rate -4 in. +1-1/2 in. lb/hr	Ore Feed Rate -6 in. +4 in. lb/hr	Ore Feed Rate -10 in. +6 in. lb/hr	Mill Discharge Solids %	Mill Discharge Solids lb/hr	Sweco Screen Oversize Solids %	Sweco Screen Oversize Solids lb/hr	DSM Screen Overflow Solids %	DSM Screen Overflow Solids lb/hr	DSM Screen Underflow Solids %	DSM Screen Underflow Solids lb/hr	Mill Water Meter %(2)	Mill Water Rate lb/hr	Mill Load Volume %	Remarks
1050	0	5.0	13,045	93	--	918	570	174	--	--	--	--	--	--	--	--	--	--	--	Start mill.
1135	45	4.5	--	--	--	918	570	174	--	--	--	--	--	--	--	--	--	--	--	--
1200	70	4.4	--	99	4,350	918	570	174	65	13,631	68	857	70	6,237	58	5,090	105	3,350	--	Shutdown, rock jammed in feeder.
1207	77	--	--	--	--	918	570	174	--	--	--	--	--	--	--	--	--	--	--	Start mill.
1230	77	--	--	--	--	918	570	174	--	--	--	--	--	--	--	--	--	--	--	--
1300	107	4.9	--	109	3,435	918	570	174	65	10,530	63	808	73	3,679	55	4,430	106	3,366	--	--
1330	137	4.8	--	108	4,815	918	570	174	66	11,642	64	878	72	5,508	61	5,408	104	3,303	--	--
1400	167	4.9	--	110	4,275	918	570	174	67	11,095	58	639	73	5,059	61	5,545	104	3,303	--	Sample.
1430	197	4.7	--	111	4,590	918	570	174	67	11,156	65	761	72	5,573	61	4,804	103	3,271	--	Sample.
1445	212	4.8	13,085	112	5,040	918	570	174	67	15,135	67	1,010	71	6,646	62	5,692	104	3,303	25	Shut down.
1500	242	--	--	--	--	918	570	174	--	--	--	--	--	--	--	--	--	--		
Average					4,417	918	570	174	66	12,198	64	826	72	5,450	60	5,162	104	3,316		

(1) Moisture: -1-1/2 in., 2.8%; -4 in. +1-1/2 in., 1.0%; -6 in. +4 in., 0.8%, -10 in. +6 in., 0.7%. Average dry ore feed rate: -1-1/2 in., 4,293.8 lb/hr, -4 in. +1-1/2 in., 908.8 lb/hr; -6 in. +4 in., 565.4 lb/hr; -10 in. +6 in., 172.8 lb/hr; total, 5,940.8 lb/hr, 2.970 dry stph. Mill volume end of test: 25%.
(2) Auxilliary water line used -- measured twice, averaged, and added as percentage of regular water meter.

Feed Rate, stph dry:	2.970 stph dry
Ball Charge:	301.8 lb, 2% of mill volume
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Instantaneous Gross Power (meter reading) kwhr	Instantaneous Corrected Power (from input-output curve) kwhr	Power Consumption Gross kwhr/st	Power Consumption Net kwhr/st	Circulating Load Weight % of Feed(1)	Mill Discharge Solids %	Remarks
1050	0	5.0	10.36	8.26	2.78	2.58	--	--	--
1135	45	4.5	11.52	9.24	3.11	2.91	--	--	--
1200	70	4.4	11.78	9.45	3.18	2.98	118.0(4)	65	--
1207	77	--	--	--	--	--	--	--	Rock jammed in feeder.
1230	77	--	--	--	--	--	--	--	--
1300	107	4.9	10.58	8.43	2.84	2.64(2)	88.0	65	--
1330	137	4.8	10.80	8.62	2.90	2.70(2)	99.0	66	--
1400	167	4.9	10.58	8.43	2.84	2.64(2)	96.0	67	--
1430(3)	197	4.7	11.03	8.82	2.97	2.77(2)	101.0	67	--
1445(3)	212	4.8	10.80	8.62	2.90	2.70(2)	114.0	67	--
1500	242								
Average						2.70	99.6		

(1) Calculated: Sum of Sweco oversize and DSM oversize as a percentage of dry mill feed.
(2) Average for power (last four readings): 2.70 kwhr/st.
(3) Sample run.
(4) Omitted from average.

EXHIBIT 2

Grinding Test 3

Procedure: Samples were wet screened on a 325M screen, products dried, and the +325M material dry screened using a Ro-Tap for 30 min.

	Screen Size Analysis								
Test Product	Mill Discharge		Sweco Screen Oversize		DSM Screen Oversize		DSM Screen Undersize		Circulating Load
Sample Time	1430	1445	1430	1445	1430	1445	1430	1445	--
Sample Weight, g:	1,174.9	1,310.3	1,365.7	1,223.1	1,183.4	1,245.5	850.1	962.4	--
Screen Product (Tyler) Mesh	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %
Head (calculated)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
+28	27.8	25.1	65.0	67.5	47.4	33.3	2.4	1.9	43.7
-28 +35	6.5	7.1	1.8	2.0	9.1	7.9	5.7	5.0	7.6
-35 +65	12.8	14.6	3.7	4.0	12.4	13.2	18.1	21.0	11.7
-65 +100	9.2	9.0	3.1	3.4	6.5	8.5	14.8	16.0	7.0
-100 +200	11.4	13.5	5.4	5.5	8.9	9.9	15.6	13.5	8.9
-200 +325	4.8	3.4	3.4	3.3	1.6	3.3	5.9	4.5	2.5
-325	27.5	27.3	17.6	14.3	14.1	23.9	37.5	38.1	18.6

EXHIBIT 2

Grinding Test 4

Date:	June 16, 1978
Feed Rate, stph:	2.5
Ore:	Crushed
Ball Charge:	Total: 301.8 lb, 2% mill volume
-1-1/2 in. +1 in. Balls, lb:	114.5
-2 in. +1-1/2 in. Balls, lb:	151.3
3 in. Balls, lb:	36.0
DSM Screen, in. width:	12
DSM Screen Openings, mm:	1.27
Measured Mill Power Tare (empty mill), kw:	2.06
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Meter Reading watt-hr	Mill-Bearing Oil Temp. °F	Ore Feed Rate (as received)(1) -3 in. lb/hr	Mill Discharge Solids %	Mill Discharge Solids lb/hr	Sweco Screen Oversize Solids %	Sweco Screen Oversize Solids lb/hr	DSM Screen Overflow Solids %	DSM Screen Overflow Solids lb/hr	DSM Screen Underflow Solids %	DSM Screen Underflow Solids lb/hr	Mill Water Meter %(1)	Mill Water Rate lb/hr	Mill Load Volume %	Remarks
1010	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9	Start mill.
1030	20	6.6	13,094	96	--	--	--	--	--	--	--	--	--	90	2,858	--	--
1100	50	6.3	--	97	5,130	63	7,598	67	362	74	1,931	61	5,243	87	2,763	--	--
1130	80	5.9	--	99	5,350	62	8,091	64	418	72	2,398	60	4,482	82	2,604	--	--
1200	110	5.9	--	99	4,995	65	12,519	66	535	70	3,717	61	3,953	80	2,540	--	--
1215	125	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Feed off (feed belt jammed).
1218	125	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Start mill.
1230	137	6.0	--	100	4,770	62	5,692	62	288	71	2,077	58	3,628	80	2,540	--	--
1300	167	6.0	--	100	5,423	65	6,786	62	326	71	1,885	60	4,428	80	2,540	--	--
1320	187	--	--	--	--	--	--	--	--	--	--	60	4,316(3)	--	--	--	--
1330	197	5.8	--	102	4,826	65	6,728	65	449	69	2,298	59	4,806	79	2,509	--	--
1400	227	5.7	--	104	4,635	64	6,797	62	260	72	1,134	60	4,617	79	2,509	--	Sample.
1415	242	5.7	13,128	104	6,793	63	6,010	64	230	70	819	59	4,328	79	2,509	15	Sample.
1500	257	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
Average					5,240	64	7,528	64	359	71	2,032	60	4,422	82	2,597	--	

(1) Moisture: -3 in., 4.3%. Average dry ore feed rate: -3 in., 5,015 lb/hr. 2.508 dry stph. Mill volume end of test: 15%.
(2) Auxiliary water line used -- measured twice, averaged, and added as percentage of regular water meter.
(3) 55-gal drum timed sample.

Feed Rate, stph:	2.508
Ball Charge:	301.8 lb, 2% of mill volume
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Instantaneous Gross Power (meter reading) kwhr	Instantaneous Corrected Power (from input-output curve) kwhr	Power Consumption Gross kwhr/st	Power Consumption Net kwhr/st	Circulating Load Weight % of Feed(1)	Mill Discharge Solids %	Remarks
1010	0	--	--	--	--	--	--	--	--
1030	20	6.6	7.85	6.00	2.39	2.15	--	--	--
1100	50	6.3	8.23	6.35	2.53	2.29	--	63	--
1130	80	5.9	8.78	6.87	2.74	2.50	50.0(4)	62	--
1200	110	5.9	8.78	6.87	2.74	2.50	81.0(4)	65	--
1215	125	--	--	--	--	--	--	--	Feed belt jammed.
1230	137	6.0	8.64	6.73	2.68	2.44	48.0	62	--
1300	167	6.0	8.64	6.73	2.68	2.44	39.0	65	--
1320	187	--	--	--	--	--	--	--	--
1330	197	5.8	8.93	7.00	2.79	2.55(2)	54.0	65	--
1400(3)	227	5.7	9.09	7.13	2.84	2.60(2)	29.0	64	--
1415(3)	242	5.7	9.09	7.13	2.84	2.60(2)	14.0	63	--
Average						2.58	36.8		

(1) Calculated; Sum of Sweco oversize and DSM oversize as a percentage of dry mill feed.
(2) Average for power (last three readings): 2.58 kwhr/st.
(3) Sample run.
(4) Omitted from average.

EXHIBIT 2

Grinding Test 4 -- continued

Procedure: Samples were wet screened on a 325M screen, products dried, and the +325M material dry screened using a Ro-Tap for 30 min.

	Screen Size Analysis								
Test Product	Mill Discharge		Sweco Screen Oversize		DSM Screen Oversize		DSM Screen Undersize		Circulating Load
Sample Time	1140	1415	1400	1415	1400	1415	1400	1415	--
Sample Weight, g:	1,139.4	886.7	715.4	726.2	1,152.9	1,020.0	763.8	769.4	--
Screen Product (Tyler) Mesh	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %
Head (calculated)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
+28	15.3	13.1	86.5	91.8	39.1	43.1	2.7	2.7	55.5
-28 +35	5.8	5.2	0.3	0.3	8.9	7.6	4.9	4.6	5.9
-35 +65	17.8	17.9	0.9	0.5	14.9	12.7	18.6	18.6	9.9
-65 +100	11.1	11.8	0.7	0.3	6.8	6.3	12.5	13.3	4.7
-100 +200	15.8	16.7	1.6	0.7	8.8	8.9	18.6	19.1	6.6
-200 +325	7.7	6.4	0.9	0.4	3.3	4.1	8.1	6.3	2.8
-325	26.5	28.9	9.1	6.0	18.2	17.3	34.6	35.4	14.6

EXHIBIT 2

Grinding Test 5

Date:	June 19, 1978
Feed Rate, stph:	2.0
Ore:	Crushed
Ball Charge:	Total 301.8 lb, 2% mill volume
-1-1/2 in. Balls, lb:	114.5
-2 in. +1-1/2 in. Balls, lb:	151.3
3 in. Balls, lb:	36.0
DSM Screen, in. width:	12
DSM Screen Openings, mm:	1.27
Measured Mill Power Tare (empty mill), kw:	2.06
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Meter Reading watt-hr	Mill-Bearing Oil Temp. °F	Ore Feed Rate (as received)(1) -3 in. lb/hr	Mill Discharge Solids %	Mill Discharge Solids lb/hr	Sweco Screen Oversize Solids %	Sweco Screen Oversize Solids lb/hr	DSM Screen Overflow Solids %	DSM Screen Overflow Solids lb/hr	DSM Screen Underflow Solids %	DSM Screen Underflow Solids lb/hr	Mill Water Meter %	Mill Water Rate lb/hr	Mill Load Volume %	Remarks
0840	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7	Start mill.
0910	30	6.7	13,136	90	3,623	--	--	--	--	--	--	--	--	75	2,382	--	--
0930	50	6.3	--	91	3,960	67	8,744	48	356	67	3,558	60	2,970	71	2,255	--	--
1000	80	6.2	--	92	3,803	66	6,663	45	324	70	2,079	60	4,077	68	2,159	--	--
1030	110	6.5	--	91	--	56	3,578	15	68	70	347	59	3,452	66	2,096	--	Shut down -- out of feed.
1035	115	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1040	115	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Start mill.
1100	135	6.5	--	94	4,230	66	4,990	38	182	75	346	62	4,241	68	2,159	--	--
1130	165	6.6	--	96	4,298	66	5,049	42	239	72	729	62	4,101	69	2,191	--	--
1155	190	--	--	--	--	--	--	--	--	--	--	--	--	--	--	13	--
1200	195	6.7	--	97	4,320	63	3,856	37	200	75	405	61	3,870	69	2,191	--	--
1230	225	6.7	--	100	3,533	62	3,894	27	101	73	394	58	3,445	64	2,032	--	--
1300	255	6.6	--	103	4,016	66	4,693	29	111	70	851	61	3,870	68	2,159	--	--
1330	285	6.3	--	104	4,005	68	9,058	34	173	68	3,672	64	3,744	61	1,937	--	--
1345	300	6.5	--	104	3,645	63	4,139	32	134	71	250	59	3,452	68	2,159	--	Sample.
1400	315	6.1	--	104	4,005	64	4,781	34	143	72	238	57	3,104	69	2,191	--	Sample.
1430	345	6.1	--	105	4,140	63	4,820	33	193	69	598	59	3,505	69	2,191	--	--
1445	360	6.0	--	106	3,713	62	4,018	38	182	71	423	56	2,696	69	2,191	--	Sample.
1500	375	5.7	13,184	107	4,028	63	4,139	36	151	70	1,323	56	2,696	69	2,191	--	Sample.
1510	380	--	--	--	--	--	--	--	--	--	--	--	--	--	--	15	Shut down.
1513	388	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Collecting mill discharge sample.
1522	397	--	--	--	3,690	--	--	--	--	--	--	--	--	--	--	--	Second barrel.
1529	404	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Third barrel.
1536	411	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Hopper went empty.
1537	412	--	--	--	--	--	--	--	--	--	--	--	--	--	--	15	Shut down mill.
Average	--	--	--	--	3,934	64	5,173	35	183	71	1,087	59	3,516	68	2,165	--	--

(1) Moisture: -3 in., 2.0%. Average dry ore feed rate: -3 in., 3,855 lb/hr, 1.928 dry stph. Mill volume end of test: 15%.

EXHIBIT 2

Grinding Test 5 -- continued

Feed Rate, stph (dry): 1.928
Ball Charge: 301.8 lb, 2% of mill charge
Corrected Mill Power Tare (empty mill), kw: 0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Instantaneous Gross Power (meter reading) kwhr	Instantaneous Corrected Power (from input-output curve) kwhr	Power Consumption Gross kwhr/st	Power Consumption Net kwhr/st	Circulating Load Weight % of Feed(1)	Mill Discharge Solids %	Remarks
0840	0	--	--	--	--	--	--	--	--
0910	30	6.7	7.73	5.89	3.05	2.74	--	--	--
0930	50	6.3	8.23	6.35	3.29	2.98	--	67	--
1000	80	6.2	8.36	6.47	3.36	3.04	--	66	--
1030	110	6.5	7.97	6.10	3.16	2.85	--	56	--
1035	115	--	--	--	--	--	--	--	Ran out of ore.
1100	135	6.5	7.97	6.10	3.16	2.85	12.0(4)	66	--
1130	165	6.6	7.85	6.00	3.11	2.80	23.0(4)	66	--
1155	190	--	--	--	--	--	--	--	Check mill volume.
1200	195	6.7	7.73	5.89	3.05	2.74	14.0	63	--
1230	225	6.7	7.73	5.89	3.05	2.74	14.0	62	--
1300	255	6.6	7.85	6.00	3.11	2.80	24.0	66	--
1330	285	6.3	8.23	6.35	3.29	2.98	96.0(4)	68	--
1345(3)	300	6.5	7.97	6.10	3.16	2.85	11.0	63	--
1400(3)	315	6.1	8.50	6.60	3.42	3.11(2)	10.0	64	--
1430	345	6.1	8.50	6.60	3.42	3.11(2)	19.0	63	--
1445(3)	360	6.0	8.64	6.73	3.49	3.18(2)	16.0	62	--
1500(3)	375	5.7	9.09	7.13	3.70	3.37	37.0	63	--
1510	385	--	--	--	--	--	--	--	Check mill load level.
1513	388	--	--	--	--	--	--	--	Start filling No. 1 mill discharge sample barrel.
1522	397	--	--	--	--	--	--	--	Start filling No. 2 mill discharge sample barrel.
1529	404	--	--	--	--	--	--	--	Start filling No. 3 mill discharge sample barrel.
1536	411	--	--	--	--	--	--	--	End filling No. 3 mill discharge sample barrel.
1537	412	--	--	--	--	--	--	--	End of test.
Average						3.13	18.0		

(1) Calculated: Sum of Sweco oversize and DSM oversize as a percentage of dry mill feed.
(2) Average for power (three readings, omitted reading at 1,500 from average): 3.13 kwhr/st.
(3) Sample run.
(4) Omitted from average.

Procedure: Samples were wet screened on a 325M screen, products dried, and the +325M material dry screened using a Ro-Tap for 30 min.

Screen Size Analysis

Test Product	Mill Discharge				Sweco Screen Oversize				DSM Screen Oversize				DSM Screen Underflow				Circulating Load
Sample Time	1345	1400	1445	1500	1345	1400	1445	1500	1345	1400	1445	1500	1345	1400	1445	1500	--
Sample Weight, g:	1,058.6	1,062.1	911.3	859.1	442.5	300.3	282.2	381.8	1,065.9	713.5	478.8	920.6	817.4	757.0	743.7	787.8	--
Screen Product (Tyler) Mesh	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %
Head (calculated)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
+28	12.0	11.5	10.2	10.8	78.4	82.9	81.4	87.5	67.0	54.5	51.9	32.0	1.8	2.0	1.9	1.6	58.1
-28 +35	3.7	3.7	2.7	2.9	1.5	0.8	1.0	0.4	5.0	4.6	4.5	3.9	3.1	3.1	2.8	2.3	3.7
-35 +65	15.3	16.3	12.9	13.4	4.1	1.9	3.0	1.1	6.2	7.4	6.9	10.9	16.8	16.3	15.8	14.2	6.7
-65 +100	12.3	13.4	12.8	12.7	2.4	1.2	1.9	0.8	3.4	5.2	5.2	9.1	14.7	14.6	14.2	14.5	4.8
-100 +200	19.1	18.5	21.3	20.6	4.1	2.7	3.7	1.6	5.3	8.2	9.3	14.2	20.5	20.5	21.7	21.8	8.0
-200 +325	8.0	6.6	9.0	8.6	1.1	1.0	1.1	1.2	1.6	2.8	4.0	5.3	8.1	8.4	7.4	7.4	2.9
-325	29.6	30.0	31.1	31.0	8.4	9.5	7.9	7.4	11.5	17.3	18.2	24.6	35.0	35.1	36.2	38.2	15.8

EXHIBIT 2

Grinding Test 6

Date:	June 20, 1978
Feed Rate, stph:	2.5
Ore:	Run-of-mine
Ball Charge:	Total: 301.8 lb, 2% mill volume
-1-1/2 in. +1 in. Balls, lb:	114.5
-2 in. +1-1/2 in. Balls, lb:	151.3
3 in. Balls, lb:	36.0
DSM Screen, in. width:	12
DSM Screen Openings, mm:	1.27
Measured Mill Power Tare (empty mill), kw:	2.06
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Meter Reading watt-hr	Mill-Bearing Oil Temp. °F	Ore Feed Rate (as received)(1) -1-1/2 in. lb/hr	-4 in. +1-1/2 in. lb/hr	-6 in. +4 in. lb/hr	-10 in. -6 in. lb/hr	Mill Discharge Solids %	Mill Discharge Solids lb/hr	Sweco Screen Oversize Solids %	Sweco Screen Oversize Solids lb/hr	DSM Screen Overflow Solids %	DSM Screen Overflow Solids lb/hr	DSM Screen Underflow Solids %	DSM Screen Underflow Solids lb/hr	Mill Water Meter %	Mill Water Rate lb/hr	Mill Load Volume %	Remarks
0820	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--(Grind out)--			Start mill.
0925	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	Start feed.
0930	5	6.8	13,195	82	--	768	474	219	--	--	--	--	--	--	--	--	80	2,540	--	--
1000	35	5.9	--	80	--	768	474	219	66	11,286	60	662	71	4,090	61	5,737	85	2,699	--	--
1030	65	5.3	--	82	3,713	768	474	219	66	9,742	54	535	68	4,896	61	3,486	84	2,668	--	--
1100	95	5.2	--	83	3,825	768	474	219	67	10,492	60	608	68	4,651	61	4,255	85	2,699	--	--
1135	130	5.2	--	84	3,510	768	474	219	66	7,960	59	597	68	3,733	61	4,255	84	2,668	25	--
1200	155	5.2	--	87	3,758	768	474	219	68	10,588	57	487	68	4,651	60	3,699	85	2,699	--	--
1230	185	5.1	--	88	3,420	768	474	219	68	10,037	55	545	69	3,974	60	4,104	89	2,826	--	--
1245	200	5.1	--	88	3,420	768	474	219	67	9,950	52	714	68	4,223	59	4,275	89	2,826	--	Sample.
1300	215	5.0	--	89	3,600	768	474	219	67	11,759	62	781	68	6,487	62	3,627	85	2,699	--	Sample.
1330	245	5.0	12,236	92	--	768	474	219	67	8,924	60	1,337	68	4,039	60	3,780	88	2,795	--	--
1337	252	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27	Shut down.
Average					3,607	768	474	219	67	10,082	58	696	68	4,527	61	4,135	85	2,712		

(1) Moisture: -1-1/2 in., 2.3%; -4 in. +1-1/2 in., 1.0%; -6 in. +4 in., 0.8%; -10 in. +6 in., 0.7%. Average dry ore feed rate: -1-1/2 in., 3,524 lb/hr; -4 in. +1-1/2 in., 760.3 lb/hr; -6 in. +4 in., 470.2 lb/hr; -10 in. +6 in., 217.5 lb/hr; Total: 4,972 lb/hr; 2.486 dry stph. Mill volume end of test: 27%.

Feed Rate, stph (dry):	2.486
Ball Charge:	301.8 lb, 2% of mill volume
Corrected Mill Power Tare (empty mill), kw:	0.6

Clock Time	Running Time min	Disc Revolutions sec/rev	Instantaneous Gross Power (meter reading) kwhr	Instantaneous Corrected Power (from input-output curve) kwhr	Power Consumption Gross kwhr/st	Power Consumption Net kwhr/st	Circulating Load Weight % of Feed(1)	Mill Discharge Solids %	Remarks
0820	--	--	--	--	--	--	--	--	Grind out.
0925	--	--	--	--	--	--	--	--	Start feed.
0930	5	6.8	7.62	5.80	2.33	2.09	--	--	--
1000	35	5.9	8.78	6.87	2.76	2.52	--	66	--
1030	65	5.3	9.78	7.78	3.13	2.92	105.0	66	--
1100	95	5.2	9.97	7.92	3.18	2.94	99.0	67	--
1135	130	5.2	9.97	7.92	3.18	2.94	87.0	66	--
1200	155	5.2	9.97	7.92	3.18	2.94	98.0	68	--
1230	185	5.1	10.16	8.09	3.25	3.01	93.0	68	--
1245(3)	200	5.1	10.16	8.09	3.25	3.01	101.0	67	--
1300(3)	215	5.0	10.36	8.26	3.32	3.08(2)	144.0	67	--
1330	245	4.0	10.36	8.26	3.32	3.08(2)	--	67	--
1337	252	--	--	--	--				End of test.
Average						3.08	103.9		

(1) Calculated: Sum of Sweco oversize and DSM oversize as a percentage of dry mill feed.
(2) Average for power (two readings): 3.08 kwhr/st.
(3) Sample run.

EXHIBIT 2

Grinding Test 6 -- continued

Procedure: Samples were wet screened on a 325M screen, products dried, and the +325M material dry screened using a Ro-Tap for 30 min.

Total Product	Screen Size Analysis								
	Mill Discharge		Sweco Screen Oversize		DSM Screen Oversize		DSM Screen Undersize		Circulating Load
Sample Time	1245	1300	1245	1300	1245	1300	1245	1300	
Sample Weight, g:	1,258.8	1,237.7	673.8	642.6	1,361.9	1,079.3	832.1	918.1	--
Screen Product (Tyler) Mesh	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %	Weight %
Head (calculated)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
+28	21.0	18.4	64.8	70.7	32.9	23.1	1.3	1.0	32.9
-28 +35	6.4	6.5	1.9	1.2	9.4	8.5	3.9	3.7	8.1
-35 +65	13.9	15.1	3.8	2.7	12.8	14.3	16.5	16.7	12.2
-65 +100	10.5	11.4	3.2	2.2	8.8	8.6	12.4	14.5	8.0
-100 +200	13.3	14.2	5.4	5.0	11.8	14.2	20.3	18.5	12.0
-200 +325	5.5	5.6	3.1	2.2	4.8	3.7	5.3	6.7	4.1
-325	29.4	28.8	17.8	16.0	19.5	27.6	40.3	38.9	22.7

Sediment Description and Classification Background

U.S. Standard Sieves

Note that the same size mesh can be a differing sieve number depending on the Sieve manufacturer (Tyler vs. ASTM)

Mesh Size (microns)	TYLER	ASTM-E11	BS-410	DIN-4188
µm	Mesh	No.	Mesh	mm
5	2500		2500	0.005
10	1250		1250	0.010
15	800		800	0.015
20	625		625	0.020
22				0.022
25	500		500	0.025
28				0.028
32				0.032
36				0.036
38	400	400	400	
40				0.040
45	325	325	350	0.045
50				0.050
53	270	270	300	
56				0.056
63	250	230	240	0.063
71				0.071
75	200	200	200	
80				0.080
90	170	170	170	0.090
100				0.100
106	150	140	150	
112				0.112
125	115	120	120	0.125
140				0.140
150	100	100	100	

Attachment B, 1/10

160				0.160
180	80	80	85	0.180
200				0.200
212	65	70	72	
250	60	60	60	0.250
280				0.280
300	48	50	52	
315				0.315
355	42	45	44	0.355
400				0.400
425	35	40	36	
450				0.450
500	32	35	30	0.500
560				0.560
600	28	30	25	
630				0.630
710	24	25	22	0.710
800				0.800
850	20	20	18	
900				0.900
1000	16	18	16	1.0
1120				1.12
1180	14	16	14	
1250				1.25
1400	12	14	12	1.4
1600				1.6
1700	10	12	10	
1800				1.8
2000	9	10	8	2.0
2240				2.24
2360	8	8	7	
2500				2.5
2800	7	7	6	2.8
3150				3.15
3350	6	6	5	
3550				3.55
4000	5	5	4	4.0
4500				4.5

4750	4	4	3.5	
5000				5.0

Sediment Classification based on Grain Size:

Unified Soil Classification System (USCS)

Sediment Name	**Diameter (mm)**	**Sieve No.**
Cobble	greater than 75 mm	
Gravel	4.75 to 75 mm	4
Sand	0.075 to 4.75 mm	200
Fines (silt and clay)	less than 0.075 mm	

USCS Division of Sands

Sediment Name	Diameter Range (mm)	Passes through Sieve No.	Retained on Sieve No.
Coarse Sand	2.0 - 4.8	4	10
Medium Sand	0.43 - 2.0	10	40
Fine Sand	0.075 - 0.43	40	200

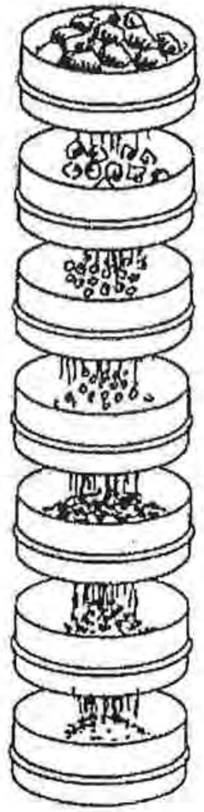


Figure 4-3. Dry sieve analysis.

USCS Classification System

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOLS	DESCRIPTIONS
COARSE GRAINED SOILS More Than Half Retained on 200 Sieve	GRAVELS More Than Half Coarse Fraction Retained on No. 4 Sieve	Clean Gravels (Little or no Fines)	GW	Well Graded Gravels, Gravel - Sand Mixtures, Little or no Fines
			GP	Poorly Graded Gravels, Gravel - Sand Mixtures, Little or no Fines
		Gravels With Fines (Appreciable Fines)	GM	Silty Gravels, Gravel-Sand-Silt Mixtures
			GC	Clayey Gravels, Gravel-Sand-Clay Mixtures
	SANDS More Than Half Coarse Fraction Passes a No. 4 Sieve	Clean Sands (Little or no Fines)	SW	Well Graded Sands, Gravelly Sands, Little or no Fines
			SP	Poorly Graded Sands, Gravelly Sands, Little or no Fines
		Sands With Fines (Appreciable Fines)	SM	Silty Sands, Sand - Silt Mixtures
			SC	Clayey Sands, Sand - Clay Mixtures
FINE GRAINED SOILS More Than Half Passes 200 Sieve	SILTS and CLAYS Liquid Limit Less Than 50		ML	Inorganic Silts & Very Fine Sands, Silty or Clayey Fine Sands, Clayey Silts
			CL	Inorganic Clays of Low to Medium Plasticity, Lean Clays
			OL	Organic Silts & Organic Silty Clays of Low Plasticity
	SILTS and CLAYS Liquid Limit Greater Than 50		MH	Inorganic Silts, Fine Sand or Silty Soils, Elastic Silts
			CH	Inorganic Clays of High Plasticity, Fat Clays
			OH	Organic Clays of Medium to High Plasticity, Organic Silts
Highly Organic Soils			PT	Peat and Other Highly Organic Soils

Visual logging of sediments entails estimating percentages of gravels, sands and fines (silt and clays). Practice and the use of the Geotechnical Gage will increase your confidence and ability in visually logging sediments.

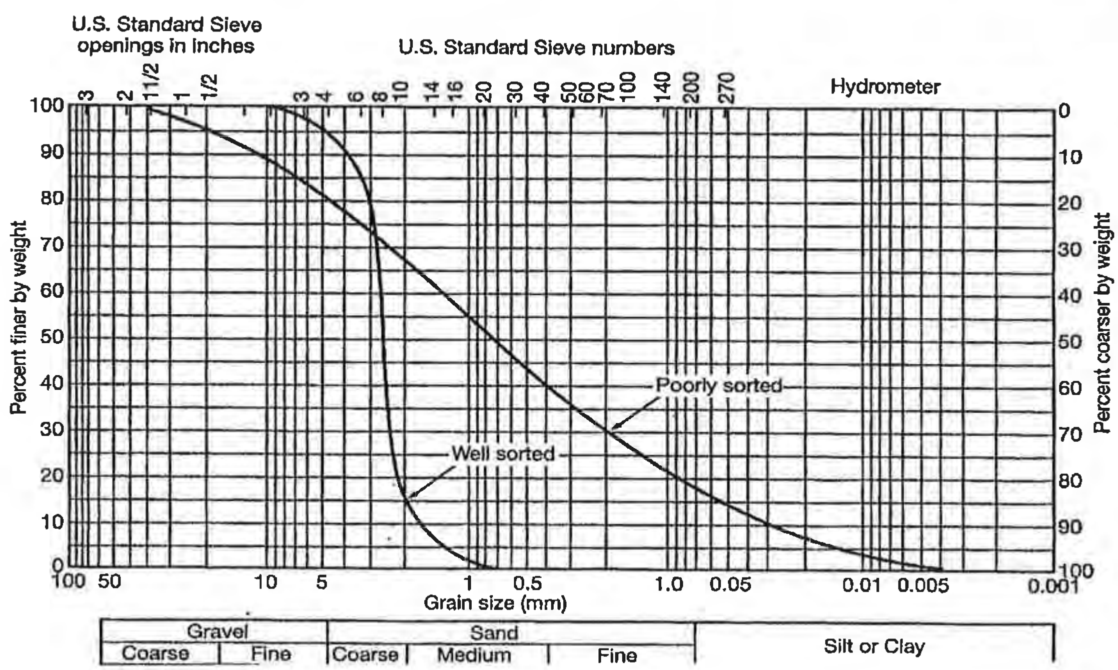
Read: Visual Exam Test

Read: Field Identification Guidelines

Ultimately, sediment samples may undergo grain size analysis through sieves. Graphing the cumulative weight percent retained/passing by sieve no. or grain size will result in the sediment grain-size distribution curve. The grain-size distribution curve is used to quantitatively classify the sediment type (your visual identification is a qualitative classification).

Read: Grain Size Distribution Measurement

Grain Size Distribution Curve



The grain-size distribution curve is used with the USCS classification chart to classify the sediment type. Other measures used to describe the sediment are the sorting or gradation of the sediment. As can be seen in the above chart, a well-sorted sediment has a small range of sediment grain sizes while a poorly sorted sediment has a large range of sediment grain sizes. In the USCS classification scheme, the gradation of the sediment is used instead of the sorting. A well-graded sediment has a large range of grain sizes while a poorly or uniformly graded sediment has a small range of grain sizes.

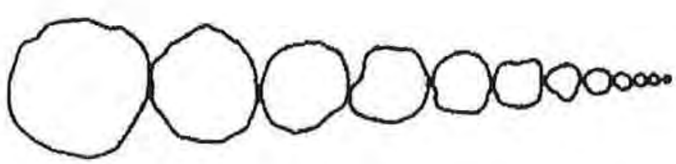


Figure 4-6. Well-graded soil.

POORLY SORTED SEDIMENT = WELL GRADED SEDIMENT

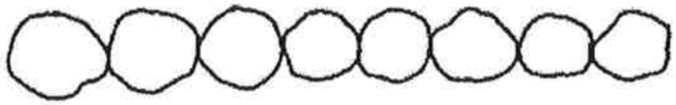


Figure 4-7. Uniformly graded soil.

WELL-SORTED SEDIMENT = POORLY OR UNIFORMLY GRADED SEDIMENT

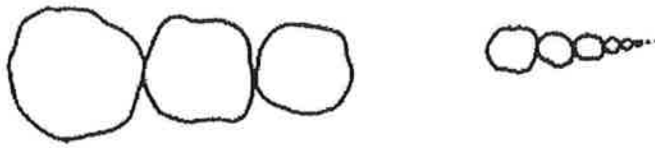


Figure 4-8. Gap-graded soil.

After sieve analysis, the data are tabulated showing the weight of sediment retained on each sieve. The cumulative weight retained is calculated starting from the largest sieve size and adding subsequent sediment weights from the smaller size sieves (see table below). The percent retained is calculated from the weight retained and the total weight of the sample. [Don't get confused by the graph - it is individual percent retained in Column 16 and cumulative percent passing in Column 17]. The cumulative percent passing in Column 17 of the table below is calculated by sequentially subtracting percent retained from 100 %. In table below, cumulative percent passing 1/4 inch sieve = 100 - 16 = 84; cumulative percent passing #4 sieve = 84-5.2 = 78.8; etc.

SIEVE ANALYSIS DATA

1. DATE STARTED	22 FEB 91
2. PROJECT	BRAVO AIRFIELD
3. EXCAVATION	1+00
4. DATE COMPLETED	28 FEB 91
5. SAMPLE DESCRIPTION	LIGHT BROWN SANDY SOIL
6. SAMPLE NUMBER	1A
7. PREWASHED	XX YES / NO
8. ORIGINAL SAMPLE WEIGHT	2459
9. + #200 SAMPLE WEIGHT	2359
10. − #200 SAMPLE WEIGHT	100

11. SIEVE SIZE	12. WEIGHT OF SIEVE	13. WEIGHT OF SIEVE + SAMPLE	14. WEIGHT RETAINED	15. CUMULATIVE WEIGHT RETAINED	16. PERCENT RETAINED	17. PERCENT PASSING
1½	202					
1	231					
½	210	210	0	0	0	100.0
¼	230	624	394	394	16.0	84.0
#4	205	332	127	521	5.2	78.8
#8	225	691	466	987	19.0	59.8
#20	215	612	397	1384	16.2	43.6
#60	235	581	346	1730	14.1	29.5
#100	250	612	362	2092	14.7	14.8
#200	260	515	255	2347	10.4	4.4

18. TOTAL WEIGHT RETAINED IN SIEVES (Sum Column 14)	2347
20. WEIGHT SIEVED THROUGH #200 (Weight in pan) 270-260	10
21. WASHING LOSS (8 - (9 + 10)) 2459-(2359+100)	0
22. TOTAL WEIGHT PASSING #200 (20 + 10) 10+100	110
23. TOTAL WEIGHT OF FRACTIONS (18 + 22)	2457

19. ERROR (8 - 23)

2459-2457 = 2

24. REMARKS

USCS SP
PERCENT-G 21.2
PERCENT-S 74.4
PERCENT-F 4.4

25. ERROR (Percent)

$\frac{\text{ERROR (19)}}{\text{ORIGINAL WT (8)}} \times 100 =$

$\frac{2}{2459} \times 100 = .08$

26. TECHNICIAN	27. COMPUTED BY (Signature)	28. CHECKED BY (Signature)
Joe Blob PVZ	Joe Blob PVZ	Fred Jones SSG

DD Form 1206, DEC 86 — Previous editions are obsolete

Figure 4-4. Data sheet, example of dry sieve analysis.

The cumulative percent passing is plotted on the grain-size distribution graph. The percentage passing the No. 4 and 200 sieves is used to classify the sediments as gravels (G), sands (S) or fines (must use plasiticity index to differentiate between silts and clays).

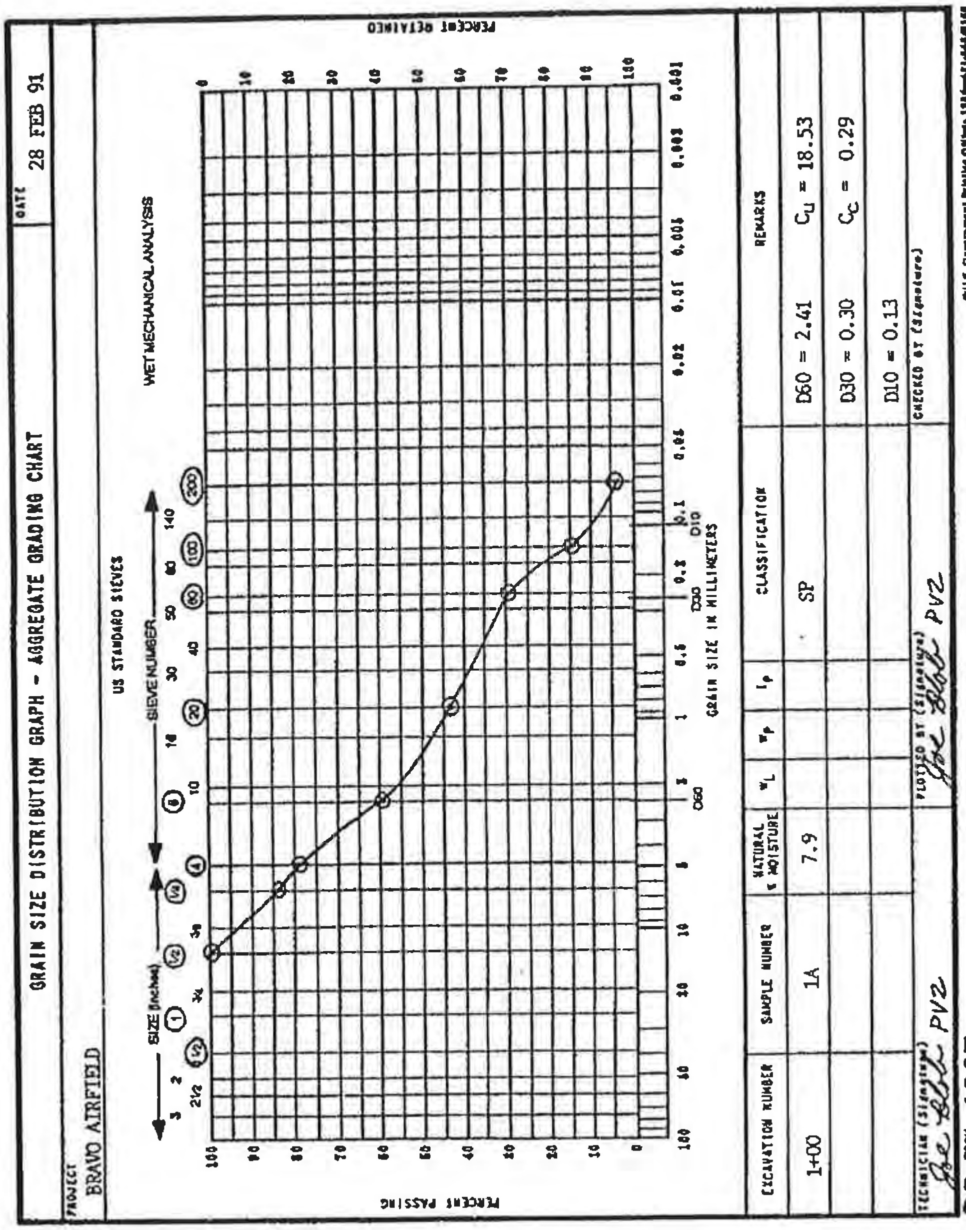


Figure 4-5. Grain-size distribution curve from sieve analysis.

The grain-size distribution graph is used to read off the grain size at which 10% of the sample passed (D_{10}), 30% of the sample passed (D_{30}) and 60% of the sample passed (D_{60}). These numbers are used to calculate several coefficients:

Hazen's effective size, D_{10}, which will be used to estimate permeability

Uniformity Coefficient, $C_u = D_{60}/D_{10}$

In the above graph,

$$D_{60} = 2.4 \text{ mm and } D_{10} = 0.13 \text{ mm}$$

$$\text{then} \quad C_u = 2.4/0.13 = 18.5$$

The uniformity coefficient is used to judge gradation.

Coefficient of Curvature, C_c

$$C_c = \frac{(D_{30})^2}{(D_{60} \times D_{10})}$$

In the above graph,

$$D_{30} = 0.3 \text{ mm}$$

$$\text{and } C_c = \frac{(0.3)^2}{(2.4)(0.13)} = .29$$

In the graph below, well-graded soils (GW and SW) are long curves spanning a wide range of sizes with a constant or gently varying slope. Uniformly graded soils (SP) are steeply sloping curves spanning a narrow range of sizes. For a gap-graded soil (GP), the curve flattens out in the area of the grain-size deficiency or gap.

The USCS criteria for well-graded gravels (GW) and sands (SW) are:

1. Less than 5% finer than No. 200 sieve
2. Uniformity coefficient greater than 4
3. Coefficient of curvature between 1 and 3

If Criterion 1 is met, but not Criteria 2 and 3, the gravels are gap-graded or uniform gravels (GP) or sands (SP)

If you are interested in more information: Gradation and Bearing Capacity

United States
Environmental Protection
Agency

Office of Research and
Development
Washington DC 20460

EPA/600/R-94/168b
September 1994

EPA

The Hydrologic Evaluation of Landfill Performance (HELP) Model

Engineering Documentation for Version 3

ATTACHMENT C. 1/3

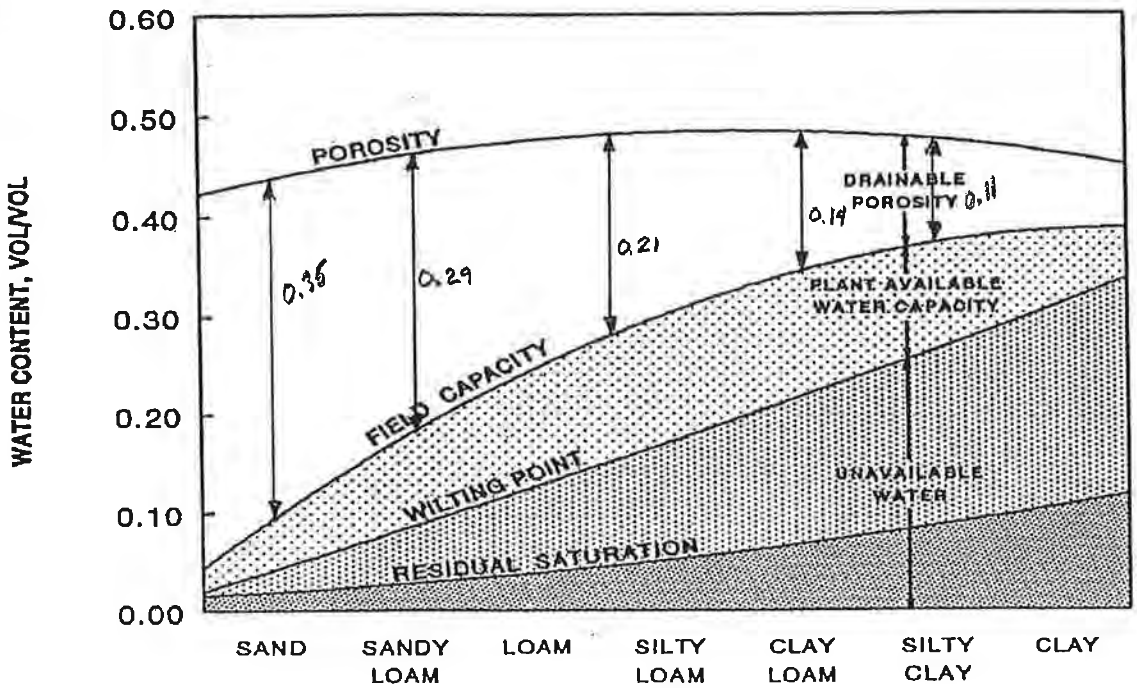


Figure 2. Relation Among Moisture Retention Parameters and Soil Texture Class

are not specified, the program assumes values near the steady-state values (allowing no long-term change in moisture storage) and runs a year of simulation to initialize the moisture contents closer to steady state. The soil water contents at the end of this year are substituted as the initial values for the simulation period. The program then runs the complete simulation, starting again from the beginning of the first year of data. The results of the volumetric water content initialization period are not reported in the output.

3.3.2 Unsaturated Hydraulic Conductivity

Darcy's constant of proportionality governing flow through porous media is known quantitatively as hydraulic conductivity or coefficient of permeability and qualitatively as permeability. Hydraulic conductivity is a function of media properties, such as particle size, void ratio, composition, fabric, degree of saturation, and the kinematic viscosity of the fluid moving through the media. The HELP program uses the saturated and unsaturated hydraulic conductivities of soil and waste layers to compute vertical drainage, lateral drainage and soil liner percolation. The vapor diffusivity for geomembranes is specified as a saturated hydraulic conductivity to compute leakage through geomembranes by vapor diffusion.

ATTACHMENT C, 2/3

TABLE 1. DEFAULT LOW DENSITY SOIL CHARACTERISTICS

Soil Texture Class			A Total Porosity vol/vol	B Field Capacity vol/vol	Wilting Point vol/vol	Saturated Hydraulic Conductivity cm/sec	A-B Drainable Porosity vol/vol
HELP	USDA	USCS					
1	CoS	SP	0.417	0.045	0.018	1.0x10^{-2}	
2	S	SW	0.437	0.062	0.024	5.8x10^{-3}	
3	FS	SW	0.457	0.083	0.033	3.1x10^{-3}	
4	LS	SM	0.437	0.105	0.047	1.7x10^{-3}	0.332
5	LFS	SM	0.457	0.131	0.058	1.0x10^{-3}	0.326
6	SL	SM	0.453	0.190	0.085	7.2x10^{-4}	0.263
7	FSL	SM	0.473	0.222	0.104	5.2x10^{-4}	0.251
8	L	ML	0.463	0.232	0.116	3.7x10^{-4}	0.231
9	SiL	ML	0.501	0.284	0.135	1.9x10^{-4}	0.217
10	SCL	SC	0.398	0.244	0.136	1.2x10^{-4}	0.154
11	CL	CL	0.464	0.310	0.187	6.4x10^{-5}	
12	SiCL	CL	0.471	0.342	0.210	4.2x10^{-5}	
13	SC	SC	0.430	0.321	0.221	3.3x10^{-5}	
14	SiC	CH	0.479	0.371	0.251	2.5x10^{-5}	
15	C	CH	0.475	0.378	0.251	2.5x10^{-5}	
21	G	GP	0.397	0.032	0.013	3.0x10^{-1}	

a = constant representing the effects of various fluid constants and gravity, 21 cm^3/sec

ϕ = total porosity, vol/vol

θ_r = residual volumetric water content, vol/vol

ψ_b = bubbling pressure, cm

λ = pore-size distribution index, dimensionless

A more detailed explanation of Equation 11 can be found in Appendix A of the HELP program Version 3 User's Guide and the cited references.

ATTACHMENT C, 3/3

ered that when well-graded mixtures of sand and gravel contained as little as 5% of fines (sizes smaller than a No. 200 sieve) high compactive efforts reduced the effective porosities nearly to zero and the permeabilities to less than 0.01% of those at moderate densities. These tests explain one of the reasons that blends of sand and gravel often used for drains are virtually useless as drainage aggregates if they contain more than insignificant amounts of fines.

In the preceding paragraphs variations in the permeability of remolded materials caused by variable compaction were discussed. Any factor that densifies soils reduces permeability. Studies of the rate of consolidation of clay and peat foundations are sometimes made by using initial coefficients of permeability of compressible formations. While the consolidation process is going on in foundations their permeabilities are becoming less. Generally, decreases in the permeabilities of clay foundations are rather moderate, but they can be large in highly compressible organic silts and clays and in peats. Modified calculation methods utilizing the changing permeability are needed in the analysis of highly compressible foundations. Some typical variations in permeability caused by consolidation are given in Fig. 2.10, a plot of consolidation pressure versus permeability.

$\sigma_n \simeq 31' \times 130$ pcf
$\simeq 4000$ psf
$\simeq 2$ Tsf

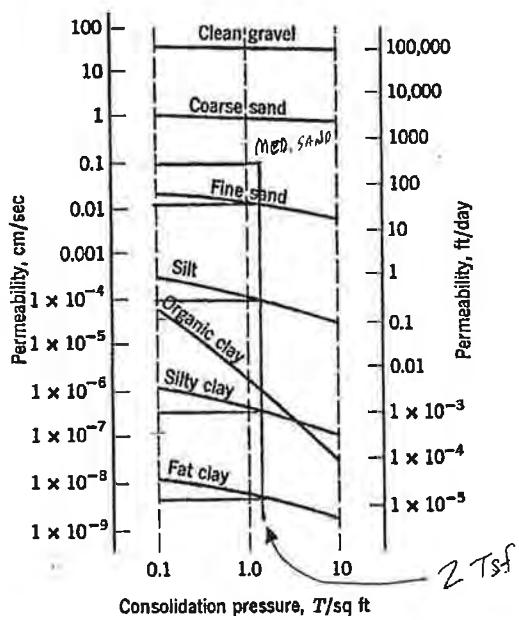


FIG. 2.10 Permeability versus consolidation pressure.

Attachment D 1/2

"Seepage, Drainage, and Flow Nets" 3rd Edition, Cedergren, H.R. 1989

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$$k = \frac{Q}{iAt} \tag{2.2}$$

Darcy's *discharge velocity* multiplied by the entire cross-sectional area, including voids e and solids 1, gives the seepage quantity Q under a given hydraulic gradient $i = \Delta h/\Delta l$ or h/L. It is an imaginary velocity that does not exist anywhere. The average *seepage velocity* v_s of a mass of water progressing through the pore spaces of a soil is equal to the discharge velocity $(v_d = ki)$ multiplied by $(1 + e)/e$ or the discharge velocity divided by the effective porosity n_e; hence permeability is related to seepage velocity by the expression

$$k = \frac{v_s n_e}{i} \tag{2.3}$$

For any seepage condition in the laboratory or in the field in which the *seepage quantity,* the area perpendicular to the direction of flow, and the hydraulic gradient are known the coefficient of permeability can be calculated. Likewise, for any situation where the *seepage velocity* is known at a point at which the hydraulic gradient and soil porosity also are known, permeability can be calculated.

Experimentally determined coefficients of permeability can be combined with prescribed hydraulic gradients and discharge areas in solving practical problems involving seepage quantities and velocities. When a coefficient of permeability has been properly determined, it furnishes a very important factor in the analysis of seepage and in the design of drainage features for engineering works.

The coefficient of permeability as used in this book and in soil mechanics in general should be distinguished from the physicists' coefficient of permeability K, which is a more general term than the engineers' coefficient and has units of centimeters squared rather than a velocity; it varies with the porosity of the soil but is independent of the viscosity and density of the fluid. The transmissibility factor T represents the capability of an aquifer to discharge water and is the product of permeability k and aquifer thickness t.

The engineers' coefficient, which is used in practical problems of seepage through masses of earth and other porous media, applies only to the flow of water and is a simplification introduced purely from the standpoint of convenience. It has units of a velocity and is expressed in centimeters per second, feet per minute, feet per day, or feet per year, depending on the habits and personal preferences of individuals using the coefficient. In standard soil mechanics terminology k is expressed in centimeters per second.

Although coefficient of permeability is often considered to be a constant for a given soil or rock, it can vary widely for a given material, depending on a number of factors. Its absolute values depend, first of all, on the properties of water, of which viscosity is the most important. For individual materials

Attachment D , 2/2

Cedergren, "Seepage, Drainage, and Flow Nets", 3rd Ed. 1989

GDE Control Products, Inc.

Multi-FLO

Technical Properties

Drainage Core

Property	Test Method	Value
Thickness, inches	ASTM D-1777	1.0
Flow Rate, gpm/ft*	ASTM D-4716	29
Compressive Strength	ASTM D-1621	6000

*

Geotextile Filter

Property	Test Method	Value
Weight, oz/sq yd2	ASTM D-3776	4.0
Tensile Strength, lb.	ASTM D-4632	100
Elongation, %	ASTM D-4632	50
Puncture, lb.	ASTM D-4833	50
Mullen Burst, psi	ASTM D-3786	200
Trapezoidal Tear, lb.	ASTM D-4533	42
Coeffecient of Perm,cm/sec	ASTM D-4491	0.1
Flow Rate, gpm/ft2	ASTM D-4491	100
Permittivity, 1/sec	ASTM D-4491	1.8
A.O.S Max US Std Sieve	ASTM D 4751	70
UV Stability, 500 hrs., %	ASTM D-4355	70
Seam Strength, lb./ft	ASTM D-4595	100
Fungus	ASTM G-21	No Growth

* Horizontal Installation , gradient = 0.01, compressive force = 10 psi for 1(

All values given represent minimum average roll values

GDE Control Products, Inc. Laguna Hills, CA. 949-305-7117

GDE, Multi-Flow
<http: www.gdecontrol.com/Multi-Flow5.html> Attachment E 1/1

TABLE 2.12 RECOMMENDED REDUCTION FACTOR VALUES FOR USE IN EQ. (2.25a)

	Range of Reduction Factors				
Application	Soil Clogging and Blinding*	Creep Reduction of Voids	Intrusion into Voids	Chemical Clogging†	Biological Clogging
Retaining wall filters	2.0 to 4.0	1.5 to 2.0	1.0 to 1.2	1.0 to 1.2	1.0 to 1.3
Underdrain filters	5.0 to 10	1.0 to 1.5	1.0 to 1.2	1.2 to 1.5	2.0 to 4.0
Erosion-control filters	2.0 to 10	1.0 to 1.5	1.0 to 1.2	1.0 to 1.2	2.0 to 4.0
* Landfill filters	5.0 to 10	1.5 to 2.0	1.0 to 1.2	1.2 to 1.5	5 to 10‡
Gravity drainage	2.0 to 4.0	2.0 to 3.0	1.0 to 1.2	1.2 to 1.5	1.2 to 1.5
Pressure drainage	2.0 to 3.0	2.0 to 3.0	1.0 to 1.2	1.1 to 1.3	1.1 to 1.3

*If stone riprap or concrete blocks cover the surface of the geotextile, use either the upper values or include an additional reduction factor.

†Values can be higher particularly for high alkalinity groundwater.

‡Values can be higher for turbidity and/or for microorganism contents greater than 5000 mg/l.

$$q_{\text{allow}} = q_{\text{ult}}\left(\frac{1}{\Pi \text{RF}}\right) \tag{2.25b}$$

where

q_{allow} = allowable flow rate,
q_{ult} = ultimate flow rate,
RF_{SCB} = reduction factor for soil clogging and blinding,
RF_{CR} = reduction factor for creep reduction of void space,
RF_{IN} = reduction factor for adjacent materials intruding into geotextile's void space,
RF_{CC} = reduction factor for chemical clogging,
RF_{BC} = reduction factor for biological clogging, and
ΠRF = value of cumulative reduction factors.

As with Eqs. (2.24) for strength reduction, this flow-reduction equation could also have included additional site-specific terms, such as blocking of a portion of the geotextile's surface by riprap or concrete blocks.

2.5 DESIGNING FOR SEPARATION

Application areas for geotextiles used for the separation function were given in Section 1.3.3. There are many specific applications, and it could be said, in a general sense, that geotextiles always serve a separation function. If they do not also serve this function, any other function, including the primary one, will not be served properly. This should not give the impression that the geotextile function of separation always plays a secondary role. Many situations call for separation only, and in such cases the geotextiles serve a significant and worthwhile function.

ATTACHMENT F 1/4

4.1.6 Allowable Flow Rate

As described previously, the very essence of the design-by-function concept is the establishment of an adequate factor of safety. For geonets, where flow rate is the primary function, this takes the following form.

$$FS = \frac{q_{allow}}{q_{reqd}} \tag{4.3}$$

where

FS = factor of safety (to handle unknown loading conditions or uncertainties in the design method, etc.),
q_{allow} = allowable flow rate as obtained from laboratory testing, and
q_{reqd} = required flow rate as obtained from design of the actual system.

Alternatively, we could work from transmissivity to obtain the equivalent relationship.

$$FS = \frac{\theta_{allow}}{\theta_{reqd}} \tag{4.4}$$

where θ is the transmissivity, under definitions as above. As discussed previously, however, it is preferable to design with flow rate rather than with transmissivity because of nonlaminar flow conditions in geonets.

Concerning the allowable flow rate or transmissivity value, which comes from hydraulic testing of the type described in Section 4.1.3, we must assess the realism of the test setup in contrast to the actual field system. If the test setup does not model site-specific conditions adequately, then adjustments to the laboratory value must be made. This is usually the case. Thus the laboratory-generated value is an ultimate value that must be reduced before use in design; that is,

$$q_{allow} < q_{ult}$$

One way of doing this is to ascribe reduction factors on each of the items not adequately assessed in the laboratory test. For example,

$$q_{allow} = q_{ult}\left[\frac{1}{RF_{IN} \times RF_{CR} \times RF_{CC} \times RF_{BC}}\right] \tag{4.5}$$

or if all of the reduction factors are considered together.

$$q_{allow} = q_{ult}\left[\frac{1}{\Pi RF}\right] \tag{4.6}$$

where

q_{ult} = flow rate determined using ASTM D4716 or ISO/DIS 12958 for short-term tests between solid platens using water as the transported liquid under laboratory test temperatures,

ATTACHMENT F

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: flow rate is the primary

(4.3)

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(4.5)

RF_{BC}

(4.6)

ISO/DIS 12958
as the transp

q_{allow} = allowable flow rate to be used in Eq. (4.3) for final design purposes,
RF_{IN} = reduction factor for elastic deformation, or intrusion, of the adjacent geosynthetics into the geonet's core space,
RF_{CR} = reduction factor for creep deformation of the geonet and/or adjacent geosynthetics into the geonet's core space,
RF_{CC} = reduction factor for chemical clogging and/or precipitation of chemicals in the geonet's core space,
RF_{BC} = reduction factor for biological clogging in the geonet's core space, and
ΠRF = product of all reduction factors for the site-specific conditions.

Some guidelines for the various reduction factors to be used in different situations are given in Table 4.2. Please note that some of these values are based on relatively sparse information. Other reduction factors, such as installation damage, temperature effects, and liquid turbidity, could also be included. If needed, they can be included on a site-specific basis. On the other hand, if the actual laboratory test procedure has included the particular item, it would appear in the above formulation as a value of unity. Examples 4.2 and 4.3 illustrate the use of geonets and serve to point out that high reduction factors are warranted in critical situations.

Example 4.2

What is the allowable geonet flow rate to be used in the design of a capillary break beneath a roadway to prevent frost heave? Assume that laboratory testing was done at the proper design load and hydraulic gradient and that this testing yielded a short-term between-rigid-plates value of 2.5×10^{-4} m²/s.

Solution: Since better information is not known, average values from Table 4.2 are used in Eq. (4.5).

TABLE 4.2 RECOMMENDED PRELIMINARY REDUCTION FACTOR VALUES FOR EQ. (4.5) FOR DETERMINING ALLOWABLE FLOW RATE OR TRANSMISSIVITY OF GEONETS

Application Area	RF_{IN}	RF_{CR}*	RF_{CC}	RF_{BC}
Sport fields	1.0 to 1.2	1.0 to 1.5	1.0 to 1.2	1.1 to 1.3
Capillary breaks	1.1 to 1.3	1.0 to 1.2	1.1 to 1.5	1.1 to 1.3
Roof and plaza decks	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2	1.1 to 1.3
Retaining walls, seeping rock, and soil slopes	1.3 to 1.5	1.2 to 1.4	1.1 to 1.5	1.0 to 1.5
Drainage blankets	1.3 to 1.5	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2
Surface water drains for landfill covers	1.3 to 1.5	1.1 to 1.4	1.0 to 1.2	1.2 to 1.5
Secondary leachate collection (landfills)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 2.0
Primary leachate collection (landfills)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 2.0

*These values are sensitive to the density of the resin used in the geonet's manufacture. The higher the density, the lower the reduction factor. Creep of the covering geotextile(s) is a product-specific issue.

ATTACHMENT F, 3/4

The above formula can be readily converted to flow rate, Q, by multiplying the velocity by the cross-sectional area A of the pipe.

For pipelines that are either flowing full or flowing partially full, the *Manning equation* is generally used.

$$V = \frac{1}{n} R_H^{0.66} S^{0.5} \tag{7.10}$$

where

V = velocity of flow (m/s),
R_H = hydraulic radius (m),
S = slope or gradient of pipeline (m/m), and
n = coefficient of roughness (see Table 7.7) (dimensionless).

Note that plastic pipe of the type discussed in this chapter, with a *smooth interior*, has a Manning coefficient from 0.009 to 0.010. Plastic pipe with a *profiled or corrugated interior* has a Manning coefficient ranging from 0.018 to 0.025.

Eqs. (7.9) and (7.10) are generally used in the form of charts or nomographs to determine pipe sizes, flow velocity or discharge flow rates (see Figures 7.6 and 7.7). For each chart we include an example from Hwang [7], illustrated on the respective nomographs by heavy lines. Note that both nomographs are for pipes flowing full.

Example 7.1

A 100 m long pipe with D = 200 mm and C = 120 carries a discharge of 30 l/s. Determine the head loss in the pipe. (See the Hazen-Williams chart in Figure 7.6.)

Solution: Applying the conditions given to the solution chart in Figure 7.6, the energy gradient is obtained.

$$S = 0.0058 \text{ m/m}$$

TABLE 7.7 VALUES OF MANNING ROUGHNESS COEFFICIENT, N, FOR REPRESENTATIVE SURFACES

Type of Pipe Surface	Representative n value
* Lucite, glass, or plastic*	0.010
Wood or finished concrete	[illegible]
Unfinished concrete, well-laid brickwork, concrete or cast iron pipe	[illegible]
Riveted or spiral steel pipe	[illegible]
Smooth, uniform earth channel	[illegible]
Corrugated flumes, typical canals, river free from large stones and heavy weeds	[illegible]
Canals and rivers with many stones and weeds	[illegible]

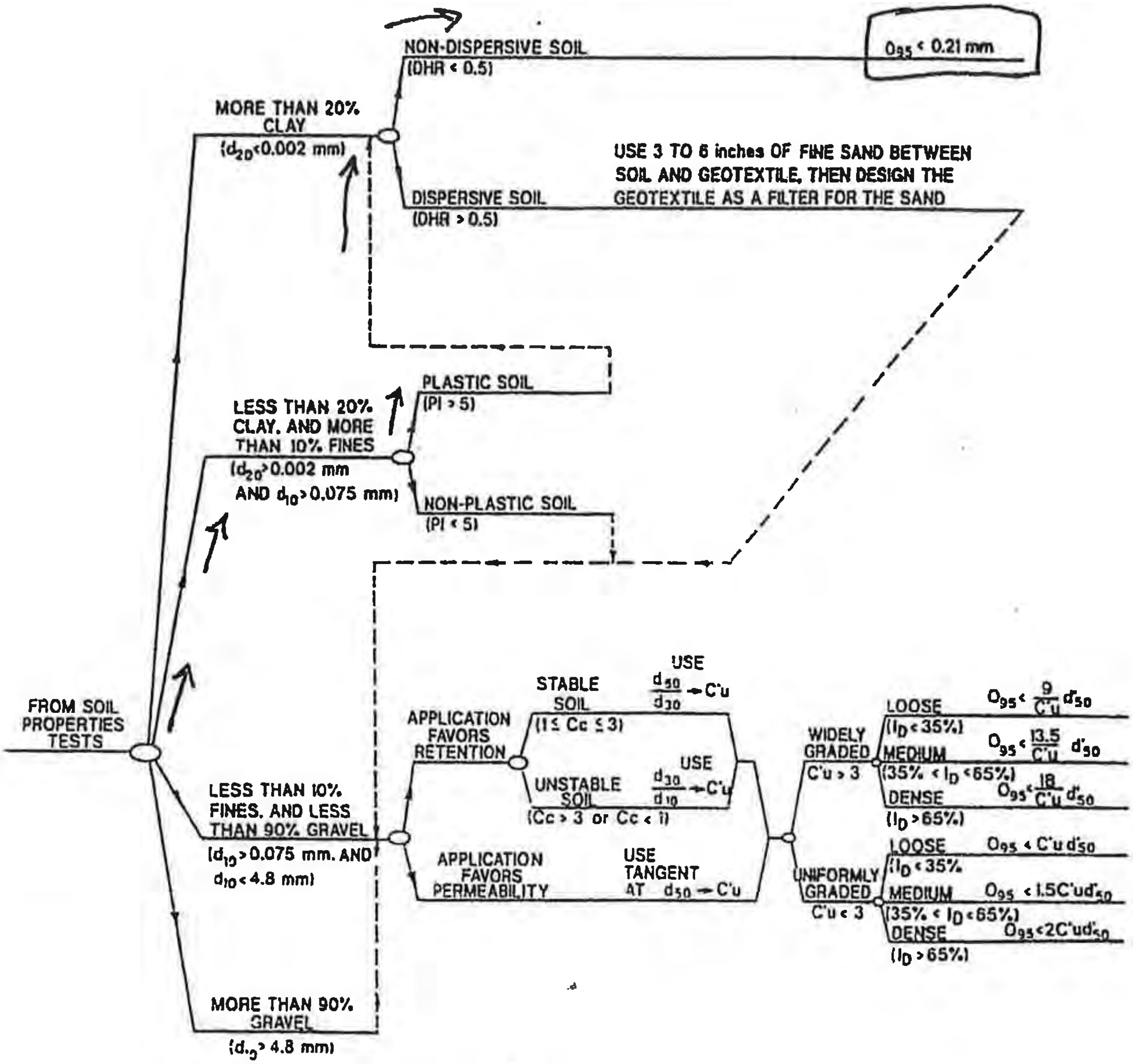
*The table does not distinguish between different types of plastic, or between smooth wall [illegible] pipes with perforations.

Source: After Fox and McDonald [9].

Koerner, R.M., "Designing with Geosynthetics," 4th Ed., 1999

Attachment F4

CHART 1
SOIL RETENTION CRITERIA
FOR STEADY-STATE FLOW CONDITIONS



NOTES:

d_x is the particle size of which x percent is smaller

$C'u = \sqrt{\frac{d'_{100}}{d'_0}}$ where: d'_{100} and d'_0 are the extremities of a straight line drawn through the particle-size distribution, as directed above; and d'_{50} is the midpoint of this line.

$Cc = \frac{(d_{30})^2}{d_{60} \times d_{10}}$

I_D is the relative denisty of the soil

PI is the plasticity index of the soil

DHR is the double-hydrometer ratio of the soil

Portions of this flow chart modified from Giroud (1988)

Source: Luettich, S.M., Giroud, J.P., and Bachus, R.C. (1991). "Geotextile Filter Design Manual". Report prepared for Nicolon Corporation, Norcross, Georgia.

Attachment G 1/3

4.2 Define the Hydraulic Gradient for the Application (i_s)

The hydraulic gradient will vary depending on the application of the filter. Anticipated hydraulic gradients for various applications may be estimated using Figure 3.

4.3 Determine the Minimum Allowable Geotextile Permeability (k_g)

After determining the soil hydraulic conductivity and the hydraulic gradient, the following equation can be used to determine the minimum allowable geotextile permeability [Giroud, 1988]:

$$k_g > i_s\, k_s$$

The hydraulic conductivity (permeability) of the geotextile can be calculated from the permittivity test method ASTM D 4491; this value can often be obtained from the manufacturer's literature as well. The geotextile permeability is defined as the product of the permittivity, ψ, and the geotextile thickness, t_g:

$$k_g > \varphi\, t_g$$

STEP 5. DETERMINE ANTI-CLOGGING REQUIREMENTS

To minimize the risk of clogging, the following criteria should be met:

- Use the largest opening size (O_{95}) that satisfies the retention criteria.
- For nonwoven geotextiles, use the largest porosity available, but not less than 30 percent.
- For woven geotextiles, use the largest percent open area available, but not less than 4 percent.

Source: Luettich, S.M., Giroud, J.P., and Bachus, R.C. (1991). "Geotextile Filter Design Manual". Report prepared for Nicolon Corporation, Norcross, Georgia.

Attachment G 2/3

Table 4-5

Typical Hydraulic Gradients[a]

DRAINAGE APPLICATION	TYPICAL HYDRAULIC GRADIENT
Standard Dewatering Trench	1.0
Vertical Wall Drain	1.5
Pavement Edge Drain	1[b]
Landfill LCDRS	1.5
Landfill LCRS	1.5
Landfill SWCRS	1.5
Inland Channel Protection	1[b]
Shoreline Protection	10[b]
Dams	10[b]
Liquid Impoundments	10[b]

NOTES: [a] Table developed after Giroud [1988].

[b] Critical applications may require designing with higher gradients than those given.

Attachment G
3/3

AMOCO WASTE RELATED GEOTEXTILES

MINIMUM PHYSICAL PROPERTIES
(Minimum Average Roll Values)

Property	Test Method	Units	4504	4506	4508	4510	4512	4516
Unit Weight	ASTM D-3776	Oz./yd.²	4.0 *	6.0	8.0	10.0	12.0	16.0
Grab Tensile	ASTM D-4632	lbs.	95	150	200	235	275	350
Grab Elongation	ASTM D-4632	%	50	50	50	50	50	50
Mullen Burst	ASTM D-3787	psi	225	350	450	550	650	750
Puncture	ASTM D-4833	lbs.	55	90	130	165	185	220
Trapezoid Tear	ASTM D-4533	lbs.	35	65	80	95	115	130
Apparent Opening Size	ASTM D-4751	US Sieve Number	70	70	100	100	100	100
Permittivity	ASTM D-4491	gal/min/ft² sec⁻¹	100 2.0	90 1.7	80 1.5	70 1.1	60 0.9	50 0.7
Permeability	ASTM D-4491	cm/sec	.2	.2	.2	.2	.2	.2
Thickness	ASTM D-1777	mils	40 *	65	90	110	130	175
U.V. Resistance	ASTM D-4355[1]	%[2]	70	70	70	70	70	70

1. Fabric conditioned per ASTM D-4355 2. Percent of minimum grab tensile after conditioning.

TYPICAL PHYSICAL PROPERTIES

Property	Test Method	Units	4504	4506	4508	4510	4512	4516
Grab Tensile	ASTM D-4632	lbs.	130/115	225/200	275/270	315/310	410/370	510/470
Grab Elongation	ASTM D-4632	%	75	65	65	65	65	65
Mullen Burst	ASTM D-3786	psi	285	410	575	650	825	920
Puncture	ASTM D-4833	lbs.	75	120	170	190	210	270
Trapezoid Tear	ASTM D-4533	lbs.	60/50	100/80	140/120	160/140	185/155	220/180
Apparent Opening Size	ASTM D-4751	US Sieve Number	70/120	70/140	100/200	100+	100+	100+
Permittivity	ASTM D-4491	gal/min/ft² sec⁻¹	150 3.1	110 2.0	100 1.8	80 1.5	70 1.3	60 1.0
Permeability	ASTM D-4491	cm/sec	.35	.31	.27	.26	.25	.23
Thickness	ASTM D-1777	mils	50	75	115	130	150	195

PACKAGING

Dimensions		4504	4506	4508	4510	4512	4516
Roll Width	ft.	15	15	15	15	15	15
Roll Length	ft.	1200	900	600	600	450	300
Gross Weight	lbs.	500	550	500	600	550	500
Area	sq. yds.	2000	1500	1000	1000	750	500

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permission or as a recommendation to infringe any patent.

Amoco Fabrics and Fibers Company 900 Circle 75 Parkway, Suite 300 Atlanta, Georgi[illegible]

Code #19100512;20 000;6/91

Amoco Fabrics & Fibers Company, 1991. "Amoco Waste Related Geotextiles" H 1/1

APPENDIX E

Boring Logs and Geotechnical Laboratory Results

Appendix E-1

Seismic Refraction Summary

Geosyntec consultants

TABLE E-1
SUMMARY OF SEISMIC REFRACTION SURVEYS
Energy Fuels, White Mesa Mill
Blanding, Utah

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
SL-12-01-01F	N37.52603	W109.51611	Fwd S32E	5A	0 to 4 4 to 36 > 36	1287 to 1392 4944 to 5053 6195 to 7403	Rippable Rippable Rippable	
SL-12-01-01R	N37.52554	W109.51566	Rev N32W	5A	0 to 6 > 6	1312 to 2563 5358 to 6372	Rippable Rippable	
SL-12-02-01F	N37.52603	W109.51611	Fwd N32W	5A	0 to 4 4 to 14 > 14	1341 to 1408 3457 to 5578 6512 to 6802	Rippable Rippable Rippable	
SL-12-02-01R	N37.52647	W109.51649	Rev S32E	5A	0 to 8 8 to 12 >12	1571 to 2191 4245 to 5672 6538 to 7012	Rippable Rippable Rippable	
TP12-02	N37.52600	W109.51614	Fwd N30W	5A	-	-		0-5.25 FT Residual Soil 5.25-6.75 FT Weathered Sandstone 6.75 to 7.0 FT Dakota Sandstone
SL-12-03-01F	N37.52499	W109.51506	Fwd S30W	5A	0 to 5 5 to 21 >21	1482 to 1658 3866 to 4754 6087 to 6492	Rippable Rippable Rippable	
SL-12-03-01R	N37.52447	W109.51466	Rev N30E	5A	0 to 6 >6	1804 to 2078 4854 to 5966	Rippable Rippable	
TP12-04	N37.52507	W109.51506	Fwd N32W	5A	-	-		0-1.5 FT Residual Soil 1.5-7.5 FT Weathered Sandstone 7.5-8.0 FT Shale Layer 8.0 FT Dakota Sandstone
SL-12-04-01F	N37.52546	W109.51749	Fwd S75E	5A	0 to 4 4 to 25 >25	1059 to 1317 3264 to 4564 5918 to 6499	Rippable Rippable Rippable	
SL-12-04-01R	N37.52532	W109.51675	Rev N75W	5A	0 to 5 5 to 14 >14	1052 to 1681 2998 to 5299 5663 to 7907	Rippable Rippable Marginal	
TP12-01	N37.52546	W109.51749	Fwd S65E	5A	-	-		0-5 FT Residual Soil 5.0-6.75 FT Weathered Sandstone 6.75 to 7.0 FT Dakota Sandstone
SL-12-05-01F	N37.52384	W109.51791	Fwd N62E	5A	0 to 9 >9	1137 to 1691 6235 to 7003	Rippable Rippable	
SL-12-05-01R	N37.52416	W109.51729	Rev S62W	5A	0 to 7 >7	1684 to 1939 6281 to 8285	Rippable Marginal	
TP12-07	N37.52388	W109.51793	Fwd N20E	5A	-	-		0-7.0 FT Residual Soil 7.0-8.5 FT Weathered Sandstone 8.5-9.5 FT Dakota Sandstone
SL-12-06-01F	N37.52438	W109.51460	Fwd S30E	5A	0 to 3 3 to 46	2083 to 2347 4826 to 4905	Rippable Rippable	

TABLE E-1
SUMMARY OF SEISMIC REFRACTION SURVEYS
Energy Fuels, White Mesa Mill
Blanding, Utah

Geosyntec consultants

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
SL-12-06-01R	N37.52388	W109.51418	Rev N30W	5A	0 to 4 >4	1489 to 2965 4955 to 6415	Rippable Rippable	
TP12-06	N37.52408	W109.51434	Fwd N30W	5A	-	-		0-2.0 FT Residual Soil 2.0-3.5 FT Weathered Sandstone 3.5 FT Dakota Sandstone
SL-12-07-01F	N37.52438	W109.51460	Fwd S30E	5A	0 to 4 4 to 19 > 19	1488 to 2035 4757 to 5046 6696	Rippable Rippable Rippable	
SL-12-07-01R	N37.52338	W109.51372	Rev N30W	5A	0 to 4 4 to 34 > 34	1308 to 2080 4899 to 5169 8444 to 8736	Rippable Rippable Marginal	
TP12-09	N37.52294	W109.51320	Fwd N20E	5A/5B	-	-		0-5.5 FT Residual Soil 5.5-6.5 FT Weathered Sandstone 6.5-7.5 FT Dakota Sandstone
SL-12-08-01F	N37.52443	W109.51648	Fwd N62E	5A	0 to 5 5 to 17 > 17	1061 to 1283 3354 to 4800 6025	Rippable Rippable Rippable	
SL-12-08-01R	N37.52477	W109.51582	Rev S62W	5A	0 to 7 > 7	1521 to 1732 4927 to 5849	Rippable Rippable	
TP12-05	N37.52443	W109.51621	Fwd N40E	5A	-	-		0-4.5 FT Residual Soil 4.5-6.5 FT Weathered Sandstone 6.5-7.5 FT Dakota Sandstone
TP12-08	N37.52326	W109.51534	Fwd N10W	5A	-	-		0-6.0 FT Residual Soil 6.0-7.5 FT Weathered Sandstone 7.5 FT Dakota Sandstone
SL-12-09-01F	N37.52544	W109.51392	Fwd N65E	5A	0 to 5 >5	1211 to 2207 5570 to 6148	Rippable Rippable	
SL-12-09-01R	N37.52570	W109.51324	Rev S65W	5A	0 to 6 6 to 17 >17	1269 to 1639 4661 to 6630 7230 to 7274	Rippable Rippable Rippable	
TP12-03	N37.52559	W109.51355	Fwd S65W	5A	-	-		0-5.5 FT Residual Soil 5.5-7.0 FT Weathered Sandstone 7.0 FT Dakota Sandstone
TP12-10	N37.52464	W109.51260	Fwd N88W	5A/5B	-	-		0-4.5 FT Residual Soil 4.5-9.0 FT Weathered Sandstone 9.0-9.5 FT Dakota Sandstone
SL-12-10-01F	N37.524778	W109.50861	Fwd S68W	5B	0 to 6 >6	1442 to 1904 5620 to 7611	Rippable Marginal	
SL-12-10-01R	N37.52452	W109.50928	Rev N68E	5B	0 to 4 >4	1835 to 2395 6387 to 7509	Rippable Marginal	

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TABLE E-1
SUMMARY OF SEISMIC REFRACTION SURVEYS
Energy Fuels, White Mesa Mill
Blanding, Utah

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
TP12-12	N37.52479	W109.50859	Fwd S65W	5B	-	-		0-6.5 FT Residual Soil 6.5-7.5 FT Weathered Sandstone 7.5-8.0 FT Dakota Sandstone
SL-12-11-01F	N37.525045	W109.507928	Fwd N68E	5B	0 to 6 >6	1157 to 1227 7036 to 7052	Rippable Rippable	
SL-12-11-01R	N37.524778	W109.50861	Rev S68W	5B	0 to 10 >10	1411 to 1480 7343 to 8088	Rippable Marginal	
SL-12-12-01F	N37.52419	W109.51025	Fwd N70E	5B	0 to 4 4 to 17 > 17	1061 to 1488 3331 to 4947 8999 to 9761	Rippable Rippable Non-Rippable	
SL-12-12-01R	N37.52441	W109.50956	Rev S70W	5B	0 to 3 3 to 18 >18	1672 to 1955 4721 to 5496 6643 to 7372	Rippable Rippable Rippable	
TP12-13	N37.52419	W109.51025	Fwd S70W	5B	-	-	-	0-0.5 FT Residual Soil 0.5-1.0 FT Weathered Sandstone 1.0-2.0 FT Dakota Sandstone
SL-12-13-01F	N37.5249	W109.51025	Fwd S70W	5B	0 to 6 >6	1349 to 3557 7286 to 9352	Rippable Non-Rippable	
SL-12-13-01R	N37.52389	W109.51102	Rev N70E	5B	0 to 5 >5	1138 to 1248 6186 to 8977	Rippable Marginal	
SL-12-14-01F	N37.52330	W109.51234	Fwd N62E	5B	0 to 6 6 to 28 >28	1098 to 1775 6361 to 6041 8046 to 8964	Rippable Rippable Marginal	
SL-12-14-01R	N37.52361	W109.51167	Rev S62W	5B	0 to 6 >6	1369 to 1419 7171 to 7762	Rippable Marginal	
TP12-15	N37.52361	W109.51167	Fwd S60W	5B	-	-		0-5.5 FT Residual Soil 5.5-6.0 FT Weathered Sandstone 6.5 FT Dakota Sandstone
TP12-17	N37.52253	W109.51065	Fwd N8E	5B	-	-	-	0-0.5 FT Residual Soil 0.5-2.0 FT Weathered Sandstone 2.0-3.5 FT Dakota Sandstone
SL-12-15-01F	N37.52542	W109.51112	Fwd S20E	5B	0 to 8 >8	1478 to 3030 6346 to 7738	Rippable Marginal	
SL-12-15-01R	N37.52493	W109.51077	Rev S30E	5B	0 to 9 9 to 16 >16	1305 to 1554 3197 to 4279 7886 to 8107	Rippable Rippable Marginal	
TP12-11	N37.52512	W109.51098	Fwd N25W	5B	-	-		0-3.5 FT Residual Soil 3.5-11.0 FT Weathered Sandstone 11.0-12.0 FT Dakota Sandstone

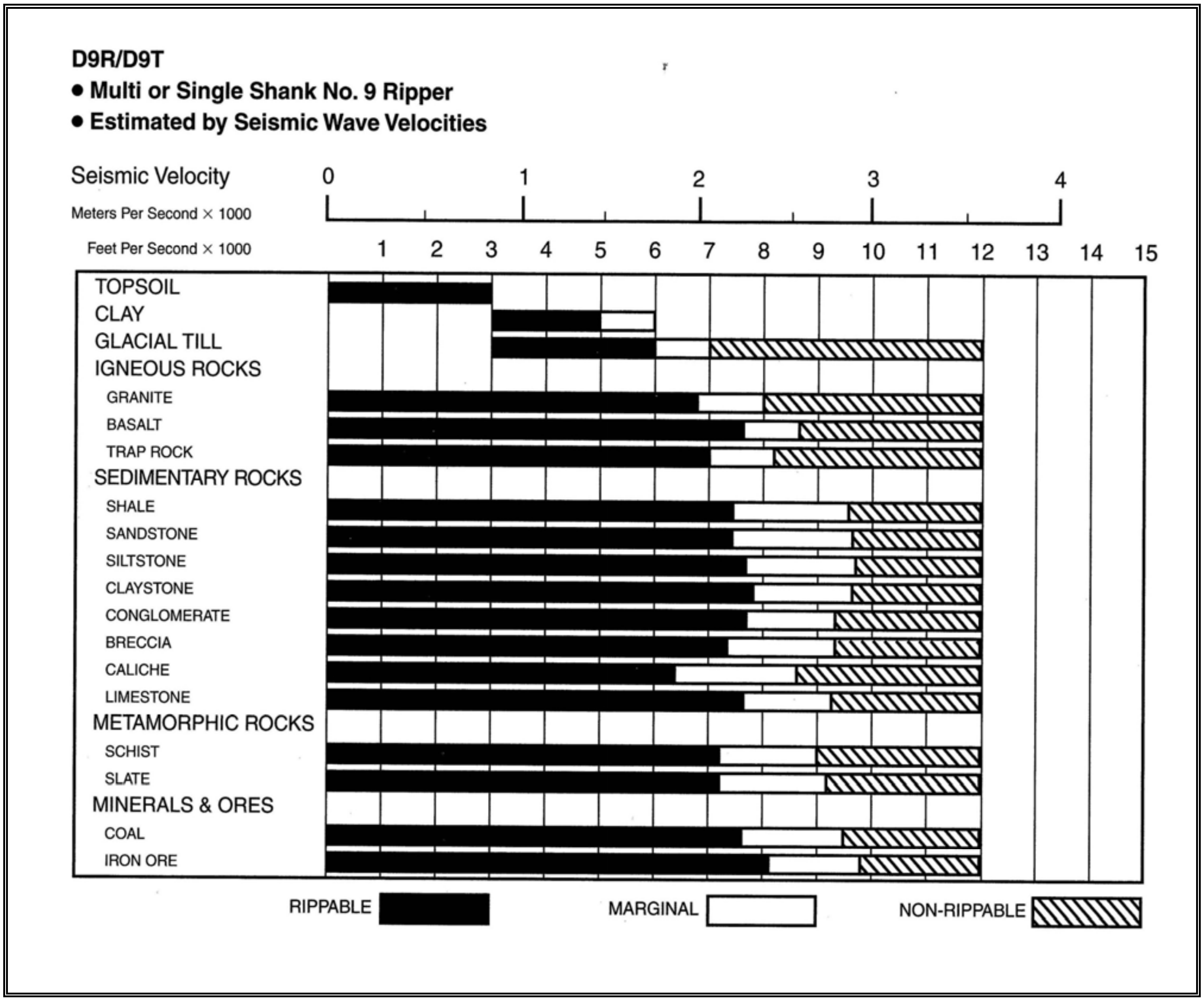
TABLE E-1
SUMMARY OF SEISMIC REFRACTION SURVEYS
Energy Fuels, White Mesa Mill
Blanding, Utah

Geosyntec consultants

Survey Number	Survey[1] End Points		Survey Line Direction	Cell (5A or 5B)	Approximate Depth Range[2] (feet bgs)	Seismic Velocity Range (Feet per Second)	Excavatability Assessment[3]	Subsurface Conditions
	Latitude	Longitude						
TP12-19	N37.52550	W109.50965	Fwd N15W	5B	-	-		0-1.5 FT Residual Soil 1.5 FT Dakota Sandstone
SL-12-16-01F	N37.52330	W109.50919	Fwd N32W	5B	0 to 6 6 to 22 >22	1388 2951 to 5517 9648	Rippable Rippable Non-Rippable	
SL-12-16-01R	N37.52380	W109.50957	Rev S32E	5B	0 to 6 >6	1215 to 1816 6435 to 6930	Rippable Rippable	
TP12-16	N37.52329	W109.50913	Fwd S40E	5B	-	-	-	0-0.5 FT Residual Soil 0.5-6.0 FT Weathered Sandstone 6.0-6.5 FT Dakota Sandstone
SL-12-17-01F	N37.52330	W109.50919	Fwd S32E	5B	0 to 4 4 to 37 >37	1391 to 2336 4801 to 4874 7554	Rippable Rippable Marginal	
SL-12-17-01R	N37.52280	W109.50872	Rev N32W	5B	0 to 5 5 to 22 >22	1694 to 1730 4762 to 5491 6479 to 6483	Rippable Rippable Rippable	
TP12-18	N37.52223	W109.50835	Fwd N30W	5B	-	-		0-4.5 FT Residual Soil 4.5-6.0 FT Weathered Sandstone 6.0-6.5 FT Dakota Sandstone
SL-12-18-01F	N37.52431	W109.50755	Fwd E-W	5B	0 to 5 5 to 26 >26	1090 to 1379 5202 to 6893 7491 to 10938	Rippable Rippable Non-Rippable	
SL-12-18-01R	N37.52430	W109.50829	Rev E-W	5B	0 to 4 4 to 20 >20	1361 to 1420 5110 to 5363 7861 to 11264	Rippable Rippable Non-Rippable	
TP12-14	N37.52431	W109.50749	Fwd S88W	5B	-	-	-	0-4.5 FT Residual Soil 4.5-7.5 FT Weathered Sandstone 7.5 FT Dakota Sandstone

Notes:
1 - Surveyed end point of refraction survey lines coordinates in Latitude/Longitude decimal degree World Geodetic System (WGS) 84. Data collected in field.
2 - Calculated depth of seismic refractor based on P-wave first arrival times using Snells Law.
3 - Excavatability assessment based on correlations between seismic wave velocities and rippability using a Single Shank No. 9 ripper on a D9N dozer (Caterpillar, 2006)
RS - Residual Soil
wxs - weathered sandstone
Kds - Cretaceous Dakota Sandstone

TABLE E-2
SEISMIC VELOCITY AND RIPPABILITY CORRELATION
Energy Fuels, White Mesa Mill
Blanding, Utah



Excavatability assessment based on correlations between seismic wave velocities and rippability of various materials using a Single Shank No. 9 ripper on a D9N dozer (Caterpillar, 2006)

Appendix E-2

Trench Logs

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BORING LOG

Project No.: SC0634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-1
Geologist/Eng.: A. GREENE / J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N 37.52346°, W109.51749° (S65E)

Page 1 of 1
Date Started: 11/5/12
Date Completed: 11/5/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 7 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1345		SURFACE: SILTY FINE TO VERY SAND, BUSHES, GRASS RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR 4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				16 FT TRENCH
				INCREASE CARBONATE CONC @ 3FT					HARD DIGGING
5				DAKOTA SANDSTONE HIGHLY WEATHERED SANDSTONE, MEDIUM STRONG FINE GRAINED PINKISH WHITE TO PINK (2.5YR 8/2 TO 8/3)					
				DAKOTA SANDSTONE MODERATELY WEATHERED, MED STRONG TO STRONG FINE GRAINED PINKISH WHITE (2.5YR 8/2)					
				BOTTOM OF TESTPIT AT 7.0 FT (BACKHOE REFUSAL)					
10									
15									

Reviewed by: ______________________ R.G.# ______________

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BORING LOG

Project No.: SC0634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-2
Geologist/Eng.: A. GREENE / J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N37.52600 W109.51614 (N30'W)

Page 1 of 1
Date Started: 11/5/12
Date Completed: 11/5/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 7.0 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
0		1320		SURFACE: RESIDUAL SOIL DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				16 FT TRENCH
				INCREASING CARBONATE AT 3.25 FT					
5				DAKOTA SANDSTONE @ 5.25' HIGHLY WEATHERED SANDSTONE, WEAK TO MOD STRONG, PINKISH WHITE (2.5YR 8/2) - ABUNDANT CARBONATE CEMENT					VERY HARD DIGGING
				DAKOTA SANDSTONE - MODERATELY WX, MEDIUM STRONG, FINE GRAINED PINKISH WHITE (2.5YR 8/2)					
				BOTTOM OF TESTPIT AT ~7FT (BACKHOE REFUSAL)					
10									
15									

Reviewed by: R.G.#

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BORING LOG

Project No.: SC0634 | Page 1 of 1
Site Name: WHITE MESA MILL (BLANDING) | Date Started: 11/8/12
Boring I.D.: TP12-3 | Date Completed: 11/8/12
Geologist/Eng.: J. WARNER | Borehole Diameter: 24 INCH BUCKET
Drilling Company: | Borehole Depth: 7.0 FT
Drilling Method: BACKHOE JD 310 | Depth to Water: N/A
Comments: N37.52559° W109.51355° (565W)

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1415		SURFACE: SILTY FINE TO VERY FINE SAND, GRASS					21 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				@ 3 FT TOP OF CARBONATE HORIZON, GRADUAL CHANGE INTO WEATHERED SANDSTONE					
5				@ 5.5 FT DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, PINKISH WHITE (2.5YR-8/2)					↓ VERY HARD DIGGING
				@ 7.0 FT DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PALE YELLOW (2.5Y-8/2 TO 8/3)					
				BOTTOM OF TEST PIT AT 7.0 FT					
10									

Reviewed by: ______ R.G.# ______

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BORING LOG

Project No.: SC0634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-4
Geologist/Eng.: J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N37.52507 W109.51506' (N32W)

Page 1 of 1
Date Started: 11/8/12
Date Completed: 11/8/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 8.0 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1320		SURFACE: SILTY FINE TO VERY FINE SAND, GRASS RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM] @1.5 FT DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, PINKISH WHITE (2.5YR-8/2)	SM				24 FT TRENCH
5									
				@7.5 FT MED STRONG, MOIST, VERY DARK GRAYISH BROWN (10YR-3/2) SHALE LAYER WITH FE OXIDATION DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PALE YELLOW (2.5Y-8/2 TO 8/3)					↓ VERY HARD DIGGING
10				BOTTOM OF TEST PIT AT 8.0 FT					

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BORING LOG

Project No.: SC06
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP 12-5
Geologist/Eng.: A. GREENE / J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N37.52443 W109.51621 (NAOE)

Page 1 of 1
Date Started: 11/5/12
Date Completed: 11/5/12
Borehole Diameter: 24-INCH BUCKET
Borehole Depth: 7.5 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
0		1215		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS					14 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]. - CONTAINS ROOTLETS TO ~2FT	SM				
5				@4.5' TOP OF CARBONATE HORIZ. BECOMES REDDISH YELLOW (5YR-6/6) GRADATIONAL CHANGE INTO WEATHERED SANDSTONE					
				@6.5' DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE. PINKISH WHITE TO PINK (2.5YR 8/2 TO 8/3)					VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 7.5 FT					
10									
15									

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BORING LOG

Project No.: 3C0634 Page 1 of 1 11/8/12 TD = 3.5 FT

Site Name: WHITE MESA MILL (BLANDING) Boring I.D.: TP12-6 24 INCH BUCKET BACKHOE JD 310

Comments: N 37.52408° W109.51434° (N30W)

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1020		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM] · MODERATELY WEATHERED SANDSTONE BOULDERS AT 1.0 FT	SM				15 FT TRENCH
				@ 2.0 FT TOP OF CARBONATE HORIZ. GRADUAL CHANGE INTO MODERATELY WEATHERED SANDSTONE					RESISTANT SANDSTONE KNOB IN CENTER OF TEST PIT AT 2.5 FT ↓ VERY HARD DIGGING
				@ 3.5 FT DAKOTA SANDSTONE MODERATELY WEATHERED, STRONG FINE GRAINED SANDSTONE, WHITE (PINKISH) TO PINKISH GRAY (7.5YR 8/2 TO 6/2)					
				BOTTOM OF TEST PIT 3.5 FT					

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BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/9/12
Boring I.D.:	TP12-7	Date Completed:	11/9/12
Geologist/Eng.:	J WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	9.5 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N 37.52388° W109.51793° (N20E)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0800		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS					22 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				TOP OF CARBONATE HORIZON AT 2.0 FT, GRADUAL CHANGE INTO WEATHERED SANDSTONE					
5									
				@7 FT					
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO PINK (2.5YR-8/2 TO 8/3)					
				@8.5 FT					VERY HARD DIGGING
				DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, FINE GRAINED, PINKISH WHITE (2.5YR-8/2)					
10				BOTTOM OF THE TEST PIT AT 9.5 FT					

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BORING LOG

Project No.: SCO 634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-8
Geologist/Eng.: J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N 37.52326° W109.51534° (N10W)

Page 1 of 1
Date Started: 11/9/12
Date Completed: 11/9/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 7.5 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0830		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS					22 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				TOP OF CARBONATE HORIZON AT 2.5 FT, GRADUAL CHANGE INTO WEATHERED SANDSTONE					
5				- CONTAINS ROOTLETS TO 5.5 FT					
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO PINK (2.5YR- 8/2 TO 8/3)					
				@ 7.5 FT DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PINKISH WHITE (2.5YR-8/2)					↓ VERY HARD DIGGING
10				BOTTOM OF TEST PIT AT 7.5 FT					

Reviewed by: ______ R.G.# ______

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BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/8/12
Boring I.D.:	TP12-9	Date Completed:	11/8/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	7.5 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A

Comments: N37.52294° W109.51320° (N20E)

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1500		SURFACE: SILTY FINE TO VERY SAND, SHORT GRASS					22 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				- CONTAINS ROOTLETS AT 2.0 FT					
				INCREASE CARBONATE AT 2.5 FT					
5				@ 6.5 FT					
				DAKOTA SANDSTONE: HIGHLY WEATHERED SANDSTONE, WEAK TO MED STRONG, PINKISH WHITE (2.5YR-8/2)					VERY HARD DIGGING
				DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG FINE GRAINED, PALE YELLOW (2.5Y-8/2-8/3)					
				BOTTOM OF TEST PIT AT 7.5 FT					
10									

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BORING LOG

Project No.: SC0634 Page 1 of 1
Site Name: WHITE MESA MILL (BLANDING) Date Started: 11/8/12
Boring I.D.: TP12-10 Date Completed: 11/8/12
Geologist/Eng.: J. WARNER Borehole Diameter: 24 INCH BUCKET
Drilling Company: Borehole Depth: 9.5 FT
Drilling Method: BACKHOE JD 310 Depth to Water: N/A
Comments: N37.52464 W109.51260° (N88W)

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1215		SURFACE: SILTY FINE TO VERY FINE SAND, GRASS					12 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				TOP OF CARBONATE HORIZON, GRADUAL CHANGE INTO WEATHERED SANDSTONE AT 3.0 FT					
				@4.5 FT					
5				DAKOTA SANDSTONE: HIGHLY WEATHERED SANDSTONE, WEAK TO MED STRONG, PINKISH WHITE (7.5YR- 8/2)					
				@ 9.0 FT					
				DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PALE YELLOW (2.5Y - 8/2 TO 8/3)					VERY HARD DIGGING
10				BOTTOM OF THE TEST PIT AT 9.5 FT					

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BORING LOG

Project No.:	SCO 634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/9/12
Boring I.D.:	TP12-11	Date Completed:	11/9/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	12.0 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N37.52512° W109.51098° (N25W)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
0		0720		SURFACE: SILTY FINE TO VERY FINE SAND, GRASSES RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR 4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM] TOP OF CARBONATE HORIZON AT 2.0 FT, GRADUAL CHANGE INTO WEATHERED SANDSTONE	SM				24 FT TRENCH
	X			@ 3.5 FT DAKOTA SANDSTONE HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO PINK (10YR 8/1 TO 8/2) - CONTAINS ROOTLETS TO 4FT					
5	X								
10									
	X			@ 11.0 FT DAKOTA SANDSTONE: MODERATELY WEATHERED, WEAK TO MED STRONG FINE GRAINED SANDSTONE, WHITE TO PINKISH WHITE (10YR 8/1 TO 8/2) BOTTOM OF TEST PIT AT 12.0 FT					VERY HARD DIGGING

Reviewed by: ____________ R.G.# ____________

Geosyntec consultants

BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/9/12
Boring I.D.:	TP12-12	Date Completed:	11/9/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	8.0 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N37. 52479' W109.50859' (S65W)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1230		SURFACE: SILTY FINE TO VERY FINE SAND, BRUSH RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]					HEAVY RAIN PRESENT 16 FT TRENCH
				TOP OF CARBONATE HORIZON AT 2 FT, GRADUALLY BECOMES WEATHERED SANDSTONE					
5									
				@ 6.5 FT DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO WHITE (7.5YR-8/2 TO 8/3) BECOMES PALE YELLOW (2.5Y-8/2-8/3)					
			@7.5	DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PALE YELLOW TO WHITE					VERY HARD DIGGING
10				BOTTOM OF TEST PIT AT 8.0 FT					

Reviewed by: ______________________ R.G.# ______________

Geosyntec consultants

BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/8/12
Boring I.D.:	TP12-13	Date Completed:	11/8/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	2.0 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N 37.52419° W 109.51025° (S70W)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0920		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS					17 FT TRENCH
			@0.5FT	RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO PINK (2.5YR-8/2 TO 8/3)					
			@2.0FT	DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, VERY PALE YELLOW (10YR-8/3)					VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 2.0 FT					

Reviewed by: ______________________ R.G.# ______________

Geosyntec consultants

BORING LOG

Project No.: SCO 634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-14
Geologist/Eng.: J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N 37.52431° W109.50749° (S88W)

Page 1 of 1
Date Started: 11/8/12
Date Completed: 11/8/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 7.5 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0745		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				16 FT TRENCH
				- CONTAINS ROOTLETS AT 2.5 FT					
				@ 4.5 FT					
5				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG FINE GRAINED, PINKISH WHITE TO PINK (2.5YR-8/2 TO 8/3)					
				@ 7.5 FT					
				DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, WHITE TO VERY PALE BROWN (10YR-8/1 TO 8/2)					↓ VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 7.5 FT					
10									

Reviewed by: ____________ R.G.# ____________

Geosyntec consultants

BORING LOG

Project No.: SC0634
Page 1 of 1
Site Name: WHITE MESA MILL (BLANDING)
Date Started: 11/8/12
Boring I.D.: TP12-15
Date Completed: 11/8/12
Geologist/Eng.: J. WARNER
Borehole Diameter: 24 INCH BUCKET
Drilling Company:
Borehole Depth: 6.5 FT
Drilling Method: BACKHOE JD 310
Depth to Water: N/A
Comments: N 37. 52361° W109. 51167° (SGOW)

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0950		SURFACE: SILTY FINE TO VERY FINE SAND, GRASS, BUSHES					15 FT TRENCH
				RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR- 4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				
				- CONTAINS ROOTLETS AT 1.5 FT					
				TOP OF CARBONATE HORIZON, GRADUAL CHANGE INTO WEATHERED SANDSTONE @ 3.5 FT					
5				- CONTAINS ROOTLETS TO 5.0 FT					
				@ 5.5 FT					
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO PINK (2.5YR 8/2 TO 8/3)					VERY HARD DIGGING
				DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, VERY PALE YELLOW (10YR- 8/3)					
				BOTTOM OF TEST PIT AT 6.5 FT					
10									

Reviewed by: ______ R.G.# ______

Geosyntec consultants

BORING LOG

Project No.:	SC0634	Page	1 of 1
Site Name:	WHITE MESA MILL (BLANDING)	Date Started:	11/8/12
Boring I.D.:	TP12-16	Date Completed:	11/8/12
Geologist/Eng.:	J. WARNER	Borehole Diameter:	24 INCH BUCKET
Drilling Company:		Borehole Depth:	6.5 FT
Drilling Method:	BACKHOE JD 310	Depth to Water:	N/A
Comments:	N 37.52329° W109.50913° (S40E)		

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0830		SURFACE: SILTY FINE TO VERY FINE SAND, SHORT GRASS					14 FT TRENCH
			@0.5	RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]					
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE (5YR-8/1 TO 8/2)					
				INCREASE SILTY FINE TO VERY FINE SAND BECOMES REDDISH BROWN (5YR-6/4)					
5									
				@ 6.0 FT					
				DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, WHITE TO VERY PALE BROWN (10YR-8/1 TO 8/2)					VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 6.5 FT					
10									

Reviewed by: ______________________ R.G.# ______________

Geosyntec consultants

BORING LOG

Project No.: SC0634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-17
Geologist/Eng.: J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N37.52253° W109.51065° (N8E)

Page 1 of 1
Date Started: 11/9/12
Date Completed: 11/9/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 3.5 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0910		SURFACE: SILTY FINE TO VERY FINE SAND, BRUSH					14 FT TRENCH
			@0.5	RESIDUAL SOIL: SILTY FINE TO VERY FINE SAND, YELLOWISH RED					
				DAKOTA SANDSTONE: HIGHLY WEATHERED, WEAK TO MED STRONG, FINE GRAINED, PINKISH WHITE TO WHITE (7.5YR - 8/2 TO 8/3) - CONTAINS RIVLETS TO 1.5 FT					
			@2.0 FT	DAKOTA SANDSTONE: MODERATLY WEATHERED, STRONG, FINE GRAINED SANDSTONE, VERY PALE YELLOW (2.5Y - 8/2 TO 8/3)					VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 3.5 FT					

Reviewed by: R.G.#

Geosyntec consultants

BORING LOG

Project No.: SC0634	Page 1 of 1
Site Name: WHITE MESA MILL (BLANDING)	Date Started: 11/9/12
Boring I.D.: TP12-18	Date Completed: 11/9/12
Geologist/Eng.: J. WARNER	Borehole Diameter: 24 INCH BUCKET
Drilling Company:	Borehole Depth: 6.5 FT
Drilling Method: BACKHOE JD 310	Depth to Water: N/A
Comments: N37.52223° W109.50835° (N30W)	

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		0930		SURFACE: SILTY FINE TO VERY FINE SAND, BRUSH RESIDUAL SOIL: DENSE, MOIST, YELLOWISH RED (5YR-4/6 TO 5/6) SILTY FINE TO VERY FINE SAND [SM]	SM				RAIN PRESENT 18 FT TRENCH
5				TOP OF CARBONATE HORIZON AT 4.5 FT, GRADUAL CHANGE INTO WEATHERED SANDSTONE					
				@ 6.0 FT DAKOTA SANDSTONE: MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PALE YELLOW (2.5Y - 8/2 TO 8/3) BOTTOM OF TEST PIT AT 6.5 FT					VERY HARD DIGGING
10									

Reviewed by: ______________________ R.G.# ______________

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BORING LOG

Project No.: SC0634
Site Name: WHITE MESA MILL (BLANDING)
Boring I.D.: TP12-19
Geologist/Eng.: J. WARNER
Drilling Company:
Drilling Method: BACKHOE JD 310
Comments: N37.52550' W109.50968' (N15W)
TP12-19 MOVED (S26W) 52 FT OFF ACCESS RD

Page 1 of 1
Date Started: 11/9/12
Date Completed: 11/9/12
Borehole Diameter: 24 INCH BUCKET
Borehole Depth: 1.5 FT
Depth to Water: N/A

Depth	Sample Interval	Time	Blows / 6 in.	Lithologic Description	Symbolic Log	% Recovery	ASTM Code	OVA Headspace	Comments
		1200		SURFACE: SILTY FINE TO VERY FINE SAND, BRUSH RESIDUAL SOIL; TOP OF CARBONATE HORIZ AT 1.5 FT, GRADUAL CHANGE INTO WEATHERED SANDSTONE					RAIN + LIGHTNING PRESENT; 14 FT TRENCH
			@1.5 FT	DAKOTA SANDSTONE MODERATELY WEATHERED, STRONG, FINE GRAINED SANDSTONE, PALE YELLOW (2.5Y- 8/2 TO 8/3)					VERY HARD DIGGING
				BOTTOM OF TEST PIT AT 1.5 FT					

Reviewed by: R.G.#

Appendix E-3

Geotechnical Laboratory Data

Excel Geotechnical Testing, Inc.
"Excellence in Testing"

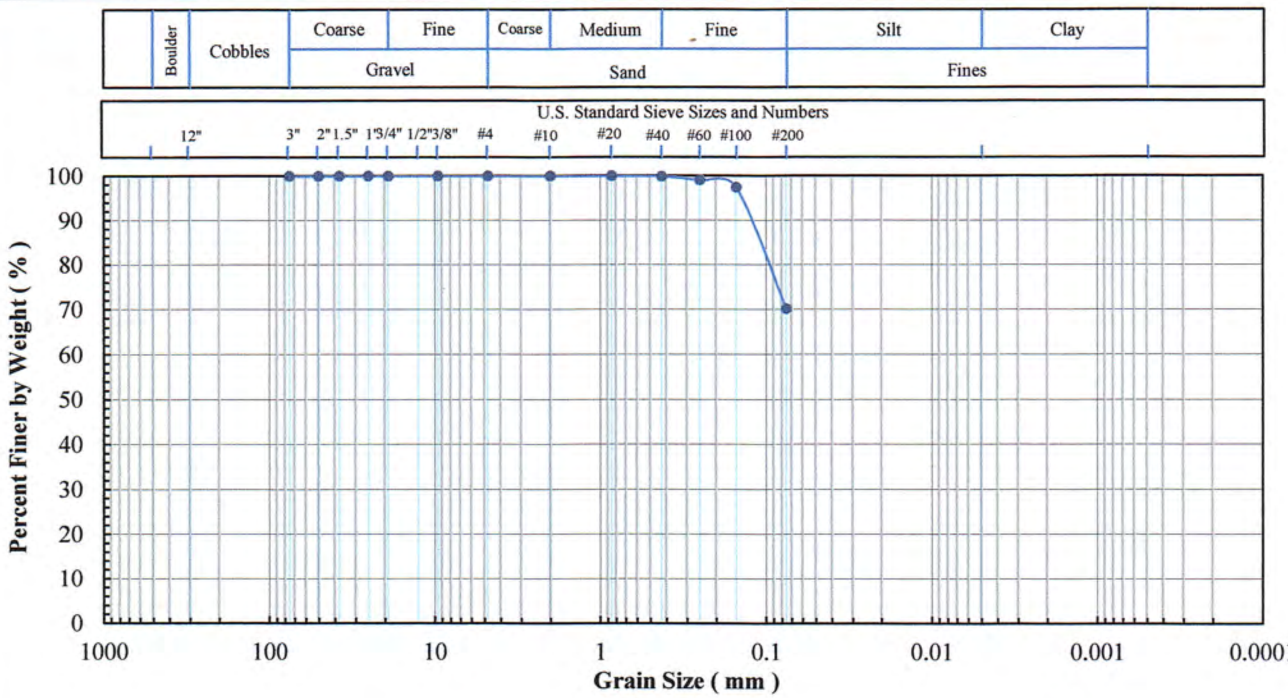
953 Forrest Street, Roswell, Georgia 30075
Tel: (770) 910 7537 Fax: (770) 910 7538

Project Name:	Energy Fuels - Cell 5A and 5B
Project No:	574
Client Sample ID:	TP12-11 (2.5')
Lab Sample No:	12K026

ASTM C 136, D 422, D 854, D 1140, D2216, D 2487, D4318

SOIL INDEX PROPERTIES

Grain Size, Spec. Gravity, Moist. Content, Eng. Classification, Atterberg Limits



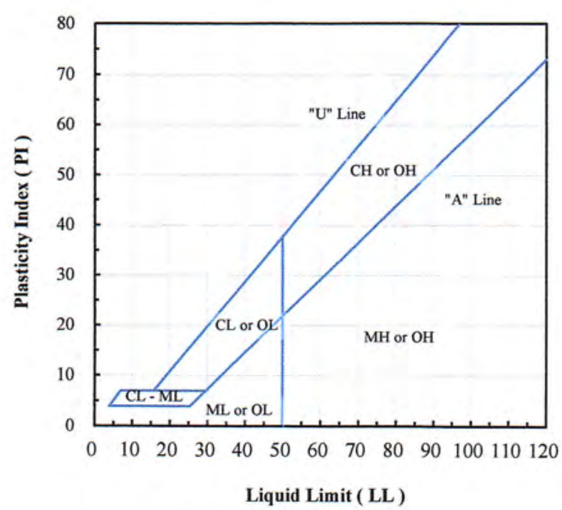
Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2.00	100.0
#20	0.850	100.0
#40	0.425	99.9
#60	0.250	99.1
#100	0.150	97.5
#200	0.075	70.2

Specific Gravity (-):	

Hydrometer Particle Diameter (mm)	% Finer

Gravel (%):	
Sand (%):	29.8
Fines (%):	70.2
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	
Coeff. Curv. (Cc):	



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (-)	PL (-)	PI (-)	Engineering Classification
TP12-11 (2.5')	12K026	4.2	70.2	NP	NP	NP	ML - Sandy silt

Note(s):

12-21-12
NSR

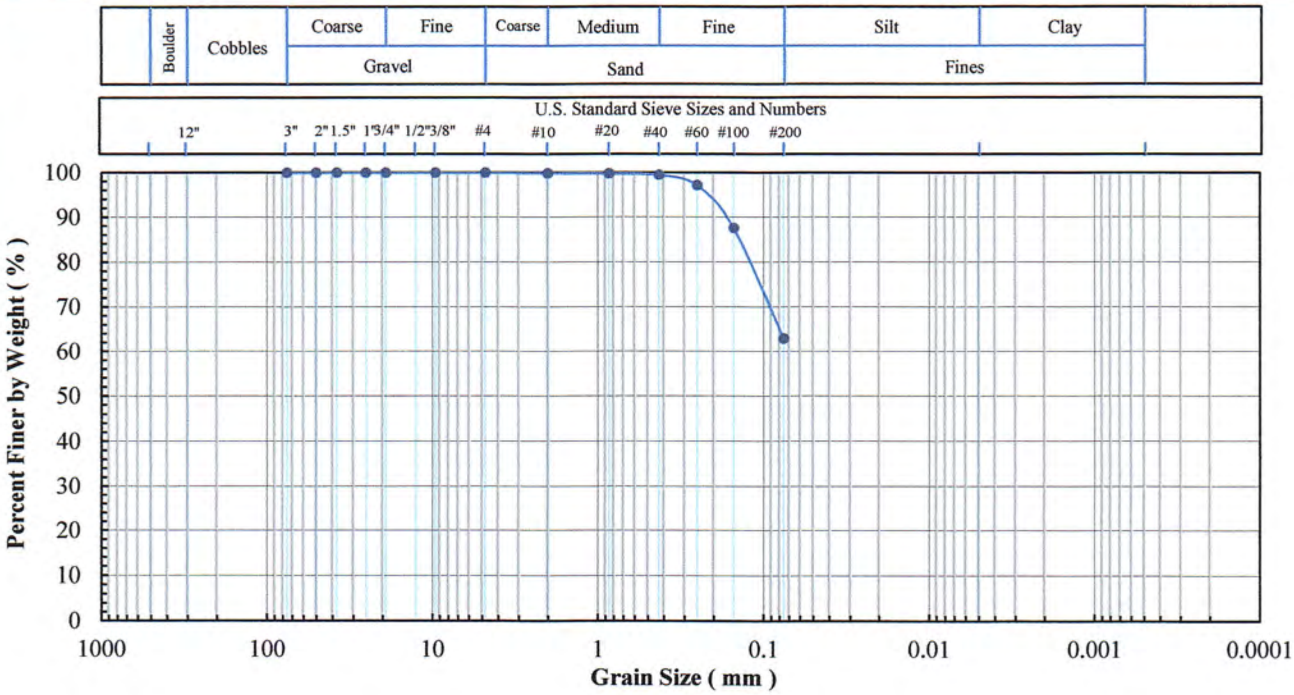
Excel Geotechnical Testing, Inc.
"Excellence in Testing"
953 Forrest Street, Roswell, Georgia 30075
Tel: (770) 910 7537 Fax: (770) 910 7538

Project Name:	Energy Fuels - Cell 5A and 5B
Project No:	574
Client Sample ID:	TP12-4 (1.0')
Lab Sample No:	12K025

ASTM C 136, D 422, D 854, D 1140, D2216, D 2487, D4318

SOIL INDEX PROPERTIES

Grain Size, Spec. Gravity, Moist. Content, Eng. Classification, Atterberg Limits



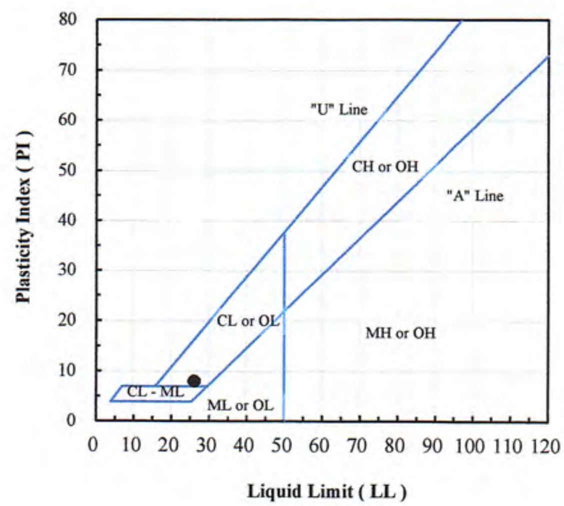
Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
3/8"	9.5	100.0
#4	4.75	100.0
#10	2.00	99.9
#20	0.850	99.8
#40	0.425	99.5
#60	0.250	97.2
#100	0.150	87.6
#200	0.075	63.0

Specific Gravity (-):	

Hydrometer Particle Diameter (mm)	% Finer

Gravel (%):	
Sand (%):	37.0
Fines (%):	63.0
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	
Coeff. Curv. (Cc):	



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (-)	PL (-)	PI (-)	Engineering Classification
TP12-4 (1.0')	12K025	4.0	63.0	26	18	8	CL - Sandy lean clay

Note(s):

12-4-12
NSR

Excel Geotechnical Testing, Inc.
"Excellence in Testing"
953 Forrest Street, Roswell, Georgia 30075
Tel: (770) 910 7537 Fax: (770) 910 7538

LAST PAGE

Test Applicability and Limitations:

- The results are applicable only for the materials received at the laboratory and tested which may or may not be representative of the materials at the site.

Storage Policy:

- Uncontaminated Material: All samples (or what is left) will be archived for a period of 3 months from the date received. Thereafter the samples will be discarded unless a written request for extended storage is received. A rate of $1.00 per sample per day will be applied after the initial 3 month storage period.

- Contaminated Material: All samples (or what is left) will be archived for a period of 3 months from the date received. Thereafter, the samples will be returned o the project manager or his/her designated receiver unless a written request for extended storage is received. A rate of $1.30 per sample per day will be applied after the initial 3 months storage.

APPENDIX F

Chemical Resistance Charts

Chemical Resistance Chart

GSE is the world's leading supplier of high quality, polyethylene geomembranes and geonets. GSE polyethylene geomembranes and geonets are resistant to a great number and combinations of chemicals. Note that the effect of chemicals on any material is influenced by a number of variable factors such as temperature, concentration, exposed area and duration. Many tests have been performed that use geomembranes and geonets and certain specific chemical mixtures. Naturally, however, every mixture of chemicals cannot be tested for, and various criteria may be used to judge performance. Reported performance ratings may not apply to all applications of a given material in the same chemical. Therefore, these ratings are offered as a guide only.

Medium	Concentration	Resistance at:	
		20° C (68° F)	60° C (140° F)
A			
Acetic acid	100%	S	L
Acetic acid	10%	S	S
Acetic acid anhydride	100%	S	L
Acetone	100%	L	L
Adipic acid	sat. sol.	S	S
Allyl alcohol	96%	S	S
Aluminum chloride	sat. sol.	S	S
Aluminum fluoride	sat. sol.	S	S
Aluminum sulfate	sat. sol.	S	S
Alum	sol.	S	S
Ammonia, aqueous	dil. sol.	S	S
Ammonia, gaseous dry	100%	S	S
Ammonia, liquid	100%	S	S
Ammonium chloride	sat. sol.	S	S
Ammonium fluoride	sol.	S	S
Ammonium nitratesat. sol.	S	S	
Ammonium sulfate	sat. sol.	S	S
Ammonium sulfide	sol.	S	S
Amyl acetate	100%	S	L
Amyl alcohol	100%	S	L
B			
Barium carbonate	sat. sol.	S	S
Barium chloride	sat. sol.	S	S
Barium hydroxide	sat. sol.	S	S
Barium sulfate	sat. sol.	S	S
Barium sulfide	sol.	S	S
Benzaldehyde	100%	S	L
Benzene	—	L	L
Benzoic acid	sat. sol.	S	S
Beer	—	S	S
Borax (sodium tetraborate)	sat. sol.	S	S
Boric acid	sat. sol.	S	S
Bromine, gaseous dry	100%	U	U
Bromine, liquid	100%	U	U
Butane, gaseous	100%	S	S
1-Butanol	100%	S	S
Butyric acid	100%	S	L
C			
Calcium carbonate	sat. sol.	S	S
Calcium chlorate	sat. sol.	S	S
Calcium chloride	sat. sol.	S	S
Calcium nitrate	sat. sol.	S	S
Calcium sulfate	sat. sol.	S	S
Calcium sulfide	dil. sol.	L	L
Carbon dioxide, gaseous dry	100%	S	S
Carbon disulfide	100%	L	U
Carbon monoxide	100%	S	S
Chloracetic acid	sol.	S	S
Carbon tetrachloride	100%	L	U
Chlorine, aqueous solution	sat. sol.	L	U
Chlorine, gaseous dry	100%	L	U
Chloroform	100%	U	U
Chromic acid	20%	S	L
Chromic acid	50%	S	L
Citric acid	sat. sol.	S	S
Copper chloride	sat. sol.	S	S
Copper nitrate	sat. sol.	S	S
Copper sulfate	sat. sol.	S	S
Cresylic acid	sat. sol.	L	—
Cyclohexanol	100%	S	S
Cyclohexanone	100%	S	L
D			
Decahydronaphthalene	100%	S	L
Dextrine	sol.	S	S
Diethyl ether	100%	L	—
Dioctylphthalate	100%	S	L
Dioxane	100%	S	S
E			
Ethanediol	100%	S	S
Ethanol	40%	S	L
Ethyl acetate	100%	S	U
Ethylene trichloride	100%	U	U
F			
Ferric chloride	sat. sol.	S	S
Ferric nitrate	sol.	S	S
Ferric sulfate	sat. sol.	S	S
Ferrous chloride	sat. sol.	S	S
Ferrous sulfate	sat. sol.	S	S
Fluorine, gaseous	100%	U	U
Fluorosilicic acid	40%	S	S
Formaldehyde	40%	S	S
Formic acid	50%	S	S
Formic acid	98-100%	S	S
Furfuryl alcohol	100%	S	L
G			
Gasoline	—	S	L
Glacial acetic acid	96%	S	L
Glucose	sat. sol.	S	S
Glycerine	100%	S	S
Glycol	sol	S	S
H			
Heptane	100%	S	U
Hydrobromic acid	50%	S	S
Hydrobromic acid	100%	S	S
Hydrochloric acid	10%	S	S
Hydrochloric acid	35%	S	S
Hydrocyanic acid	10%	S	S
Hydrofluoric acid	4%	S	S
Hydrofluoric acid	60%	S	L
Hydrogen	100%	S	S
Hydrogen peroxide	30%	S	L
Hydrogen peroxide	90%	S	U
Hydrogen sulfide, gaseous	100%	S	S
Lactic acid	100%	S	S
Lead acetate	sat. sol.	S	—
Magnesium carbonate	sat. sol.	S	S
Magnesium chloride	sat. sol.	S	S
Magnesium hydroxide	sat. sol.	S	S
Magnesium nitrate	sat. sol.	S	S
Maleic acid	sat. sol.	S	S
Mercuric chloride	sat. sol.	S	S
Mercuric cyanide	sat. sol.	S	S
Mercuric nitrate	sol.	S	S

GSE ENVIRONMENTAL™

Medium	Concentration	Resistance at:	
		20° C (68° F)	60° C (140° F)
Mercury	100%	S	S
Methanol	100%	S	S
Methylene chloride	100%	L	—
Milk	—	S	S
Molasses	—	S	S
N			
Nickel chloride	sat. sol.	S	S
Nickel nitrate	sat. sol.	S	S
Nickel sulfate	sat. sol.	S	S
Nicotinic acid	dil. sol.	S	—
Nitric acid	25%	S	S
Nitric acid	50%	S	U
Nitric acid	75%	U	U
Nitric acid	100%	U	U
O			
Oils and Grease	—	S	L
Oleic acid	100%	S	L
Orthophosphoric acid	50%	S	S
Orthophosphoric acid	95%	S	L
Oxalic acid	sat. sol.	S	S
Oxygen	100%	S	L
Ozone	100%	L	U
P			
Petroleum (kerosene)	—	S	L
Phenol	sol	S	S
Phosphorus trichloride	100%	S	L
Photographic developer	cust. conc.	S	S
Picric acid	sat. sol.	S	—
Potassium bicarbonate	sat. sol.	S	S
Potassium bisulfide	sol.	S	S
Potassium bromate	sat. sol.	S	S
Potassium bromide	sat. sol.	S	S
Potassium carbonate	sat. sol.	S	S
Potassium chlorate	sat. sol.	S	S
Potassium chloride	sat. sol.	S	S
Potassium chromate	sat. sol.	S	S
Potassium cyanide	sol.	S	S
Potassium dichromate	sat. sol.	S	S
Potassium ferricyanide	sat. sol.	S	S
Potassium ferrocyanide	sat. sol.	S	S
Potassium fluorid	sat. sol.	S	S
Potassium hydroxide	10%	S	S
Potassium hydroxide	sol.	S	S
Potassium hypochlorite	sol.	S	L
Potassium nitrate	sat. sol.	S	S
Potassium orthophosphate	sat. sol.	S	S
Potassium perchlorate	sat. sol.	S	S
Potassium permanganate	20%	S	S
Potassium persulfate	sat. sol.	S	S
Potassium sulfate	sat. sol.	S	S
Potassium sulfite	sol.	S	S
Propionic acid	50%	S	S
Propionic acid	100%	S	L
Pyridine	100%	S	L
Q			
Quinol (Hydroquinone)	sat. sol.	S	S
S			
Salicylic acid	sat. sol.	S	S
Silver acetate	sat. sol.	S	S
Silver cyanide	sat. sol.	S	S
Silver nitrate	sat. sol.	S	S
Sodium benzoate	sat. sol.	S	S
Sodium bicarbonate	sat. sol.	S	S
Sodium biphosphate	sat. sol.	S	S
Sodium bisulfite	sol.	S	S
Sodium bromide	sat. sol.	S	S
Sodium carbonate	sat. sol.	S	S
Sodium chlorate	sat. sol.	S	S
Sodium chloride	sat. sol.	S	S
Sodium cyanide	sat. sol.	S	S
Sodium ferricyanide	sat. sol.	S	S
Sodium ferrocyanide	sat. sol.	S	S
Sodium fluoride	sat. sol.	S	S
Sodium hydroxide	40%	S	S
Sodium hydroxide	sat. sol.	S	S
Sodium hypochlorite	15% active chlorine	S	S
Sodium nitrate	sat. sol.	S	S
Sodium nitrite	sat. sol.	S	S
Sodium orthophosphate	sat. sol.	S	S
Sodium sulfate	sat. sol.	S	S
Sodium sulfide	sat. sol.	S	S
Sulfur dioxide, dry	100%	S	S
Sulfur trioxide	100%	U	U
Sulfuric acid	10%	S	S
Sulfuric acid	50%	S	S
Sulfuric acid	98%	S	U
Sulfuric acid	fuming	U	U
Sulfurous acid	30%	S	S
T			
Tannic acid	sol.	S	S
Tartaric acid	sol.	S	S
Thionyl chloride	100%	L	U
Toluene	100%	L	U
Triethylamine	sol.	S	L
U			
Urea	sol.	S	S
Urine	—	S	S
W			
Water	—	S	S
Wine vinegar	—	S	S
Wines and liquors	—	S	S
X			
Xylenes	100%	L	U
Y			
Yeast	sol.	S	S
Z			
Zinc chloride	sat. sol.	S	S
Zinc (II) chloride	sat. sol.	S	S
Zinc (IV) chloride	sat. sol.	S	S
Zinc oxide	sat. sol.	S	S
Zinc sulfate	sat. sol.	S	S

Specific immersion testing should be undertaken to ascertain the suitability
of chemicals not listed above with reference to special requirements.

Notes:
(S) Satisfactory: Liner material is resistant to the given reagent at the given concentration and temperature. No mechanical or chemical degradation is observed.
(L) Limited Application Possible: Liner material may reflect some attack. Factors such as concentration, pressure and temperature directly affect liner performance against the given media. Application, however, is possible under less severe conditions, e.g. lower concentration, secondary containment, additional liner protections, etc.
(U) Unsatisfactory: Liner material is not resistant to the given reagent at the given concentration and temperature. Mechanical and/or chemical degradation is observed.
(–) Not tested
sat. sol. = Saturated aqueous solution, prepared at 20°C (68°F)
sol. = aqueous solution with concentration above 10% but below saturation level
dil. sol. = diluted aqueous solution with concentration below 10%
cust. conc. = customary service concentration

GSE is a leading manufacturer and marketer of geosynthetic lining products and services. We've built a reputation of reliability through our dedication to providing consistency of product, price and protection to our global customers.

Our commitment to innovation, our focus on quality and our industry expertise allow us the flexibility to collaborate with our clients to develop a custom, purpose-fit solution.

[DURABILITY RUNS DEEP] For more information on this product and others, please visit us at GSEworld.com, call 800.435.2008 or contact your local sales office.

GSE ENVIRONMENTAL™

CHEMICAL RESISTANCE LIST

GENERAL INFORMATION

Concerning the expected lifetime the data in the chemical resistance table are referring to the information on the expected lifetime (depending on the temperature) specified in the standards DIN8074, DIN8075, DIN8077, DIN8078, ISO10931 and the standard DVS2205. For chemical media having an influence (swelling, stress cracking, oxidizing) on the material the expected lifetime can only be reached in case that the correct chemical resistance factors are used for the dimensioning of the components. Concerning special materials (PPs, PPs-el, HDPE-el; PE100 RC) and sealing materials the chemical resistance has to be checked by contacting the technical department of AGRU Kunststofftechnik (Email: anwt@agru.at).

All data in the media list are based on generally available information, experience and information of the raw material suppliers, the data are therefore just indicative for the chemical resistance of AGRU's thermoplastic materials.

Products produced by AGRU Kunststofftechnik GmbH have not been tested on the resistance against the media, described in the chemical resistance list, so the information in the chemical resistance list is based on analog circuits.

A legal guarantee of certain properties, nor the suitability for the individual case cannot be derived from this chemical resistance list due to the possible influence of many factors that may affect processing and the application and do not relieve users from their responsibility of carrying out their own tests and experiments.

For chemical inquiries we kindly ask to send the following questionnaire with all information to anwt@agru.at respectively to wi@agru.at.

For return shipments of products, which have been in contact with chemical media, it is kindly requested to fill out the following blank.

CLASSIFICATION

+: Chemically resistant

-: Not resistant

+/-(q): Swelling effect (diffusion and permeation): a chemical reduction factor of 1.1-1.6 has to be considered for the dimensioning of the components (according to the standards DVS, DIBt and based on statements / recommendations of the raw material suppliers)

+/-(s): Stress cracking property: a chemical reduction factor of 1.1-2.0 has to be considered for the dimensioning of the components (according to the standards DVS, DIBt and based on statements / recommendations of the raw material suppliers)

+/-(o): Oxidizing influence: a chemical reduction factor of 1.1-2.0 has to be considered for the dimensioning of the components (according to the standards DVS, DIBt and based on statements / recommendations of the raw material suppliers)

CONCENTRATION

TR: Technically pure
GL: Saturated solution
H: Commercial composition
S: Suspension
VL: Diluted solution

CHEMISCHE BESTÄNDIGKEITSLISTE

GENERELL INFORMATION

Bezüglich der zu erwartenden Lebensdauer beziehen sich die Aussagen in der chemischen Beständigkeitsliste auf die Lebensdauerangaben in Abhängigkeit von der Temperatur, festgelegt in den Normen DIN8074, DIN8075, DIN8077, DIN8078 und ISO10931 sowie der DVS Richtlinie 2205. Bei Medien, die einen chemischen Einfluss (quellend, spannungsrissauslösend, oxidierend) auf die Werkstoffe haben, kann die zu erwartende Lebensdauer nur dann erreicht werden, wenn die entsprechenden chemischen Abminderungsfaktoren für die Bauteildimensionierung korrekt berücksichtigt werden. Für Sonderwerkstoffe (PPs, PPs-el, PEHD-el, PE100 RC) und Dichtungswerkstoffe ist die chemische Beständigkeit mit der Anwendungstechnik der Firma AGRU Kunststofftechnik (Email: anwt@agru.at) abzuklären.

Alle Angaben in der Medienliste beruhen auf allgemein erhältlichen Informationen, Erfahrungen und Informationen der Rohstofflieferanten und sind somit Richtwerte zur Einschätzung der chemischen Beständigkeit.

Produkte von AGRU Kunststofftechnik GmbH wurden nicht auf Beständigkeit gegen diese Medien geprüft; es handelt sich daher um Analogschlüsse.

Eine rechtliche verbindliche Zusicherung bestimmter Eigenschaften oder die Eignung im Einzelfall kann aufgrund der Fülle möglicher Einflüsse bei der Verarbeitung und Anwendung nicht abgeleitet werden und befreien den Anwender nicht von eigenen Prüfungen und Versuchen.

Für chemische Anfragen bitten wir, das nachstehende Formular auszufüllen und an anwt@agru.at bzw. wi@agru.at zu senden.

Für Rücksendungen von Produkten, die mit chemischen Medien in Berührung waren, wird gebeten, folgendes Formular auszufüllen.

A G R U Kunststofftechnik GmbH | A-4540 Bad Hall Austria, Ing.-Pesendorfer-Str. 31 | Tel.: ++43 7258 790-0, Fax: ++43 7258 3863 | Firmenbuchnummer: 171838 d, Firmenbuchgericht: LG Steyr

KLASSIFIZIERUNG

+: Chemisch beständig

-: Nicht beständig

+/-(q): Bedingt beständig - Quellende Wirkung (Diffusion und Permeation): ist bei der Bauteildimensionierung mit chemischen Abminderungsfaktoren von 1,1-1,6 zu berücksichtigen (gemäß den DVS, DIBt Richtlinien und basierend auf Stellungnahmen / Empfehlungen der Rohstofflieferanten)

+/-(s): Bedingt beständig - Spannungsrissauslösende Wirkung: ist bei der Bauteildimensionierung mit chemischen Abminderungsfaktoren von 1,1-2,0 zu berücksichtigen (gemäß den DVS, DIBt Richtlinien und basierend auf Stellungnahmen / Empfehlungen der Rohstofflieferanten)

+/-(o): Bedingt beständig - Oxidierende Wirkung: ist bei der Bauteildimensionierung mit chemischen Abminderungsfaktoren von 1,1-2,0 zu berücksichtigen (gemäß den DVS, DIBt Richtlinien und basierend auf Stellungnahmen / Empfehlungen der Rohstofflieferanten)

KONZENTRATION

TR: Technisch rein
GL: Gesättigte Lösung
H: Handelsübliche Zusammensetzung
S: Suspension
VL: Verdünnte Lösung

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
3-Aminopropyltriethoxysilan	3-Aminopropyltriethoxysilan	$C_9H_{23}NO_3Si$	TR	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	+/-(o)	+/-(o)	+	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Acetaldehyde	Acetaldehyd	CH_3CHO	40%	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Acetaldehyde	Acetaldehyd	CH_3CHO	TR	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Acetaldehyde + Acetic acid	Acetaldehyd + Essigsäure	$CH_3CHO + CH_3COOH$	all	20	+	+	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Acetamide	Acetamid	CO_3CONH_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetanilide	Acetanilid	$C_6H_5NHCOCH_3$	TR	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	+	+	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	+/-(q)
Acetate (Ester of acetic acid)	Essigsäureester	$CH_3COOC_2H_5$, $-OC_4H_9$, …	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetic acid	Essigsäure	CH_3COOH	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Acetic acid	Essigsäure	CH_3COOH	96%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Acetic acid	Essigsäure	CH_3COOH	80%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetic acid	Essigsäure	CH_3COOH	60%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Acetic acid	Essigsäure	CH_3COOH	50%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetic acid	Essigsäure	CH_3COOH	10%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetic anhydride	Essigsäureanhydrid (Acetanhydrid)	$(CH_3CO)_2O$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetone	Aceton	CH_3COCH_3	≤ 1%	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Acetone	Aceton	CH_3COCH_3	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Acetonitrile	Essigsäurenitril (Acetonnitril)	CH_3CN	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Acetophenone	Acetophenon	$C_6H_5COCH_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	-
				120	-	-	-	-
Acetyl acetone	Acetylaceton	$CH_3COCH_2COCH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Acetyl bromide	Acetylbromid	CH_3COBr	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Acetyl chloride	Acetylchlorid	CH_3COCl	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Acetylene	Acetylen	CHCH	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Acrylate	Acrylsäureester	$CH_2{=}CHCOOR$	60%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Acrylic acid	Acrylsäure	$CH_2{=}CHCOOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Acrylic acid butyl ester	Acrylsäurebutylester	$CH_2CHCOOC_4H_9$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Acrylonitrile	Acrylnitril	$CH_2{=}CHCN$	TR	20	+	+	+	+
				40	+	+	+/-(s)	+
				60	+/-(q)	+/-(q)	+/-(s)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Adipic acid	Adipinsäure	$HOOC(CH_2)_4COOH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Adipic acid dinonester	Adipinsäuredinonester	$(CH_2)_4(COOC_9H_{17})_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Adipic acid dioctyl ester	Adipinsäuredioctylester	$(CH_2)_4(COOC_8H_{15})_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Air	Luft	N_2, O_2…	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Alanindiacetic acid + Trisodium salt	Alanindiessigsäure + Trinatriumsalz		40%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Alcalic clay	Alkalische Tonerde	Al_2O_3 x Na_2O	H	20	+	+	-	+
				40	+	+	-	+
				60	+	+/-(s)	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Alcoholic spirits (Gin, Whiskey, etc.) approx. 40% ethyl alcohol	Spirituosen ca. 40% Ethylalkohol			20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Aliphatic hydrocarbons	Aliphatische Kohlenwasserstoffe	C_nH_{2n}	100-200ppm	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Alkylarylpolyglycolether	Alkylarylpolyglycolether		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Allyl acetate	Essigsaureallylester (Allylacetat)	$CH_3COOCH_2CHCH_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Allyl alcohol	Allylalkohol	$CH_2=CHCH_2OH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	-
				120	-	-	-	-
Allyl chloride (3-Chloropropene)	Allylchlorid (3-Chlorpropen)	CH_2CHCH_2Cl	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Aluminium acetate	Aluminiumacetat	$Al(CH_3COO)_2OH$	all	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Aluminium ammonium sulfate	Aluminiumammoniumsulfat	$AlNH_4(SO_4)_2 \times 12H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Aluminium chlorate	Aluminiumchlorat	$Al(ClO_3)_3$	≤ GL	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Aluminium chloride	Aluminiumchlorid	$AlCl_3$	10%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium chloride	Aluminiumchlorid	$AlCl_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium chloride sulfate	Aluminiumchloridsulfat	$AlClSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Aluminium fluoride	Aluminiumfluorid	AlF_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium hexafluorosilicate	Aluminiumhexafluorsilicat	$Al_2(SiF_6)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium hydroxide	Aluminiumhydroxid	$Al(OH)_3$	≤ GL	20	+	+	-	+
				40	+	+	-	+
				60	+	+/-(s)	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Aluminium iron(II) sulfate	Aluminiumeisen(II)sulfat	$Al_2Fe(SO_4)_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium metaphosphate	Aluminiummetaphosphat	$Al(PO_3)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium nitrate	Aluminiumnitrat	$Al(NO_3)_3 \times 9H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium oxide	Aluminiumoxid (Korund)	Al_2O_3	≤ GL	20	+	+	-	+
				40	+	+	-	+
				60	-	+/-(o)	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Aluminium oxychloride	Aluminiumoxychlorid	$AlOCl$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Aluminium polyhydroxychloro-sulfate	Aluminiumpolyhydroxychlorsulfat		≤ GL	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+
				120	-	-	-	-
Aluminium potassium sulfate	Aluminiumkaliumsulfat	$Al_2(SO_4)_3 \times K_2SO_4 \times 24H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Aluminium sulfate	Aluminiumsulfat	$Al_2(SO_4)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Amino acids	Aminosäuren	$RCHNH_2COOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	-
				120	-	-	-	-
Aminobenzoic acid	Aminobenzoesäure	$NH_2C_6H_4COOH$	10%	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Aminoethoxyethanol	Aminoethoxyethanol	$C_4H_{11}NO_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Aminonaphthalinsulfonic acid	Aminonaphthalinsulfonsäure	$C_{10}H_6NH_2SO_3H$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Aminotrimethylenphosphoric acid	Aminotrimethylenphosphorsäure		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Ammoniac	Ammoniak	NH_3	TR	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Ammonium acetate	Ammoniumacetat	CH_3COONH_4	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Ammonium aluminium sulfate	Ammoniumaluminiumsulfat	$NH_4Al(SO_4)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium bromide	Ammoniumbromid	NH_4Br	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium carbonate	Ammoniumcarbonat	$(NH_4)_2CO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium chloride	Ammoniumchlorid	NH_4Cl	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ammonium citrate	Ammoniumcitrat	$(NH_4)_2C_6H_6O_7$	VL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Ammonium dichromate	Ammoniumdichromat	$(NH_4)_2Cr_2O_7$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	+/-(o)	+/-(o)
				120	-	-	-	-
Ammonium dihydrogen-phosphate	Ammoniumdihydrogenphosphat	$NH_4H_2PO_4$	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium fluoride	Ammoniumfluorid	NH_4F	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium fluoroborate	Ammoniumfluorborat	NH_4BF_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium formiate	Ammoniumformiat	NH_4COOH	≤ GL	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ammonium hexafluorosilicate	Ammoniumhexafluorsilicat	$(NH_4)_2SiF_6$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium hydrogenfluoride	Ammoniumhydrogenfluorid	NH_4HF_2	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium hydrogensulfide	Ammoniumhydrogensulfid	NH_4HS	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium hydrogensulfite	Ammoniumhydrogensulfit	NH_4HSO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium hydrogenphosphate	Ammoniumhydrogenphosphat	$(NH_4)_2HPO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ammonium hydroxide	Ammoniumhydroxid (Salmiakgeist)	NH_4OH	≤ GL	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Ammonium hydroxide	Ammoniumhydroxid (Salmiakgeist)	NH_4OH	30%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Ammonium iron(II) sulfate	Ammoniumeisen(II)sulfat	$(NH_4)_2Fe(SO_4)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium metaphosphate	Ammoniummetaphosphat	NH_4PO_3	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium molybdate	Ammoniummolybdat	NH_4MoO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium nitrate	Ammoniumnitrat	NH_4NO_3	10%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium nitrate	Ammoniumnitrat	NH_4NO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium orthophosphate	Ammoniumorthophosphat	$(NH_4)PO_4$ x $3H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium oxalate	Ammoniumoxalat	$(NH_4OOC)_2$	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ammonium persulfate	Ammoniumperoxodisulfat	$(NH_4)_2S_2O_8$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(o)	+/-(o)	+	+
				80	-	+/-(o)	+	+
				100	-	-	+	-
				120	-	-	-	-
Ammonium phosphate	Ammoniumphosphat	$(NH_4)_3PO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ammonium sulfamate	Ammoniumsulfamat	$NH_4OSO_2NH_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium sulfate	Ammoniumsulfat	$(NH_4)_2SO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium sulfide	Ammoniumsulfid	$(NH_4)_2S$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium sulfite	Ammoniumsulfit	$(NH_4)_2SO_3$ x H_2O	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium tetrafluoroborate	Ammoniumtetrafluorborat	NH_4BF_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ammonium thiocyanate	Ammoniumthiocyanat	NH_4SCN	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Ammonium tungstate	Ammoniumwolframat	$(NH_4)_2WO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Amyl acetate	Amylacetat	$CH_3(CH_2)_4OOCCH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Amyl alcohol	Amylalkohol	$CH_3(CH_2)_4OH$	TR	20	+	+	+	+
(1-Pentanol)	(1-Pentanol)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Amyl chloride	Pentylchlorid	$C_5H_{11}Cl$	TR	20	-	-	+	+
	(1-Chlorpentan)			40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Amyl sec. alcohol	Amylsekundäralkohol	$CH_3(CH_2)_2CHOHCH_3$	TR	20	+	+	+	+
(2-Pentanol)	(2-Pentanol)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Aniline	Anilin	$C_6H_5NH_2$	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Aniline hydrochloride	Anilinchlorhydrat	$C_6H_5NH_3Cl$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Anisole	Anisol	$C_6H_5OCH_3$	TR	20	+/-(s)	+/-(s)	+	+
	(Methoxybenzol,			40	+/-(s)	+/-(s)	+/-(s)	+
	Methylphenylether)			60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Anthrachinone-2-sulfonic acid	Anthrachinon-2-Sulfonsäure	$C_6H_4(CO)_2C_6H_3SO_3H$	2%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Anthraquinone	Anthrachinon	$C_6H_4(CO)_2C_6H_4$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Antiformin	Antiformin	$NaOCl$ x $NaOH$ x Na_2CO_3	2%	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Antifreeze agent	Frostschutzmittel		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Antimon oxychloride	Antimonoxychlorid	$SbOCl$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Antimony pentachloride	Antimonpentachlorid	$SbCl_5$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Antimony trichloride	Antimontrichlorid	$SbCl_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Antimony trifluoride	Antimontrifluorid	SbF_3	20%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Apple acid	Apfelsäure	$C_4H_6O_5$	1%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Apple juice	Apfelsaft		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Apple wine	Apfelwein		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Aqua regia	Königswasser	$HNO_3 + HCl$	≤ GL	20	-	-	+	+
(75% hydrochloric acid	(75% Salzsäure			40	-	-	+	+
25% nitric acid)	25% Salpetersäure)			60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Arsenic acid	Arsensäure	H_3AsO_4	80%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Arsenic pentoxide	Arsenpentoxid	As_2O_5	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Arsine	Arsin	AsH_3	TR	20	+	+	+	+
	(Arsenwasserstoff)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Ascorbic acid	Ascorbinsäure	$C_6H_8O_6$	TR	20	+	+	+	+
(Vitamin C)	(Vitamin C)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Asphalt	Asphalt		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
2-Butanone	2-Butanon	$CH_3COC_2H_5$	TR	20	+	+	+	+
(Methyl ethyl ketone, MEK)	(Methylethylketon, MEK)		TR	40	+/-(q)	+	+/-(q)	+
			TR	60	+/-(q)	+/-(q)	-	+
			TR	80	-	-	-	+/-(q)
			TR	100	-	-	-	-
			TR	120	-	-	-	-
2-Butenal	2-Butenal	$CH_3CH=CHCHO$	TR	20	+	+	+	+
(Crotonic aldehyde)	(Crotonaldehyde)		TR	40	+/-(q)	+	+	+
			TR	60	+/-(q)	+/-(q)	+	+
			TR	80	-	+/-(q)	+	+
			TR	100	-	-	+/-(q)	+
			TR	120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
2-Butoxyethanol	2-Butoxyethanol	$C_6H_{14}O_2$	5%	20	+	+	+	+
			5%	40	+/-(q)	+	+	+
			5%	60	+/-(q)	+/-(q)	+	+
			5%	80	-	+/-(q)	+	+
			5%	100	-	-	+/-(q)	+
			5%	120	-	-	-	-
Barium carbonate	Bariumcarbonat	$BaCO_3$	S	20	+	+	+	+
			S	40	+	+	+	+
			S	60	+	+	+	+
			S	80	-	+	+	+
			S	100	-	-	+	+
			S	120	-	-	-	+
Barium chloride	Bariumchlorid	$BaCl_2$	≤ GL	20	+	+	+	+
			≤ GL	40	+	+	+	+
			≤ GL	60	+	+	+	+
			≤ GL	80	-	+	+	+
			≤ GL	100	-	-	+	+
			≤ GL	120	-	-	-	+
Barium cyanide	Bariumcyanid	$Ba(CN)_2$	≤ GL	20	+	+	+	+
			≤ GL	40	+	+	+	+
			≤ GL	60	+	+	+	+
			≤ GL	80	-	+	+	+
			≤ GL	100	-	-	+	+
			≤ GL	120	-	-	-	+
Barium hydroxide	Bariumhydroxid	$Ba(OH)_2$	≤ GL	20	+	+	-	+
			≤ GL	40	+	+	-	+
			≤ GL	60	+	+	-	+
			≤ GL	80	-	+	-	+
			≤ GL	100	-	-	-	+
			≤ GL	120	-	-	-	+
Barium nitrate	Bariumnitrat	$Ba(NO_3)_2$	≤ GL	20	+	+	+	+
			≤ GL	40	+	+	+	+
			≤ GL	60	+	+	+	+
			≤ GL	80	-	+	+	+
			≤ GL	100	-	-	+	+
			≤ GL	120	-	-	-	+
Barium salts (nitrate, sulfate, chloride, phosphate)	Bariumsalze (Nitrate, Sulfate, Chloride, Phosphate)		≤ GL	20	+	+	+	+
			≤ GL	40	+	+	+	+
			≤ GL	60	+	+	+	+
			≤ GL	80	-	+	+	+
			≤ GL	100	-	-	+	+
			≤ GL	120	-	-	-	+
Barium sulfate	Bariumsulfat (Schwerspat)	$BaSO_4$	S	20	+	+	+	+
			S	40	+	+	+	+
			S	60	+	+	+	+
			S	80	-	+	+	+
			S	100	-	-	+	+
			S	120	-	-	-	+
Barium sulfide	Bariumsulfid	BaS	S	20	+	+	+	+
			S	40	+	+	+	+
			S	60	+	+	+	+
			S	80	-	+	+	+
			S	100	-	-	+	+
			S	120	-	-	-	+
Beef tallow emulsion, sulphonated	Rindertalg-Emulsion, sulfoniert		H	20	+/-(q)	+/-(q)	+	+
			H	40	+/-(q)	+/-(q)	+	+
			H	60	+/-(q)	+/-(q)	+	+
			H	80	-	-	+/-(q)	+
			H	100	-	-	-	+/-(q)
			H	120	-	-	-	-
Beer	Bier		H	20	+	+	+	+
			H	40	+	+	+	+
			H	60	+	+	+	+
			H	80	-	+	+	+
			H	100	-	-	+	+
			H	120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Beeswax	Bienenwachs		TR	20	+	+	+	+
			TR	40	+	+	+	+
			TR	60	+/-(q)	+/-(q)	+	+
			TR	80	-	+/-(q)	+	+
			TR	100	-	-	+	+
			TR	120	-	-	-	+
Benzal chloride (Alphadichlorotoluene)	Benzalchlorid	$C_6H_5CHCl_2$	TR	20	+/-(q)	+/-(q)	+	+
			TR	40	-	-	+	+
			TR	60	-	-	+/-(q)	+/-(q)
			TR	80	-	-	+/-(q)	+/-(q)
			TR	100	-	-	-	-
			TR	120	-	-	-	-
Benzaldehyde	Benzaldehyd	C_6H_5CHO	TR	20	+	+	+	+
			TR	40	+	+	+	+
			TR	60	+/-(q)	+/-(q)	+	+
			TR	80	-	-	-	-
			TR	100	-	-	-	-
			TR	120	-	-	-	-
Benzaldehyde in Isopropanol	Benzaldehyd in Isopropanol	C_7H_6O in C_3H_8O	1%	20	+	+	+	+
			1%	40	+	+	+	+
			1%	60	+/-(q)	+/-(q)	+	+
			1%	80	-	-	-	-
			1%	100	-	-	-	-
			1%	120	-	-	-	-
Benzamide	Benzamid	$C_6H_5CONH_2$	TR	20	+	+	+	+
			TR	40	+	+	+/-(q)	+
			TR	60	+/-(q)	+/-(q)	-	+
			TR	80	-	+/-(q)	-	-
			TR	100	-	-	-	-
			TR	120	-	-	-	-
Benzene	Benzen	C_6H_6	TR	20	+/-(q)	+/-(q)	+	+
			TR	40	-	-	+	+
			TR	60	-	-	-	+/-(q)
			TR	80	-	-	-	-
			TR	100	-	-	-	-
			TR	120	-	-	-	-
Benzenesulfonic acid	Benzolsulfonsäure	$C_6H_5SO_3H$	30%	20	+	+	+	+
			30%	40	+/-(q)	+/-(q)	+	+
			30%	60	+/-(q)	+/-(q)	+/-(q)	+
			30%	80	-	-	+/-(q)	+/-(q)
			30%	100	-	-	-	-
			30%	120	-	-	-	-
Benzenesulfonic acid	Benzolsulfonsäure	$C_6H_5SO_3H$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Benzenesulfonyl chloride	Benzolsulfonylchlorid (Benzolsulfochlorid)	$C_6H_5SO_2Cl$	80%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Benzine (Petrol)	Benzin	C_5H_{12} up to $C_{12}H_{26}$	H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Benzine, normal	Benzin, normal		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Benzine, super	Benzin, super		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Benzine, test	Benzin, test		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Benzine-Benzol-Mixture	Benzin-Benzol-Gemisch		all	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Benzoic acid	Benzoesäure	H_5C_6COOH	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Benzoic acid, chlorinated	Benzoesäure, gechlort	H_5C_6COCl	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Benzophenone	Benzophenon (Diphenylketon)	$C_6H_5COC_6H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Benzoyl chloride	Benzoylchlorid (Benzolsäurechlorid)	C_6H_5COCl	3%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Benzyl alcohol	Benzylalkohol	$C_6H_5CH_2OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Benzyl amine	Benzylamin (alpha-Aminotoluol)	$C_6H_5CH_2NH_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Benzyl chloride	Benzylchlorid (Alpha-Chlortoluene)	$C_6H_5CH_2Cl$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Benzyl ether	Benzylether (Dibenzylether)	$C_6H_5CH_2OCH_2C_6H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Benzyl ethyl aniline	Benzylethylanilin	$C_6H_5CH_2N(C_6H_5)(C_2H_5)$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Beryllium sulfate	Berylliumsulfat	$BeSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Betaine	Betain (Trimethylammoniaacetat)	$(CH_3)_3NCH_2COO$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Biodiesel	Biodiesel		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Bismuth carbonate	Wismutcarbonat	$BiCO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Bismuth pentafluoride	Wismutpentafluorid	BiF_5	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Bismuth salts (nitrate, sulfate, chloride, phosphate)	Wismutsalze (Nitrate, Sulfate, Chloride, Phosphate)		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Bitumen	Bitumen		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Black liquor	Schwarzlauge		all	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Bone oil	Knochenöl		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)
Borax	Borax	$Na_2B_4O_7$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Boric acid	Borsäure	H_3BO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Boron trifluoride	Bortrifluorid (Trifluorboran)	BF_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Brake fluid	Bremsflüssigkeit		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Brandy	Branntweine		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Brine alcaline	Salzsole alkalisch		all	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Bromid acid	Bromsäure	$HBrO_3$	VL	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Bromine + dibromomethane	Brom + Dibrommethan	$Br_2 + CH_2Br_2$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+
				100	-	-	-	-
				120	-	-	-	-
Bromine + phosphite hydrogen + phosphate hydrogen	Brom + Hydrogenphosphit + Hydrogenphosphat	$Br_2 + H_3PO_3 + H_3PO_4$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Bromine water	Bromwasser	Br_2	2.8%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Bromine, liquid	Brom, flüssig	Br_2	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Bromine, vapours	Bromdämpfe	Br_2	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Bromochloromethane	Bromchlormethan	CH_2BrCl	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Bromochlorotrifluoroethane	Bromchlortrifluorethan (Halothan)	$CF_3CHBrCl$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Bromoform	Bromform (Tribrommethan)	$CHBr_3$	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	+/-(s)	+
				100	-	-	-	+/-(s)
				120	-	-	-	-
Butadiene	Butadien	$H_2C{=}CHCH{=}CH_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butane	Butan	C_4H_{10}	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Butane, chlorinated	Butan, gechlort	C_4H_9Cl	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	-
Butanediol	Butandiol	HOC_4H_8OH	10%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Butanediol	Butandiol (2,3-Butylenglykol)	HOC_4H_8OH	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(q)	+	+
				80	-	+/-(q)	+	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Butanetriol	Butantriol	$C_4H_7(OH)_3$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Butanol	Butanol	$C_3H_7CH_2OH$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Butene	Buten (n-Butylen)	$CH_3CH_2CHCH_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Butenediol	Butendiol	$CH_2OHCHCHCH_2OH$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Butinediol	Butindiol	$CH_2OHCCCH_2OH$	TR	20	+	+	+	+
	(Korantin BH flüssig)			40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Butter	Butter		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Buttermilk	Buttermilch		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Butyl acetate	Essigsäurebutylester	$CH_3COOC_4H_9$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Butyl aldehyde	Butylaldehyd	$CH_3CH_2CH_2CHO$	TR	20	+	+	+	+
	(Butanal)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyl benzyl phthalate	Butylbenzylphthalat	$CH_3(CH_2)_3OOCC_6H_4COO$-	TR	20	+	+	+	+
	(Phthalsäurebenzylbutylester)	$CH_2C_6H_5$		40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyl bromide	Butylbromid	C_4H_9Br	TR	20	+/-(q)	+/-(q)	+	+
	(1-Brombutan)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Butyl chloride	Butylchlorid	C_4H_9Cl	TR	20	+/-(q)	+/-(q)	+	+
	(1-Chlorbutan)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Butyl cyclohexyl ester	Butylcyclohexylester	$ClCOOC_{10}H_{19}$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyl diglykol	Butyldiglykol	$C_8H_{18}O_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Butyl ether	Butylether	$C_4H_9OC_4H_9$	TR	20	+/-(s)	+/-(s)	+	+
	(n-Dibutylether)			40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Butyl glycol	Butylglykol	$HOCH_2CH_2O(CH_2)_3CH_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyl glycolate	Butylglykolat	$HOCH_2COO(CH_2)_3CH_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyl phenol	Butylphenol	$C_{10}H_{14}O$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyl phenone	Butylphenon	$C_6H_5CO(CH_2)_2CH_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butylcyclohexylchloroformiate	Butylcyclohexylchlorformiat	$ClCOOC_6H_{10}C_4H_9$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butylene, liquid	Butylen, flüssig	C_4H_8	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyleneglycol	Butylenglykol	$HOCH_2CH{=}CHCH_2OH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyric acid	Buttersäure	$CH_3CH_2CH_2COOH$	TR	20	+	+	+	+
	(Butansäure)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Butyrolacetone	Butyrolaceton	OC_4H_6O	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
1-Chloro-1,2,2-trifluoroethylene	Chlortrifluorethylen	$CClFCF_2$	TR	20	+/-(o)	+/-(o)	+/-(o)	+
	(Trifluorvinylchlorid)			40	-	-	+/-(o)	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
1-Chloro-2,3-epoxypropane	Epichlorhydrin	CH_2OCHCH_2Cl	TR	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
1-Cyclohexyl-2-pyrrolidone	1-Cyclohexyl-2-pyrrolidon	$C_{10}H_{17}NO$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
2-4-Chloro-2-methylphenoxy-propionic acid	Chlormethylphenoxypropion-säure (MECOPROP)	$ClCH_3C_6H_3OCH(CH_2)_2$-COOH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
2-Chloro-1-bromoethane	Chlorbrommethan (1-Brom-2-Chlormethan)	$BrCH_2CH_2Cl$	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
2-Chlorobenzoyl chloride	Chlorbenzoylchlorid	ClC_6H_4COCl	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
2-Chloromethyltriethylammonium chloride	2-Chlormethyltriethylammonium-chlorid		TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
2-Chlorophenol	Chlorphenol	ClC_6H_4OH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
3-Chloro-2-hydroxypropyl-ammonium chloride	3-Chlor-2-hydroxypropyl-ammoniumchlorid		TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
4-Chloro-2-methylphenoxyacetic acid	Chlormethylphenoxyessigsäure (MCPA)	$ClCH_3C_6H_3OCH_2CH_2$-COOH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
4-Chloro-2-nitrophenol	Chlornitrophenol	$ClC_6H_3NO_2OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
4-Chlorotoluene	Chlortoluol (4-Chlor-1-methylbenzol, 4-Chlortoluol)	$ClC_6H_4CH_3$	TR	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Cadmium chloride	Cadmiumchlorid	$CdCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Cadmium cyanide	Cadmiumcyanid	$Cd(CN)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Cadmium sulfate	Cadmiumsulfat	$CdSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium acetate	Calciumacetat	$Ca(CH_3COO)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Calcium bromide	Calciumbromid	$CaBr_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium carbide	Calciumcarbid	CaC_2	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium carbonate	Calciumcarbonat	$CaCO_3$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium chlorate	Calciumchlorat	$Ca(ClO_3)_2$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	+/-(o)	+/-(o)
				120	-	-	-	-
Calcium chloride	Calciumchlorid	$CaCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium fluoride	Calciumfluorid	CaF_2	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium hydrogencarbonate	Calciumhydrogencarbonat (Calciumbicarbonat)	$Ca(HCO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Calcium hydrogensulfide	Calciumhydrogensulfid	$Ca(HS)_2$	≤ GL	20	+	+	+	+
	(Calciumbisulfid)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium hydrogensulfite	Calciumhydrogensulfit	$Ca(HSO_3)_2$	≤ GL	20	+	+	+	+
	(Calciumbisulfit)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium hydroxide	Calciumhydroxid	$Ca(OH)_2$	S	20	+	+	-	+
	(gelöschter Kalk, Kalkhydrat)			40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Calcium hypochlorite	Calciumhypochlorit	$Ca(OCl)_2$	≤ GL	20	-	-	-	+
(chloride of lime)	(Chlorkalk)			40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Calcium lactate	Calciumlactat	$Ca(C_3H_5O_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Calcium nitrate	Calciumnitrat	$Ca(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium oxide	Calciumoxid	CaO	S	20	+	+	-	+
				40	+	+	-	+
				60	+/-(o)	+/-(o)	-	+
				80	-	+/-(o)	-	+
				100	-	-	-	+
				120	-	-	-	+
Calcium phosphate	Calciumphosphat	$Ca_3(PO_4)_2$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium sulfate	Calciumsulfat	$CaSO_4$	S	20	+	+	+	+
	(Gips)			40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium sulfide	Calciumsulfid	CaS	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Calcium sulfide	Calciumsulfid	CaS	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Calcium sulfite	Calciumsulfit	$CaSO_3$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Camphor	Campher	$C_{10}H_{16}O$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Camphor oil	Campheröl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Cane sugar	Rohrzucker	$C_{12}H_{22}O$	H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Caprylic acid	Caprylsäure (Octansäure)	$CH_3(CH_2)_6COOH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Carbazole	Carbazol (Dibenzopyrrol)	$C_6H_4NHC_6H_4$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Carbon dioxide, anhydrous	Kohlendioxid, trocken	CO_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Carbon dioxide, gaseous	Kohlendioxid, gasförmig	CO_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Carbon dioxide, moist	Kohlendioxid, feucht	CO_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Carbon disulfide, gaseous	Schwefelkohlenstoff, gasförmig	CS_2	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Carbon disulfide, liquid	Schwefelkohlenstoff, flüssig	CS_2	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Carbon monoxide	Kohlenmonoxid	CO	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Carbon tetrachloride	Kohlenstofftetrachlorid	CCl_4	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Carbonic acid	Kohlensäure	H_2CO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Carbonileum	Carbonileum		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Carbontetrabromide	Tetrabromkohlenstoff	CBr_4	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Carbontetrachloride	Tetrachlorkohlenstoff	CCl_4	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Carbontetrachloride	Tetrachlorkohlenstoff	CCl_4	5%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Carbontetrafluoride	Tetrafluorkohlenstoff	CF_4	TR	20	-	-	+	+
	(Tetrafluoromethan)			40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Carbonyl sulfide	Carbonylsulfid	O=C=S	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Casein	Casein		TR	20	+	+	+	+
	(Calciumcaseinat)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Castor oil	Rizinusöl		TR	20	+	+	+	+
	(Kastoröl)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Cedar oil	Zedernöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	-
Cellosolve acetate	Cellosolvacetat	$CH_3COOCH_2CH_2OC_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cetyl alkohol	Cetylalkohol	$C_{16}H_{33}OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	-
				120	-	-	-	-
Chinin hydrochloride	Chininhydrochlorid (Chininchlorhydrat)	$C_{20}H_{24}O_2N_2$ x HCl	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Chinin monosulfate	Chininmonosulfat (Schwefelsäurechininester)	$C_{20}H_{24}O_2N_2$ x H_2SO_4	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Chloral (Trichloroaldeyhde)	Chloral (Trichloroaldeyhd)	CCl_3CHO	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chloral hydrate	Chloralhydrat (2,2,2 Trichlor-1,1-ethandiol)	$CCl_3CH(OH)_2$	TR	20	+	+/-(o)	+/-(o)	+
				40	+/-(o)	-	-	+
				60	-	-	-	+/-(o)
				80	-	-	-	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Chloramine	Chloramin (Aktivin)	RNHCl, $RNCl_2$	1%	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chloric acid	Chlorsäure	$HClO_3$	1%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chloric acid	Chlorsäure	$HClO_3$	10%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chloric acid	Chlorsäure	$HClO_3$	20%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Chloric acid	Chlorsäure	$HClO_3$	38%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chlorid salt	Chloridsalze		TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Chlorinated lime	Chlorkalk	$CaCl(OCl) + Ca(OH)_2$	≤ GL	20	-	-	-	+
	(Blechkalk,	$+ CaCl_2$		40	-	-	-	+
	Calciumchloridhypochlorit)			60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Chlorine dioxide, aqueous	Chlordioxid, wässrige Lösung	ClO_2	0.2%	20	-	-	+/-(o)	+
solution				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Chlorine dioxide, aqueous	Chlordioxid, wässrige Lösung	ClO_2	1%	20	-	-	+/-(o)	+
solution				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Chlorine dioxide, gaseous	Chlordioxid, gasförmig	ClO_2	60%	20	-	-	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Chlorine water	Chlorwasser	$Cl_2 + HCl + HOCl$	≤ GL	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Chlorine, anhydrous	Chlor, trocken	Cl_2	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	-
Chlorine, atomic, chlorine radical,	Chlor, atomar, Chlorradikal,	Cl•	all	20	-	-	-	-
gaseous, moist	gasförmig, feucht			40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chlorine, gaseous, anhydrous	Chlor, gasförmig, trocken	Cl_2	10%	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Chlorine, gaseous, moist	Chlor, gasförmig, feucht	Cl_2	0.5%	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Chlorine, gaseous, moist	Chlor, gasförmig, feucht	Cl_2	0.8%	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Chlorine, gaseous, moist	Chlor, gasförmig, feucht	Cl_2	1%	20	-	-	+	+
				40	-	-	+	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Chlorine, gaseous, moist	Chlor, gasförmig, feucht	Cl_2	5%	20	-	-	+	+
				40	-	-	+	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Chloroacetyl chloride	Chloracetylchlorid (Chloressigsäurechlorid, Monochloracetylchlorid)	$C_2H_2Cl_2O$	TR	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+/-(o)
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chloroacetyl chloride	Chloressigsäurechlorid	$ClCH_2COCl$	98%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chlorobenzene	Chlorbenzen (Phenylchlorid)	C_6H_5Cl	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chlorobenzenosulfon acid	Chlorbenzensulfonsäure	$ClC_6H_4SO_3H$	80%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Chlorobutane	Chlorbutan	C_4H_9Cl	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chlorocresoles	Chlorkresole (Chlorhydroxytoluole, Chlormethylphenole)	$CH_3C_6H_3ClOH$	TR	20	-	-	+	+
				40	-	-	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chlorodifluoromethane	Chlordifluormethan (Freon 22)	$ClCHF_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chlorodimethyl ether	Chlormethylmethylether (Chlordimethylether)	$ClCH_2OCH_3$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Chloroethanol	Chlorethanol	$ClCH_2CH_2OH$	TR	20	+/-(o)	+/-(o)	+	+
	(Ethylenchlorhydrin)			40	-	-	+	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Chloroethyl acetate	Essigsäurechlorethylester	$CH_3COOCH_2CH_2Cl$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Chloroform	Chlorform	$CHCl_3$	TR	20	+/-(o)	+/-(o)	+	+
	(Trichlormethan)			40	-	-	+	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Chloroformic acid ethyl ester	Ameisensäureethylester,	$ClCOOC_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
	chloriert			40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chloroformic acid methyl ester	Ameisensäuremethylester,	$HCOOCH_3$	TR	20	+/-(q)	+/-(q)	+	+
	chloriert			40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chlorohexanol	Chlorhexanol	$HO(CH_2)_6Cl$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Chloromethyl acetate	Essigsäurechlormethylester	CH_3COOCH_2Cl	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Chloromethyloximether	Chlormethyloximether		TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Chloronaphthalene	Chlornaphtalin	$C_6H_4C_4H_3Cl$	TR	20	+/-(q)	+/-(q)	+	+
	(Naphthylchlorid)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Chloropicric	Chlorpikrin	Cl_3CNO_2	TR	20	+/-(o)	+/-(o)	+	+
	(Nitrochlorform,			40	-	-	+	+
	Trichlornitromethan)			60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Chloropropyltriethoxysilan	Chlorpropyltriethoxysilan	$C_3H_7ClSi(OC_2H_5)_3$	TR	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Chlorosulfonic acid	Chlorsulfonsäure (Chlorschwefelsäure)	$ClSO_2OH$	TR	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chlorotoluensulfonic acid	Chlortoluolsulfonsäure	$ClC_6H_3CH_3SO_3H$	TR	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chlorotrifluoromethane	Chlortrifluormethan	CClF3	TR	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Chloroxylene	Chlorxylole	$CH_3C_6H_3CH_3Cl$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Choline	Cholinchlorid	$C_5H_{14}ClNO$	75%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Chrome alum (Chromium(III) potassium sulfate)	Chromalaun (Chromkaliumsulfat)	$KCr(SO_4)_2$ x $12H_2O$	≤ GL	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Chromesalts (2- and 3-valent)	Chromsalze (2- und 3-wertig)	Cr^{2+}, Cr^{3+}	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80		+	+	+
				100	-	-	+	+
				120	-	-	-	+
Chromic acid	Chromsäure	H_2CrO_4	50%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Chromic acid	Chromsäure	H_2CrO_4	40%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Chromic acid	Chromsäure	H_2CrO_4	30%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Chromic acid	Chromsäure	H_2CrO_4	20%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Chromic acid	Chromsäure	H_2CrO_4	10%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Chromic acid	Chromsäure	H_2CrO_4	1%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Chromium(II) chloride	Chromchlorid (II)	$CrCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Chromium(III) chloride	Chromchlorid (III)	$CrCl_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Chromium(III) nitrate	Chrom(III)nitrat	$Cr(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Chromium(III) sulfate	Chrom(III)sulfat	$Cr_2(SO_4)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Chromosulfuric acid	Chromschwefelsäure	$CrO_3 + H_2SO_4 + H_2O$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Cider	Obstwein		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Cinnamon oil	Zimtöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	-
Citric acid	Citronensäure	$C_3H_4OH(COOH)_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Citric acid	Citronensäure (2-Hydroxy-1,2,3-propancarbon-säure)	$C_3H_4OH(COOH)_3$	< 10%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Citrus oil	Zitrusöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Clove oil	Nelkenöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Coal gas, benzene free	Leuchtgas, benzolfrei		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Cobalt(II) chloride	Cobalt(II)chlorid	$CoCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Cocofat acid diethanolamide	Kokosfettsäurediethanolamid		49%	20	+	+	+	+
				40	+	+/-(q)	+/-(q)	+
				60	+/-(q)	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Coconut fat alcohol	Kokosfettalkohol		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Coconut oil	Kokosnussöl		H	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Cod liver oil	Lebertran		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Coffee-extracts	Kaffee-Extrakt		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Coke gas (61% hydrogen, 26% methane, 4% carbon monoxide, nitrogen 8%)	Kokereigas (61% Wasserstoff, 26% Methan, 4% Kohlenstoffmonoxid, 8% Stickstoff)	$H_2 + CH_4 + CO + N_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Cola concentrates	Cola-Konzentrate		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Compressed air, containing oil	Pressluft, ölhaltig		H	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Cooking oil	Speiseöl		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Cooking salt	Kochsalz		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper carbonate	Kupfercarbonat	$CuCO_3$ x $Cu(OH)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper salts	Kupfersalze		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper tetrafluoroborate	Kupfertetrafluorborat	$Cu(BF_4)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(I) chloride	Kupfer(I)chlorid	CuCl	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(I) cyanide	Kupfer(I)cyanid	CuCN	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(II) chloride	Kupfer(II)chlorid	$CuCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(II) chloride	Kupfer(II)chlorid	$CuCl_2$	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(II) cyanide	Kupfer(II)cyanid	$Cu(CN)_2$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Copper(II) fluoride	Kupfer(II)fluorid	CuF_2	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(II) nitrate	Kupfer(II)nitrat	$Cu(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Copper(II) sulfate	Kupfer(II)sulfat	$CuSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Corn oil	Maiskeimöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Cotton seed oil	Baumwollsamenöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Cresol	Kresole	$HOC_6H_4CH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cresol carbonic acid	Kresolcarbonsäure	$HOCH_3C_6H_3COOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cresolsulfonic acid	Kresolsulfonsäure	$HOCH_3C_6H_3SO_3H$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	+/-(s)	+/-(s)	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	-
Cresolsulfonic acid	Kresolsulfonsäure	$HOCH_3C_6H_3SO_3H$	80%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	+/-(s)	+/-(s)	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	-
Cresolsulfonic acid	Kresolsulfonsäure	$HOCH_3C_6H_3SO_3H$	50%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	+/-(s)	+/-(s)	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	-
Crotonic acid	Crotonsäure (2-Butensäure)	$CH_3CHCHCOOH$	VL	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Crotonic aldehyde	Crotonaldehyd (2-Butenal)	C_4H_6O	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cumol	Cumol (2-Phenylpropan, Isopropylbenzol)	$C_6H_5CH(CH_3)_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cyanamide	Cyanamid	H_2NCN	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Cyanide-sulfuric chloride-salts	Zyanid-Schwefelchlorid-Salze		TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Cyclohexane	Cyclohexan (Hexahydrobenzol)	C_6H_{12}	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cyclohexanol	Cyclohexanol	$C_6H_{12}O$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Cyclohexanone	Cyclohexanon	$C_6H_{10}O$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	-	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cyclohexene	Cyclohexen (Tetrahydrobenzol)	C_6H_{10}	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Cyclohexyl acetate	Essigsäurecyclohexylester (Cyclohexylacetat)	$CH_3COOC_6H_{11}$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Cyclohexylamine	Cyclohexylamin (Aminocyclohexan)	$C_6H_{11}NH_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Cyclopentane	Cyclopentan	C_5H_{10}	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
1,1-Dichloro-1-fluoroethane	1,1-Dichlor-1-fluorethan	FCl_2CCH_3	TR	20	+/-(s)	+/-(s)	+/-(s)	+
	(Freon 141b)			40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
1,1-Dichloro-1-fluoromethane	1,1-Dichlor-1-fluormethan	CCl_2F_2	TR	20	+/-(s)	+/-(s)	+/-(s)	+
	(Freon 12)			40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
1,1-Difluoro-1-chloroethane	1,1-Difluor-1-chlorethan	F_2ClCCH_3	TR	20	+/-(s)	+/-(s)	+/-(s)	+
	(Freon 142b)			40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
1,1-Difluoroethane	1,1-Difluorethan	F_2CHCH_3	TR	20	+/-(s)	+/-(s)	+/-(s)	+
	(Freon 152a)			40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
1,2-Diaminoethane	1,2-Diaminethan	$NH_2CH_2CH_2NH_2$	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
1,2-Dibromobenzene	Dibrombenzen	$C_6H_4Br_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+/-(s)
				80	-	-	+	-
				100	-	-	+/-(s)	-
				120	-	-	-	-
1,2-Dibromoethane	Dibromethan	$BrCH_2CH_2Br$	TR	20	+/-(q)	+/-(q)	+	+
	(Ethylenbromid)			40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	
3,4-Dichlorotoluene	Dichlortoluol	$CH_3C_6H_3Cl_2$	TR	20	+	+	+/-(s)	+
	(1-Methyl-3,4-dichlortoluol)			40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Decan	Dekan	$C_{10}H_{22}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Dekahydronaphtalene	Decalin	$C_{10}H_{18}$	TR	20	+/-(q)	+/-(q)	+	+
	(Perhydronaphthalin)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Diacetone alcohol	Diacetonalkohol	$(CH_3)_2C(OH)CH_2COCH_3$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
	(4-Hydroxy-4-Methyl-2-Pentanon,			40	+/-(q)	+/-(q)	+/-(q)	+
	Diaceton)			60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
DIALA oil	DIALA öl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Dibutyl sebazate	Sebazinsäuredibutylester (Dibutylsebazat)	$H_9C_4OCO(CH_2)_8COO-C_4H_9$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Dibutylglykolphtalate	Dibutylglykolphtalat		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Dibutylphthalate	Dibutylphthalat	$(C_4H_9)_2(COO)_2C_6H_4$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Dibutylsebacate	Dibutylsebazat	$C_8H_{16}(COOC_4H_9)_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Dibutylthiourea	Dibutylthioharnstoff	$H_9C_4NHSCNHC_4H_9$	TR	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	+	+	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	+
Dibutyltinmercaptide	Dibutylzinnmercaptid (Dibutylmercaptostaanan)	$(C_4H_9)_2SSn$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Dichloroacetic acid	Dichloressigsäure	$Cl_2CHCOOH$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dichloroacetic acid methyl ester	Dichloressigsäuremthylester	$Cl_2CHCOOCH_3$	TR	20	+	+	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	-	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dichlorobenzene	Dichlorbenzen	$C_6H_4Cl_2$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichlorodimethylsilane	Dichlordimethylsilan	$(CH_3)_2SiCl_2$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Dichlorodiphenyldichloroethane	Dichlordiphenyldichlorethan (DDD)	$ClC_6H_4CH(CHCl_2)C_6H_4$-Cl	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichlorodiphenyltrichloroethane	Dichlordiphenyltrichlorethan (DDT)	$ClC_6H_4CH(CCl_3)C_6H_4Cl$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichloroethane	Dichlorethan (Ethylendichlorid)	$C_2H_4Cl_2$	35%	20	+	+	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	-	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dichloroethylene	Dichlorethylen (1,1 Dichlorethylen, 1,2 Dichlorethylen)	ClCHCHCl	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichlorofluoromethane	Dichlorfluormethan (Freon 21)	$CHCl_2F$	TR	20	+	+	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichlorohydrin	Dichlorhydrin	$C_3H_6Cl_2O$	5%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dichloroisopropylether	Dichlorisopropylether	$C_5H_{10}ClOC_5H_{10}Cl$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichloromethane (methylene chloride)	Dichlormethan (Methylenchlorid)	CH_2Cl_2	TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichloropropane	Dichlorpropan (1,2-Dichlorpropan, Propylendichlorid)	$ClCH_2CHClCH_3$	TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dichloropropanol	Dichlorpropanol (1,3 Dichlor-2-propanol)	$C_3H_6Cl_2O$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Dichloropropene (1,3)	Dichlorpropen (1,3)	$ClCH_2CHCHCl$	TR	20	+	+	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Dichlorotetrafluoroethan	Dichlortetrafluorethan	$CClF_2CClF_2$	TR	20	+	+	+/-(s)	+
	(Cyrofluoran)			40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Dicyclohexylcarbodiimid	Dicyclohexylcarbodiimid	$C_{13}N_2H_{22}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Diesel oil	Dieselkraftstoff		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Diethanolamine	Diethanolamin	$(HOCH_2CH_2)_2NH$	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Diethyl carbonate	Diethylcarbonat	$C_5H_{10}O_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Diethyl ether	Diethylether	$CH_3CH_2OCH_2CH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	-	+	+	+
				60	-	+	+/-(q)	+
				80	-	+	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	+
Diethyl ketone	Diethylketon	$C_2H_5COC_2H_5$	TR	20	+	+	+	+
	(3-Pentanon)			40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Diethyl-2,2'-hydroxyamine	Diethyl-2,2'-hydroxyamin	$(HOCH_2CH_2)_2NH$	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Diethylamine	Diethylamin	$(H_5C_2)_2NH$	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Diethylaminoethyl chloride	Diethylaminethylchlorid	$(C_2H_5)_2NCH_2CH_2Cl$	TR	20	+	+	+	+
	(Chlorethyldiethylamin)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Diethylenediamine	Diethylendiamin	$(CH_2CH_2NH)_2$	50%	20	+	+	+/-(q)	+
(Piperazine)	(Hexahydropyrazin, Piperazin)			40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Diethyleneglykol	Diethylenglykol	$C_4H_{10}O_3$	5%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Diethylenetriamine	Diethylentriamin (2,2 Iminodiethylamin)	$NH_2C_2H_4NHC_2H_4NH_2$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Diethylentriaminopentaacetic acid	Diethylentriaminpentässigsäure (DTPA)	$(HOOH_2C)N((CH)_2N\text{-}(COOH)_2)_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Diethylmalonate	Malonsäurediethylester	$H_2C(COOC_2H_5)_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Diglycolic acid	Diglykolsäure	$(COOH)_2(CH_2)_2O$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Diglycolic acid	Diglykolsäure	$(COOH)_2(CH_2)_2O$	30%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Dihexyl ether	Dihexylether	$H_{13}C_6OC_6H_{13}$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Dihydroxydimethylsilane	Dihydroxydimethylsilan	$(CH_3)_2Si(OH)_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Diisoamyl ether	Diisoamylether (Diisopentylether)	$H_{11}C_5OC_5H_{11}$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Diisobuten	Diisobuten	$(CH_3)_3CCH_2(CH_3)CCH_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Diisobutyl ketone (2,6-Dimethyl-4-heptanone-Isovalerone)	Diisobytylketon	$((CH_3)_2CHCH_2)_2CO$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Diisocyanate	Diisocyanate		TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Diisopropyl ether	Diisopropylether	$(CH_3)_2CHOCH(CH_3)_2$	TR	20	+	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Diisopropyl ketone A	Diisopropylketon A	$(CH_3)_2CHCOCH(CH_3)_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dimethoxyethane	Dimethoxyethan	$C_4H_{10}O_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(o)	+/-(o)	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	+
				120	-	-	-	+
Dimethyl ether	Dimethylether	C_2H_6O	5%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(s)	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dimethyl sulfate	Dimethylsulfat	$(CH_3)_2SO_4$	TR	20	+	+	+	+
	(Schwefelsäuredimethylester)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Dimethyl sulfoxide	Dimethylsulfoxide	$(CH_3)_2SO$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(o)	+/-(o)	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	+
				120	-	-	-	-
Dimethylacetamide	Dimethylacetamid	$CH_3CON(CH_3)_2$	TR	20	+	+	+/-(s)	+
	(N,N-Dimethylacetamid, DMAc)			40	+	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Dimethylamine	Dimethylamin	$(CH_3)_2NH$	TR	20	+	+	+/-(s)	+
				40	+	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Dimethylaniline	Dimethylanilin	$C_6H_5N(CH_3)_2$	TR	20	+	+	+/-(s)	+
				40	+	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Dimethyldichlorosilane	Dimethyldichlorsilizium	$(CH_3)_2SiCl_2$	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+
				100	-	-	-	+/-(s)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Dimethyldodecylamine	Dimethyldodecylamin	$(CH_3)_2NC_{12}H_{23}$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Dimethylen chloride	Dimethylenchlorid		5%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Dimethyleneglykol	Dimethylenglykol		5%	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Dimethylformamide	Dimethylformamid	C_3H_7NO	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	+/-(q)	+/-(q)	-	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Dimethylheptanol	Dimethylheptanol	$CH_3CH(CH_3)(CH_2)_3CH$- $(CH_3)CHOH$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Dimethylhexadien	Dimethylhexadien	$CH_2C(CH_3)CH_2CH_2C$- $(CH_3)CH_2$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Dimethylhydrazine	Dimethylhydrazin	$NN_2N(CH_3)_2$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Dimethylphtalate	Dimethylphtalat	$C_6H_4(COOH_3)_2$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Dimethylpolysiloxan	Dimethylpolysiloxan (Polymer FD 80)	$HO((CH_3)_2SiO)_nH$	H	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Dimethylpropionyl chloride	Dimethylpropionylchlorid (Pivaloylchlorid)	$(CH_3)_3CCOCl$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Di-n-amyl ester	Di-n-amylether (Pentylether)	$H_{11}C_5OC_5H_{11}$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Dioctylphthalate	Dioctylphthalat	$COOC_8H_{17}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Dioxane	Dioxan	$O(C_2H_4)_2O$	TR	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	+	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Diphenyl ether	Diphenylether	$C_6H_5OC_6H_5$	TR	20	+	+	+	+
				40	+/-(q)	+	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Diphenylamine	Diphenylamin	$C_6H_5NHC_6H_5$	TR	20	+	+	+	+
				40	+/-(q)	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Diphenylethylene	Diphenylethylen	$C_6H_5CHCHC_6H_5$	6%	20	+/-(q)	+/-(q)	+	+
	(Stilben)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Diphenylglykolic acid	Diphenylglykolsäure	$(C_6H_5)_2C(OH)COOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Diphenyloxide	Diphenyloxid	$C_6H_5OC_6H_5$	TR	20	+	+	+	+
	(Diphenylether, Phenylether)			40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Diphosphoric acid	Diphosphorsäure	$H_4P_2O_7$	15%	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Dipotassium hydrogen-	Dikaliumhydrogenphosphat	K_2HPO_4	all	20	+	+	+	+
phosphate				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Disodium phosphate	Dinatriumphosphat	$Na_2HPO_4 \times 2H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Disodium tetraborate	Dinatriumtetraborat	$Na_2BO_7 \times 10H_2O$	VL	20	+	+	+	+
	(Borax)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Disulfuric acid	Dischwefelsäure	$H_2S_2O_7$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Divinylbenzene	Divinylbenzen	$CH_2CHC_6H_4CHCH_2$	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Dodecanoic acid chloride	Dodecansäurechlorid	$C_{11}H_{23}COCl$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Dodecylbenzensulfonic acid	Dodecylbenzensulfonsäure	$C_{12}H_{25}C_6H_4SO_3H$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Dodecylbenzensulfonic acid	Dodecylbenzensulfonsäure	$C_{12}H_{25}C_6H_4SO_3H$	60%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
2,3-Epoxypropyltrimethyl-ammonium chloride	2,3-Epoxypropyltrimethyl-ammoniumchlorid	$C_6H_{14}ClNO$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
2-Ethylhexanolyl chloride	2-Ethylhexanolylchlorid		TR	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Elektrolyte bath (Sulfuric acid + Cresol sulfone acid)	Elektrolytbad (Schwefelsäure + Kresolsulfonsäure)	$H_2SO_4 + CH_3C_6H_3(OH)$-(SO3H)	all	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	+/-(q)
Ethan, gaseous	Ethan, gasförmig	CH_3CH_3	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	-
Ethanethiol	Ethanthiol (Ethylmercaptan)	C_2H_5SH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Ethanol	Ethanol	$C_2H_5OH + H_2O$	TR	20	+/-(q)	+/-(q)	+	+
				40	-	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ethanol	Ethanol	$C_2H_5OH + H_2O$	96%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Ethanol	Ethanol	$C_2H_5OH + H_2O$	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Ethanol	Ethanol	$C_2H_5OH + H_2O$	10%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	+
				120	-	-	-	-
Ethanol / acetic acid	Ethanol / Essigsäure		TR	20	+/-(q)	+/-(q)	+	+
(fermentation mixture)	(Gärungsgemisch)			40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Ethanolamine	Ethanolamin	$H_2NC_2H_4OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				60	-	-	-	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ethen	Ethen	CH_2CH_2	TR	20	+/-(q)	+/-(q)	+	+
	(Ethylen)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Ethyl acetate	Ethylacetat	$CH_3COOCH_2CH_3$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	-	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ethyl acrylate	Acrylsäureethylester	CH_2=$CHCCOCH_2CH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	-	+/-(q)	-
				100	-	-	-	-
				120	-	-	-	-
Ethyl alcohol, denatured	Ethylalkohol, vergällt	C_2H_5OH + 2% $C_6H_5CH_3$	96%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Ethyl benzoate	Benzoesäureethylester	$C_6H_5COOC_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
	(Ethylbenzoat)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ethyl bromide	Ethylbromid	CH_3CH_2Br	TR	20	+/-(s)	+/-(s)	+	+
	(Bromethan)			40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ethyl butyrate	Buttersäureethylester	$CH_3CH_2CH_2COOC_2H_5$	TR	20	+	+	+	+
	(Ethylbutyrat)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Ethyl chloride	Ethylchlorid	CH_3CH_2Cl	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Ethylacetoacetate	Acetessigester	$CH_3COCHCOOC_2H_5$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Ethylbenzene	Ethylbenzen	$C_6H_5C_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ethylchloroformiate	Chlorameisensäureethylester	$ClCOOC_2H_5$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Ethylcyanoacetate	Cyanessigsäureethylester	$CH_2CNCOOC_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
	(Ethylcyanoacetat)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Ethylenbenzene	Ethylenbenzen	C_8H_{10}	TR	20	+/-(q)	+/-(q)	+	+
	(Phenylethan)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Ethylenbutyrate	Ethylenbutyrat	$C_6H_{12}O_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Ethylene chloride	Ethylenchlorid	$ClCH_2CH_2Cl$	TR	20	-	-	+/-(s)	+
(1,2-Dichloroethane)	(1,2-Dichlorethan)			40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Ethylenediamine	Ethylendiamin	$H_2NCH_2CH_2NH_2$	TR	20	+	+	+/-(s)	+
	(1,2-Diaminoethan,			40	+	+	-	+
	1,2-Ethandiamin)			60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	+
Ethylenediaminetetraacetic acid	Ethylendiamintetraessigsäure	$C_2H_4N_2(CH_2COOH)_4$	TR	20	+	+	+/-(s)	+
	(EDTA)			40	+	+	+/-(s)	+
				60	+/-(q)	+/-(q)	+/-(s)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ethyleneglykol	Ethylenglykol	$(CH_2OH)_2$	TR	20	+	+	+	+
	(1,2-Ethandiol, Glykol)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Ethyleneglykoldiethylether	Ethylenglykoldiethylether	$CH_3CH_2OCH_2CH_2O$-	TR	20	+	+	+	+
	(Diethylglykolether)	CH_2CH_3		40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Ethyleneglykolmonomethylether	Ethylenglykolmonomethylether	$CH_3OCH_2CH_2OH$	TR	20	+	+	+	+
	(2-Methoxyethanol, Methylglykol)			40	+	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	-	+/-(s)	+
				100	-	-	-	-
				120	-	-	-	-
Ethyleneoxide	Ethylenoxid	CH_2CH_2O	TR	20	-	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	+
Ethylether	Ethylether	$H_5C_2OC_2H_5$	TR	20	+/-(o)	+/-(o)	+	+
	(Diethylether)			40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ethylformalat	Ethylformalat	$C_3H_6O_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Ethylhexanol	Ethylhexanol	$(C_4H_9)(C_2H_5)CHCH_2OH$	TR	20	+	+	+	+
	(Isooctanol)			40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80		+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Ethylpropionate	Ethylpropionat	$C_2H_5CHOOC_2H_5$	TR	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Fatty acid amides	Fettsäurenamide	$RCONH_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Fatty acids	Fettsäuren		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Fatty alcohol alkoxylate	Fettalkoholalkoxylat		20%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Fatty alcohol ethoxylate	Fettalkoholethoxylat	$R(OC_2H_4)_nOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Fatty alcohol ethylether sulfate	Fettalkoholethersulfat	$R(OC_2H_4)_nSO_3Na$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Fatty alcohol sulphonate	Fettalkoholsulfonate		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Fatty alcohols	Fettalkohole	C_8 up to C_{18}	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Fenarimol	Fenarimol	$C_{17}H_{12}Cl_2N_2O$	12%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Fermentation mash	Gärungsmaische	$C_2H_5OH + CH_3COOH$	all	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Fertilizer salts	Düngesalze		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Fire extinguishing form	Feuerlöschschaum		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Fish oil, sulfited	Fischöl, sulfitiert		H	20	+	+	+	+
(Licrol 3235)	(Licrol 3235)			40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Fluoboric acid	Fluorborsäure	HBF_4	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Fluorine, liquid	Fluor, flüssig	F_2	≤ GL	20	-	-	-	+/-(s)
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Fluorine, gaseous	Fluor, gasförmig	F_2	TR	20	-	-	-	+/-(s)
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Fluoroboric acid	Borfluorwasserstoffsäure (Tetrafluorborsäure)	HBF_4	50%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Fluorosilic acid	Fluorsiliziumsäure	H_2SiF_6	50%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Fluorosulfuric acid	Fluorschwefelsäure (Fluorosulfonsäure)	HSO_3F	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Fluorotrichloromethane	Fluortrichlormethan (Trichlorfluormethan, Frigen 11)	CCl_3F	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Fluosilicic acid	Kieselfluorwasserstoffsäure	H_2SiF_6	50%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Fluosilicic acid	Kieselfluorwasserstoffsäure	H_2SiF_6	32%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Fluosilicic acid	Kieselfluorwasserstoffsäure	H_2SiF_6	10%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Formaldehyde	Formaldehyd (Formalin)	CH_2O	40%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Formaldehyde	Formaldehyd (Formalin)	CH_2O	10%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Formamide	Formamid (Ameisensäureamid)	CH_3NO	TR	20	+/-(s)	+/-(s)	+/-(q)	+
				40	+/-(s)	+/-(s)	+/-(q)	+
				60	+/-(s)	+/-(s)	+/-(q)	+
				80	-	+/-(s)	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Formic acid	Ameisensäure	HCOOH	< 60%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Formic acid	Ameisensäure	HCOOH	< 85%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Formic acid	Ameisensäure	HCOOH	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Formic acid ethyl ester	Ameisensäureethylester	$HCOOC_2H_5$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Formic acid methyl ester	Ameisensäuremethylester	$HCOOCH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Fructose	Fructose (Fruchtzucker)	$C_6H_{12}O_6$	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Fruit juices	Fruchtsäfte		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Fruit juices, unfermented	Obstsäfte		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Fruit pulp	Obstpulp		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Fuel	Kraftstoffe		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)
Fuel oil	Heizöl		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Fumaric acid	Fumarsäure	$C_2H_2(COOH)_2$	TR	20	+	+	+	+
	(1,4 Butendisäure)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Furan	Furan	C_4H_4O	TR	20	-	-	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Furfural	Furfural	OCH=CHCH=CCHO	TR	20	-	-	+/-(o)	+
	(Furfuran)			40	-	-	-	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Furfurylalcohol	Furfurylalkohol	$OH_3C_4CH_2OH$	TR	20	+	+	+	+
	(2-Furanylmethanol)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Gallic acid	Gallussäure	$C_6H_2(OH)_3COOH$	TR	20	+	+	+	+
	(3,4,5-Trihydroxybenzolsäure)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	-
				120	-	-	-	-
Gallium chloride	Galliumchlorid	$GaCl_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Gelatine	Gelatine		all	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Gipssupsension	Gipssupsension		S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Gluconic acid	Gluconsäure	$C_6H_{12}O_7$	TR	20	+	+	+	+
	(D-Gluconsäure)			40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)
Glucose	Dextrose	$C_6H_{12}O_6$	TR	20	+	+	+	+
	(D-Glucose)			40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Glucose	Dextrose	$C_6H_{12}O_6$	20%	20	+	+	+	+
	(D-Glucose)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Glucose	Glucose	$O(CHOH)_4CHCH_2OH$	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Glue	Leim		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Glutamic acid	Glutaminsäure	$HOOCCH_2CH_2CH(NH_2)$-COOH	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Glutaraldeyde	Glutaraldeyd	$C_5H_8O_2$	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Glutaric acid	Glutarsäure (Pentandisäure)	$HOOC(CH_2)_3COOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Glycerine	Glycerin	$C_3H_5(OH)_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Glycerinechlorohydrine	Glycerinchlorhydrin (3-Chlor-1,2-Propandiol)	$CH_2ClCHOHCH_2OH$	TR	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	-	-	+	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Glycerinemonolaurate	Glycerinmonolaurat (Monolaurinsäureglycerinester)	$CH_3(CH_2)_{10}COOC_3H_5$-$(OH)_2$	H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Glycerinetriacetate	Glycerintriacetat (Triessigsäureglycerinester)		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Glycerintriacetate	Triacetin (Glycerintriacetat)	$(CH_3COO)_3C_3H_5$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Glycerol	Glycerol	$(HOCH_2)_2CHOH$	VL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Glycerol	Glycerol	$(HOCH_2)_2CHOH$	10%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	-
Glycocol	Glykokol	NH_2CH_2COOH	10%	20	+	+	+	+
(glycin)	(Glycin)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Glycolic acid	Glykolsäure	$HOCH_2COOH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Glycolic acid	Glykolsäure	$HOCH_2COOH$	70%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Glycolic acid	Glykolsäure	$HOCH_2COOH$	37%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Glycolic acid	Glykolsäure	$HOCH_2COOH$	30%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Glyoxylic acid	Glyoxylsäure	OHCCOOH	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Glyoxylic acid	Glyoxylsäure	OHCCOOH	10%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Guanidinehydrochloride	Guanidinhydrochlorid	CH_5N_3 x HCl	all	20	+	+	+	+
	(Guanidiumchlorid)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
2-Hydroxyethyl hydrazine	2-Hydroxyethylhydrazin	$C_2H_8N_2O$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Hard coal tar oil	Steinkohlenteeröl		TR	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Heptane	Heptan (n-Heptan)	C_7H_{16}	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Heptanol	Heptanol (2,6-Dimethyl-4-heptanol)	$((CH_3)_2CHCH_2)_2CHOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Heptanone (2,6-Dimethyl-4-heptanone)	Heptanon (Isovalerone)	$((CH_3)_2CHCH_2)_2CO$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Hexachlorobutadiene	Hexachlorbuta-1,3-dien (Perchlorbutadien)	C_4Cl_6	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Hexachlorocyclohexane	Hexachlorcyclohexan (Lindan, Gammahexan)	$C_6H_6Cl_6$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Hexachloroethane	Hexachlorethan (Perchlorethan)	CCl_3CCl_3	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hexadiene (2,5-Dimethyl-1,5-hexadiene)	Hexadien	$CH_2C(CH_3)CH_2CH_2C$-$(CH_3)CH_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Hexafluoroethane	Hexafluorethan	C_2F_6	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Hexafluorosilicic acid	Hexafluorkieselsäure	H_2SiF_6	< 50%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Hexamethyldisilazane	Hexamethyldisilazane (HMDS)	$(CH_3)_3SiNHSi(CH_3)_3$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hexamethylenediamine	Hexamethylendiamin	$C_6H_{16}N_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Hexamethylenetetramine	Hexamethylentetramin	$(NCH_2)_3N(CH_2)_3$	TR	20	+	+	+	+
	(Urotropin)			40	+	+	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	-
				100	-	-	-	-
				120	-	-	-	-
Hexamethylphosphamide	Hexamethylphosphamid	$((CH_3)_2N)_3PO$	TR	20	+	+	+	+
	(HMPT)			40	+	+	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hexamethylphosphotriamide	Hexamethylphosphotriamide	$((CH_3)_2N)_3PO$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Hexane, liquid	Hexan, flüssig	C_6H_{14}	TR	20	+	+	+	+
	(n-Hexan)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Hexanetriole	Hexantriol	$C_6H_{11}(OH)_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Hexanol	Hexanol	$CH_3(CH_2)_4CH_2OH$	TR	20	+	+	+	+
	(Hexylalkohol)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hexanon	Hexanon	$CH_3CO(CH_2)_3CH_3$	TR	20	+/-(q)	+/-(q)	+/-(s)	+
	(Methylbutylketon)			40	+/-(q)	+/-(q)	+/-(s)	+
				60	+/-(q)	+/-(q)	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Hexene	Hexen	C_6H_{12}	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Honey	Honig		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrazine	Hydrazin	N_2H_4	10%	20	+	+	+/-(s)	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Hydrazine	Hydrazin	N_2H_4	15%	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Hydrazine	Hydrazin	N_2H_4	40%	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Hydrazine	Hydrazin	N_2H_4	70%	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Hydrazine	Hydrazin	N_2H_4	TR	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Hydrazine hydrate	Hydrazinhydrat	N_2H_4 x H_2O	< 24%	20	+	+	+/-(s)	+
				40	+	+	+/-(s)	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Hydrazine hydrochloride	Hydrazinhydrochlorid (Hydraziniumdihydrochlorid)	$NH_3NH_3Cl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrobromic acid (Hydrogen bromide)	Bromwasserstoffsäure	HBr	66%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+	+
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Hydrochinone	Hydrochinon (1,4-Dihydroxybenzol)	HOC_6H_4OH	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydrochloric acid	Salzsäure	HCl	39%	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	+/-(s)	+
				100	-	-	-	-
				120	-	-	-	-
Hydrochloric acid	Salzsäure	HCl	36%	20	+/-(s)	-	+	+
				40	+/-(s)	-	+	+
				60	+/-(s)	-	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrochloric acid	Salzsäure	HCl	30%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrochloric acid	Salzsäure	HCl	20%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Hydrochloric acid	Salzsäure	HCl	10%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrochloric acid	Salzsäure	HCl	5%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrocyanic acid	Cyanwasserstoffsäure (Blausäure)	HCN	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrocyanic acid, gaseous	Cyanwasserstoffsäure, gasförmig (Blausäure)	HCN	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrofluoric acid	Flusssäure (Fluorwasserstoffsäure)	HF	TR	20	-	-	+/-(q)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	+/-(q)
Hydrofluoric acid	Flusssäure (Fluorwasserstoffsäure)	HF	85%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Hydrofluoric acid	Flusssäure (Fluorwasserstoffsäure)	HF	70%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Hydrofluoric acid	Flusssäure (Fluorwasserstoffsäure)	HF	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Hydrofluoric acid	Flusssäure (Fluorwasserstoffsäure)	HF	≤ 40%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(s)	+/-(q)
				100	-	-	+/-(s)	+/-(q)
				120	-	-	-	+/-(q)
Hydrofluoric acid	Flusssäure (Fluorwasserstoffsäure)	HF	10%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Hydrogen	Wasserstoff	H_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Hydrogen chloride, gaseous	Chlorwasserstoff, gasförmig	HCl	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Hydrogen peroxide	Wasserstoffperoxid	H_2O_2	10%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydrogen peroxide	Wasserstoffperoxid	H_2O_2	30%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydrogen peroxide	Wasserstoffperoxid	H_2O_2	50%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydrogen peroxide	Wasserstoffperoxid	H_2O_2	70%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydrogen peroxide	Wasserstoffperoxid	H_2O_2	90%	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydrogen sulfide	Schwefelwasserstoff	H_2S	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydrogen sulfide	Schwefelwasserstoff	H_2S	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Hydroiodic acid	Iodwasserstoffsäure	HI	≤ GL	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Hydroiodic acid	Iodwasserstoffsäure	HI	57%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Hydroxyacetic acid	Hydroxyessigsäure	HOCCOOH	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Hydroxyethylethylene diamin triacetatacid	Hydroxyethylethylendiamin-triessigsäure, z.B. Trilon D		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Hydroxylamine sulfate	Hydroxylaminsulfat	$(H_2NOH)_2H_2SO_4$	all	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	+	+	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hydroxylamine sulfate	Hydroxylammoniumsulfat	$(H_2NOH)_2H_2SO_4$	< 12%	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	+	+	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Hypochlorous acid	Hypochlorige Säure (Unterchlorige Säure)	HOCl	33%	20	-	-	+	+
				40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	-	+
				100	-	-	-	+/-(o)
				120	-	-	-	+/-(o)
Ink	Tinte		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Iodine	Iod	I_2	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+
				120	-	-	-	-
Iodine solution (Iodine in ethanol)	Jodtinktur (Iod in Ethanol)	I_2 in C_2H_6O	6.5%	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	-
Iodine, anhydrous, gaseous	Iod, trocken, gasförmig	I_2	all	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+
				120	-	-	-	-
Iodoform	Iodoform (Triiodmethan)	CHI_3	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Iprodione	Iprodion (Glycophen, Promodion)	$C_{13}H_{13}Cl_2N_3O_3$	13 mg/l	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Iron salts	Eisensalze		all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Iron(II) chloride	Eisen(II)chlorid	$FeCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(II) nitrate	Eisen(II)nitrat	$Fe(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(II) sulfate	Eisen(II)sulfat	$FeSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(II) sulfide	Eisen(II)sulfid	FeS	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(III) aluminium chloride mixture	Eisen(III)-Aluminiumchlorid-mischung (Flockungsmittel) wie z.B. Südflock K2		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(III) chloride	Eisen(III)chlorid	$FeCl_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(III) chloride sulfate	Eisen(III)chloridsulfat	$FeClSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(III) hydroxide	Eisen(III)hydroxid	$(CH_3)_2CHCH_2CHOHCH_3$	TR	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Iron(III) nitrate	Eisen(III)nitrat	$Fe(NO_3)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Iron(III) sulfate	Eisen(III)sulfat	$Fe_2(SO_4)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Isobutan	Isobutan	C_4H_{10}	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Isobutylamine	Isobutylamin	$CH_3CH(CH_3)CH_2NH_2$	TR	20	+	+	+	+
	(1-Amino-2-methylpropan)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Isononanic acid chloride	Isononansäurechlorid	$C_9H_{17}ClO$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Isooctane	Isooctan	C_8H_{18}	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Isopentanol	Isopentanol	$(CH_3)_2CHCH_2CH_2OH$	TR	20	+	+	+	+
	(Isoamylalkohol)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Isophorone	Isophoron	$C_9H_{14}O$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Isopropanol	Isopropanol	$(CH_3)_2CHOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Isopropyl acetate	Essigsäureisopropylester	$CH_3COOCH(CH_3)_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Isopropyl ether	Isopropylether	$C_6H_{14}O$	TR	20	+/-(o)	+/-(o)	+	+
				40	-	-	+	+
				60	-	-	+/-(o)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Isopropylamine	Isopropylamin	C_3H_9N	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+
				100	-	-	-	-
				120	-	-	-	-
Isothiazolone	Isothiazolone		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Isovalerone	Isovaleron	$((CH_3)_2CHCH_2)_2CO$	TR	20	+/-(q)	+/-(q)	+	+
(2,6-Dimethyl-4-heptanone)	(Diisobutylketone)			40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Jet petrol	Kerosin (Flugzeugkraftstoff)		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Lactic acid (2-Hydroxypropanoic acid)	Milchsäure (2-Hydroxypropansäure)	$CH_3CHOHCOOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Lactic acid (2-Hydroxypropanoic acid)	Milchsäure (2-Hydroxypropansäure)	$CH_3CHOHCOOH$	90%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Lactic acid (2-Hydroxypropanoic acid)	Milchsäure (2-Hydroxypropansäure)	$CH_3CHOHCOOH$	75%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Lactic acid (2-Hydroxypropanoic acid)	Milchsäure (2-Hydroxypropansäure)	$CH_3CHOHCOOH$	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Lactic acid (2-Hydroxypropanoic acid)	Milchsäure (2-Hydroxypropansäure)	$CH_3CHOHCOOH$	10%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Lactose	Lactose (Milchzucker)	$C_{12}H_{22}O_{11}$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Lanoline	Lanolin (Wollfett, Wollwachs)		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	-	+
				120	-	-	-	-
Lauric acid	Laurinsäure	$C_{12}H_{24}O_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Lauric acid chloride	Laurylsäurechlorid (Lauroylchlorid)	$CH_3(CH_2)_{10}COCl$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Lauryl alcohol	Laurylalkohol	$C_{12}H_{25}OH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Lauryl chloride	Laurylchlorid	$C_{11}H_{23}COCl$	TR	20	+	+	+	+
	(Dodecylchlorid)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Lauryl mercaptane	Laurylmercaptan	$C_{12}H_{25}SH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Lauryl sulfate	Laurylsulfat	$(C_{12}H_{25}O)_2SO_2$	TR	20	+	+	+	+
	(Schwefelsäurediarylester)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Laurylmercaptan	Dodecanethiol	$C_{12}H_{25}SH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Lead acetate	Bleiactetat	$Pb(CH_3COO)_2$	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Lead chloride	Bleichlorid	$PbCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Lead nitrate	Bleinitrat	$Pb(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Lead sulfate	Bleisulfat	$PbSO_4$	S	20	+	+	+	+
	(Bleivitriol)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Lead tetrafluoroborate	Bleitetrafluorborat	$Pb(BF_4)_2$	< 50%	20	+	+	+	+
	(Bleifluorborat)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Light oil	Leichtöl		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Linoleic acid	Linolsäure	$C_{17}H_{31}COOH$	TR	20	+	+	+	+
	(Octadecadiensäure)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Linseed oil	Leinöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Liqueurs	Liköre		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Liquid fertiliser	Flüssigdünger		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Liquid manure	Jauche		TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	-	+
				120	-	-	-	+
Lithium bromide	Lithiumbromid	LiBr	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Lithium chloride	Lithiumchlorid	LiCl	40%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Lithium chromate	Lithiumchromat	LiCr	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	+/-(o)
				120	-	-	-	-
Lithium hydroxide	Lithiumhydroxid	LiOH	≤ GL	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Lithium sulfate	Lithiumsulfat	Li_2SO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Lubricating oils	Schmieröle		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
1-Methyl-2-pyrrolidone	1-Methyl-2-pyrrolidon	C_5H_9NO	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	-	-	-	+/-(q)
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
2-Mercaptobenzothiazole	2-Mercaptobenzothiazol	$C_7H_5NS_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
2-Mercaptoethanol	Mercaptoethanol (Thioglykol)	$HSCH_2CH_2OH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
2-Methylbutane	2-Methylbutan	C_5H_{12}	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Machine oil	Maschinenöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Magnesium carbonate	Magnesiumcarbonat	$MgCO_3$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium chloride	Magnesiumchlorid	$MgCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium chloride hexahydrate	Magnesiumchloridhexahydrat	$MgCl_2$ x $6H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium citrate	Magnesiumcitrat	$C_3H_4OHCOOH(COO)_2Mg$ x $5H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium hydrogen carbonate	Magnesiumhydrogencarbonat	$Mg(HCO_3)_2$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium hydroxide	Magnesiumhydroxid	$Mg(OH)_2$	≤ GL	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Magnesium hydroxide carbonate	Magnesiumhydroxidcarbonat	$MgCO_3$ x $Mg(OH)_2$ x H_2O	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Magnesium nitrate	Magnesiumnitrat	$Mg(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium nitrate	Magnesiumnitrat	$Mg(NO_3)_2$	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium salts	Magnesiumsalze		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Magnesium sulfate	Magnesiumsulfat	$MgSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Maleic acid	Maleinsäure	$(CHCOO)_2$	TR	20	+/-(q)	+/-(q)	+	+
(cis-butenedioic acid)	(cis-Butendisäure)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Maleic anhydride	Maleinsäureanhydrid	$C_2H_2(CO)_2O$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Malonic acid	Malonsäure	$HOOCCH_2COOH$	TR	20	+/-(q)	+/-(q)	+	+
	(Propandisäure)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Manganese sulfate	Mangansulfat	$MnSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Marmalade	Marmelade		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mayonnaise	Mayonnaise		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Menthol	Menthol	$(CH_3)_2CHC_6H_3CH_3OH$	TR	20	+	+	+	+
	(3-p-Methanol)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Mercury salts	Quecksilbersalze		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mercury(I) nitrate	Quecksilber(I)nitrat	$HgNO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mercury(II) chloride	Quecksilber(II)chlorid	$HgCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mercury(II) cyanide	Quecksilber(II)cyanid	$Hg(CN)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mercury(II) nitrate	Quecksilber(II)nitrat	$Hg(NO_3)_2$	S	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mercury(II) sulfate	Quecksilber(II)sulfat	$HgSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mercury, liquid	Quecksilber, flüssig	Hg		20	-	-	-	-
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Mesitylen	Mesitylen		TR	20	+	+	+	+
(Trimethylbenzol)	(Trimethylbenzol)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Metal pickle	Metallbeize		VL	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Metal soap	Metallseife			20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Methacrylic acid	Methacrylsäure	$C_4H_6O_2$	TR	20	+	+	+	+
	(2-Methylpropensäure,			40	+	+	+	+
	Isobutensäure)			60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Methane	Methan	CH_4	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methanesulfonic acid	Methansulfonsäure (Methylschwefelsäure)	CH_3SO_3H	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Methanesulfonic acid	Methansulfonsäure (Methylschwefelsäure)	CH_3SO_3H	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methanesulfonyl chloride	Methansulfonylchlorid (Mesylchlorid)	CH_3SO_2Cl	TR	20	+/-(s)	+/-(s)	-	+
				40	-	-	-	+
				60	-	-	-	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methanol	Methanol (Methylalkohol)	CH_3OH	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methanol	Methanol (Methylalkohol)	CH_3OH	50%	20	+	+	+/-(q)	+
				40	+/-(q)	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methanol	Methanol (Methylalkohol)	CH_3OH	20%	20	+	+	+	+
				40	+/-(q)	+	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methanthiol	Methanthiol (Methylmercaptan, Methylsulfhydrat)	CH_4S	5%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Methoxybutanol	Methoxybutanol	$CH_3CH(OCH_3)(CH_2CH_2$-OH)	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methoxybutyl acetate	Essigsäuremethoxybutylester (Butoxyl)	$CH_3COOCH_2CH_2CH$-$(OCH_3)(CH_3)$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Methoxyethyloleate	Ölsäuremethoxyethylester (Methoxyethyloleat)		TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Methoxypropanol	Methoxypropanol	$CH_3CH(OCH_3)(CH_2OH)$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methoxypropylamine	Methoxypropylamin	$CH_3O(CH_2)_3NH_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methyl acetate	Methylacetat	CH_3COOCH_3	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methyl acrylate	Acrylsäuremethylester	$CH_2CHCOOCH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Methyl acrylate (Propenoic acid methyl ester)	Methylacrylat	$CH_2{=}CHCOOCH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Methyl amine	Methylamin (Aminethan)	CH_3NH_2	TR	20	+/-(q)	+/-(q)	-	+
				40	+/-(q)	+/-(q)	-	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl amine	Methylamin (Aminethan)	CH_3NH_2	32%	20	+/-(q)	+/-(q)	-	+
				40	+/-(q)	+/-(q)	-	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl benzoate	Benzoesäuremethylester (Methylbenzoat)	$C_6H_5COOC_2H_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl bromide	Methylbromid	CH_3Br	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Methyl butyrate	Methylbutyrat (Buttersäuremethylester, Methylbutanoat)	$CH_3CH_2CH_2COOCH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Methyl chloride	Methylchlorid	CH_3Cl	TR	20	-	-	+	+
				40	-	-	+/-(s)	+/-(s)
				60	-	-	-	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Methyl ethyl ether	Methylethylether	$H_3COC_2H_5$	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl ethyl ketone	Methylethylketon	$CH_3COC_2H_5$	TR	20	+/-(q)	+	-	+
				40	+/-(q)	+	-	+
				60	-	+/-(q)	-	+/-(q)
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methyl formiate	Methylformiat (Ameisensäuremethylester, Methansäuremethylester, Methylmethanat)	$C_2H_4O_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl isobutyl ketone	Methylisobutylketon (4-Methyl-2-pentanon)	$CH_3COCH_2CH(CH_3)_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl isobutyl ketone	Methylisobutylketon (4-Methyl-2-pentanon)	$CH_3COCH_2CH(CH_3)_2$	1%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyl sulfate	Methylsulfat	CH_3OSO_3H	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methyl sulfate	Methylsulfat	CH_3OSO_3H	50%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methyl tert-butyl ether	Methyl-tertiär-butylether	$C_5H_{12}O$	TR	20	+/-(s)	+/-(s)	+/-(s)	+/-(s)
				40	-	-	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methylchloroformiate	Chlorameisensäuremethylester	$ClCOOCH_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Methylchlorophenoxyacetic acid	Methylchlorphenoxyessigsäure	$Cl(CH_3)C_6H_3OCH_2COOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Methylchlorophenoxypropanoic acid	Methylchlorphenoxypropionsäure	$Cl(CH_3)C_6H_3OCH(CH_3)$-COOH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Methylcyclohexane	Methylcyclohexan	$H_3CC_6H_{11}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Methylene bromide	Dibrommethan (Methylenbromid)	CH_2Br_2	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Methylene chloride	Methylenchlorid (Dichlormethan)	CH_2Cl_2	TR	20	-	-	+/-(s)	+/-(s)
				40	-	-	+/-(s)	+/-(s)
				60	-	-	-	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyleneiodide	Diiodmethan (Methylenjodid)	CH_2I_2	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methylmethacryalate (2-Methylpropenoic acid methyl ester)	Methylmethacryalat	$CH_2{=}C(CH_3)COOCH_3$	50%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methylmethacrylate	Methacrylsäuremethylester (MMA)	$CH_2C(CH_3)(COOCH_3)$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Methylpropionate	Methylpropionat	$CH_3CH_2COOH_3$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methylstyrol	Methylstyrol (4-Vinyltoluol)	$CH_3C_6H_4CHCH_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	-	-	-	+/-(q)
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Methyltrichlorosilan	Methyltrichlorsilan	CH_3SiCl_3	TR	20	+/-(s)	+/-(s)	+/-(s)	+/-(s)
				40	-	-	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Milk	Milch		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Mineral oil, no aromatic	Mineralöl, aromatenfrei	$CH_3CHOHCOOH$	H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+	+/-(q)
				120	-	-	-	+/-(q)

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Mineral water	Mineralwasser			20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Molasses	Melasse		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Molasses flavor	Melassewürze		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Monobromicacetic acid	Monobromessigsäure	$C_2H_3BrCO_2$	80%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Monochloroacetic acid	Chloressigsäure (MONO)	$ClCH_2COOH$	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Monochloroacetic acid	Chloressigsäure (MONO)	$ClCH_2COOH$	85%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Monochloroacetic acid	Chloressigsäure (MONO)	$ClCH_2COOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Monochloroacetic acid ethyl ester	Monochloressigsäureethylester	$ClCH_2COOC_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Monochloroacetic acid methyl ester	Monochloressigsäuremethyl-ester	$ClCH_2COOCH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Monoethanolamine	Monoethanolamin (2-Aminoethanol, Ethanolamin, Aminoethylalkohol)	C_2H_7NO	30%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	-	+/-(q)	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Mononitrochlorobenzene	Mononitrochlorbenzol		TR	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Monophosphane	Monophosphan	PH_3	TR	20	+/-(q)	+/-(q)	+	+
	(Phosphan,			40	+/-(q)	+/-(q)	+	+
	Phosphorwasserstoff)			60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Monophosphane	Monophosphan	PH_3	4%	20	+/-(q)	+/-(q)	+	+
	(Phosphan,			40	+/-(q)	+/-(q)	+	+
	Phosphorwasserstoff)			60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Monopropylene glykol	Monopropylenglykol	$C_3H_8O_2$	6%	20	+/-(q)	+/-(q)	+	+
	(1,2-Propandiol,			40	+/-(q)	+/-(q)	+	+
	Propylenglykol)			60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Morpholine	Morpholin	$HNCH_2CH_2OCH_2CH_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Motor oil	Motorenöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Mustard	Senf		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Nail polish remover	Nagellackentferner		H	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	-	-	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Naphtha	Naphta		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Naphthalene	Naphthalin	$C_{10}H_8$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Naphthalenesulfonic acid	Naphtalinsulfonsäure	$C_{10}H_7SO_3H$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Naphtylbenzothiazylolethene	Naphtylbenzothiazylolethen		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Natrium aluminium sulfate	Natriumaluminiumsulfat	$NaAl(SO_4)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Natural gas, gaseous	Erdgas, gasförmig		TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Natural gas, liquid	Erdgas, flüssig		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
n-Butylmercaptan	Butylmercaptan	C_4H_9SH	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
n-Heptan	n-Heptan	$(C_7H_{16})_n$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
n-Hexan	n-Hexan	$(C_6H_{14})_n$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
NDM	NDM		H	20	+/-(q)	+/-(q)	+	+
(n-Dodecylmercaptan)	(n-Dodecylmercaptan)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+
				120	-	-	-	-
Nickel acetate	Nickelacetat	$Ni(CH_3COO)_2$	≤ GL	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Nickel nitrate	Nickelnitrat	$Ni(NO_3)_2$	≤ GL	20	+	+	+	+
	(Nickeldinitrat)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Nickel salts	Nickelsalze		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Nickel sulfamate	Nickelsulfamat		55%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Nickel sulfate	Nickelsulfat	$NiSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Nickel(II) chloride	Nickel(II)chlorid	$NiCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Nicotine	Nikotin	$C_5H_4NC_4H_7NCH_3$	VL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Nicotinic acid	Nicotinsäure	$(NC_5H_4)COOH$	VL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	98%	20	-	-	-	+/-(q)
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	90%	20	-	-	-	+/-(q)
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	65%	20	-	-	+/-(o)	+
				40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	53%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	40%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	30%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	20%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Nitric acid	Salpetersäure	HNO_3	10%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid	Salpetersäure	HNO_3	6.3%	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Nitric acid glycerinester	Salpetersäureglycerinester		TR	20	-	-	+/-(o)	+
	(Nitroglycerin)			40	-	-	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Nitric oxide	Stickoxide		TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Nitrilotriacetatacid	Nitrilotriessigsäure	$N(CH_2COOH)_3$	H	20	+/-(q)	+/-(q)	+/-(q)	+
	(Trilon AS)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Nitrobenzene	Nitrobenzen	$C_6H_5NO_2$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Nitrobenzoic acid	Nitrobenzoesäure	$C_6H_4NO_2COOH$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Nitrocellulose	Nitrocellulose		TR	20	+	+	+	+
	(Cellulosenitrat)			40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Nitroethane	Nitroethan	$CH_3CH_2NO_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Nitrogen	Stickstoff	N_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Nitrogen fluoride	Stickstofffluorid	NF_3	TR	20	+	+	+	+
	(Trifluoramin)			40	+	+	+	+
				60	+	+	+/-(q)	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Nitroglykol	Nitroglykol (Ethylenglykoldinitrat)	$O_2NOCH_2CH_2ONO_2$	VL	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Nitromethane	Nitromethan	CH_3NO_2	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Nitropropane	Nitropropan	$CH_3CH_2CH_2NO_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Nitrotoluene (o-,m-,p-)	Nitrotoluole (o-,m-,p-)	$C_7H_7NO_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Nitrous acid	Salpetrige Säure	HNO_2	VL	20	+/-(o)	+/-(o)	+/-(o)	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+
				100	-	-	-	-
				120	-	-	-	-
Nitrous gases	Nitrose Gase	NO_x	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Nonylalcohol	Nonylalkohol (1-Nonanol)	$CH_3(CH_2)_7CH_2OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Nonylphenylpolyglykolether	Nonylphenylpolyglykolether	$C_9H_{19}C_6H_4(OC_2H_4)_nOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Nonylphenylpolyglykolether	Nonylphenylpolyglykolether	$C_9H_{19}C_6H_4(OC_2H_4)_nOH$	20%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Nonylphenylpolyglykolether	Nonylphenylpolyglykolether	$C_9H_{19}C_6H_4(OC_2H_4)_nOH$	5%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Nonylphenylpolyglykolether	Nonylphenylpolyglykolether	$C_9H_{19}C_6H_4(OC_2H_4)_nOH$	2%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Nut oil	Nussöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
oCresol	oCresol	$C_6H_4CH_3OH$	TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Octane	Octan	$CH_3(CH_2)_6CH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Octanol	Octanol (Octylalkohol)	$C_8H_{17}OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Octene	Octen	$CH_3(CH_2)_4CHCHCH_3$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Octylcresol	Octylcresol	$CH_3(CH_2)_7C_6H_3OHCH_3$	TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Oils (animal)	Öle, tierische		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Oils (etherel)	Öle, etherische		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Oleic acid	Ölsäure	$C_{17}H_{33}COOH$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Oleum	Oleum	$H_2SO_4 + SO_3$		20	-	-	-	+
(sulfuric acid	(Schwefelsäure			40	-	-	-	-
+ sulfur trioxide 10%)	+ Schwefeltrioxid 10%)			60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Oleum	Oleum	$H_2SO_4 + SO_3$		20	-	-	-	+
(sulfuric acid	(Schwefelsäure			40	-	-	-	-
+ sulfur trioxide 30%)	+ Schwefeltrioxid 30%)			60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Oleum vapours	Oleumdämpfe		traces	20	-	-	-	+
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Olive oil	Olivenöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Optical brightener	Optische Aufheller		H	20	+	+	+	+
				40	+	+	+	+
				60	-	+	+	+
				80	-	-	+	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Orange peel oil	Apfelsinenschalenöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Oxalic acid	Oxalsäure	HOOCCOOH	TR	20	+/-(q)	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Oxalic acid	Oxalsäure	HOOCCOOH	VL	20	+/-(q)	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Oxalic acid	Oxalsäure	HOOCCOOH	50%	20	+/-(q)	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Oxygen	Sauerstoff	O_2	all	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Ozone	Ozon	O_3	≤ GL	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, aqueous	Ozon, wässrig	O_3	1 ppm	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, aqueous	Ozon, wässrig	O_3	2.5 ppm	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Ozone, aqueous	Ozon, wässrig	O_3	30 ppm	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, aqueous	Ozon, wässrig	O_3	100 ppm	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, aqueous	Ozon, wässrig	O_3	700 ppm	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, gaseous	Ozon, gasförmig	O_3	0.5 ppm	20	+/-(s)	+/-(s)	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, gaseous	Ozon, gasförmig	O_3	0.15%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, gaseous	Ozon, gasförmig	O_3	1%	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, gaseous	Ozon, gasförmig	O_3	up to 2%	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Ozone, gaseous	Ozon, gasförmig	O_3	6%	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Palm oil, palm nut oil	Palmöl, Palmkernöl		H	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Palmitic acid	Palmitinsäure	$C_{15}H_{31}COOH$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
p-Aminoazobenzene	Aminoazobenzen	$NH_2C_6H_4NNC_6H_5$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Paraffin emulsion	Paraffinemulsion		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Paraffin oil	Paraffinöl		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Paraffine	Paraffine		TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Paraldehyde	Paraldehyd (Paracetylaldehyd)	$(OCHCH_3)_3$	TR	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Patassium aluminium fluoride	Kaliumaluminiumfluorid	$KAlF_4$	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
p-dibromobenzene	p-dibrombenzen	$C_6H_4Br_2$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Peanut butter	Erdnussbutter		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Peanut oil	Erdnussöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Pectin	Pektin (Polygalactaronsäuremethylerster)		TR	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+	+/-(q)	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Pentachlorofluoroethane, aqueous	Pentachlorfluorethan, wässrig	CCl_3CCl_2F	12%	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Pentan, liquid	Pentan (n-Pentan, Amylhydrid), flüssig	C_5H_{12}	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Pentanol	Pentanol (Amylalkohol)	$C_5H_{11}OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Pentyl laurate	Laurylsäureamylester	$CH_3(CH_2)_{10}COOC_5H_{11}$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Peppermint oil	Pfefferminzöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Peracetic acid	Peroxyessigsäure (Ethanperoxysäure, Peressigsäure)	$C_2H_4O_3$	40%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Peracetic acid	Peroxyessigsäure (Ethanperoxysäure, Peressigsäure)	$C_2H_4O_3$	15%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Peracetic acid	Peroxyessigsäure (Ethanperoxysäure, Peressigsäure)	$C_2H_4O_3$	1%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Perchloric acid	Perchlorsäure	$HClO_4$	70%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Perchloric acid	Perchlorsäure	$HClO_4$	50%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Perchloric acid	Perchlorsäure	$HClO_4$	20%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Perchloric acid	Perchlorsäure	$HClO_4$	10%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Perchloroethylene	Perchlorethylen (Tetrachlorethylen)	$Cl_2C=CCl_2$	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Petrol of airplane	Flugzeugbenzin		H	20	+/-(q)	+/-(q)	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Petroleum	Erdöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Petroleum	Petroleum		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Petroleumether	Petrolether	C_5H_{12} or C_6H_{14}	TR	20	+/-(s)	+/-(s)	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Phenol	Phenol	C_6H_5OH	≤ 5%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phenol	Phenol	C_6H_5OH	≤ 10%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Phenol	Phenol	C_6H_5OH	≤ 90%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phenol	Phenol	C_6H_5OH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phenol resin	Phenolharz-Formmassen		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phenolsulfon acid	Phenolsulfonsäure (Paraphenolsulfonsäure, p-Phenolsulfonsäure)	$C_6H_6O_4S$	≤ 2%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Phenolsulfon acid	Phenolsulfonsäure (Paraphenolsulfonsäure, p-Phenolsulfonsäure)	$C_6H_6O_4S$	65%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Phenolsulfon acid	Phenolsulfonsäure	$C_6H_6O_4S$	70%	20	+/-(q)	+/-(q)	+	+
	(Paraphenolsulfonsäure,			40	+/-(q)	+/-(q)	+	+
	p-Phenolsulfonsäure)			60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Phenyl bromide	Phenylbromid	C_6H_5Br	TR	20	-	-	+/-(s)	+
	(Brombenzol)			40	-	-	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Phenyl hydrazine	Phenylhydrazin	$C_6H_5NHNH_2$	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	-	+
				60	+/-(q)	+/-(q)	-	+
				80	-	-	-	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Phenylhydrazine hydrochloride	Phenylhydrazinchlorhydrat	$C_6H_5NHNH_3Cl$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Phenylphenol	Phenylphenol	$C_6H_5C_6H_4OH$	TR	20	+/-(q)	+/-(q)	+	+
	(2-Hydroxybiphenyl)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Phenylsulfone	Phenylsulfon		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Phosgene, gaseous	Phosgen, gasförmig	$COCl_2$	TR	20	-	-	+/-(o)	+
				40	-	-	+/-(o)	+/-(o)
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Phosgene, liquid	Phosgen, flüssig	$COCl_2$	TR	20	-	-	+/-(o)	+
				40	-	-	+/-(o)	+/-(o)
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Phosphane, gaseous	Phosphorwasserstoff, gasförmig	PH_3	TR	20	+	+	+	+
	(Phosphan)			40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	-
Phosphoric acid	Phosphorsäure	H_3PO_4	30%	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Phosphoric acid	Phosphorsäure	H_3PO_4	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Phosphoric acid	Phosphorsäure	H_3PO_4	85%	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Phosphoric acid	Phosphorsäure	H_3PO_4	95%	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	+
Phosphoric acid	Phosphorsäure	H_3PO_4	98%	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Phosphoric acid diethyl ester	Phosphorsäurediethylester		40%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Phosphoric acid tri-2-chloroethyl ester	Phosphorsäuretri-2-chlorethyl-erster	$(Cl_3CCH_2O)_3PO$	TR	20	+	+	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Phosphoric acid tri-2-kresyl ester	Phosphorsäuretri-2-kresylester	$OP(OC_6H_4CH_3)_3$	TR	20	+	+	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Phosphoric acid tributyl ester	Phosphorsäuretributylester (Tributylphosphat)	$(C_4H_9)_3PO_4$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Phosphoric acid triethyl ester	Phosphorsäuretriethylester (Triethylphosphat)	$(C_2H_5O)_3PO$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Phosphoric acid trioctyl ester	Phosphorsäuretrioctylester (Trioctylphosphat)	$(C_8H_{14})_3PO_4$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Phosphorus	Phosphor	$(P_4)_n$	TR	20	-	-	-	-
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Phosphorus chloride	Phosphortrichlorid	PCl_3	TR	20	+	+/-(o)	+/-(o)	+
				40	+/-(o)	-	+/-(o)	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Phosphorus oxychloride	Phosphoroxychlorid	$POCl_3$	TR	20	+/-(o)	+/-(o)	+/-(o)	+/-(o)
				40	-	-	-	+/-(o)
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Phosphorus pentachloride	Phosphorpentachlorid	PCl_5	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Phosphorus pentoxide	Phosphorpentoxyd	P_2O_5	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+/-(s)	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	-
Phtalic acid butyl benzyl ester	Phthalsäurebutylbenzylester		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid	Phthalsäure	$HOOCC_6H_4COOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid diamyl ester	Phthalsäurediamylester	$H_{11}C_5COOC_6H_4COOC_5H_{11}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid dibutyl ester	Phthalsäuredibutylester	$C_{16}H_{22}O_4$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid diethyl ester	Phthalsäurediethylester	$H_{17}C_8COOC_6H_4COOC_8H_{17}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid dihexyl ester	Phthalsäuredihexylester (Dihexylphtalat)	$H_{13}C_6COOC_6H_4COOC_6H_{13}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid diisooctyl ester	Phthalsäurediisooctylester (Diisooctylphtalat)	$H_{17}C_8COOC_6H_4COOC_8H_{17}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid dimethyl ester	Phthalsäuredimethylester	$C_6H_4(COOCH_3)_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Phthalic acid dinonyl ester	Phthalsäuredinonylester	$H_{19}C_9COOC_6H_4COOC_9H_{19}$	TR	20	+/-(q)	+/-(q)	+	+
	(Dinonylphtalat)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic acid dioctyl ester	Phthalsäuredioctylester	$C_{24}H_{38}O_4$	TR	20	+/-(q)	+/-(q)	+	+
	(DOP)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Phthalic anhydride	Phthalsäureanhydrid	$C_6H_4(CO)_2O$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	-	-
				120	-	-	-	-
Picric acid	Pikrinsäure	$C_6H_2(OH)(NO_2)_3$	1%	20	+/-(q)	+/-(q)	+	+
	(2,4,6-Trinitrophenol)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Picric acid	Pikrinsäure	$C_6H_2(OH)(NO_2)_3$	50%	20	+/-(q)	+/-(q)	+	+
	(2,4,6-Trinitrophenol)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Picric acid	Pikrinsäure	$C_6H_2(OH)(NO_2)_3$	TR	20	+/-(q)	+/-(q)	+	+
	(2,4,6-Trinitrophenol)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Pine needle oil	Fichtennadelöl		H	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Pine oil	Kiefernadelöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Piperazine	Piperazine	$NHCH_2CH_2NHCH_2CH_2$	50%	20	+/-(q)	+/-(q)	+	+
	(Diethylendiamin)			40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Pivalic acid chloride	Pivalinsäurechlorid		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Polyacryl amide	Polyacrylamid		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Polyacryl chloride	Polyacrylchlorid	$(C_3H_5ClO)_n$	H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Polyaluminium chloride	Polyaluminiumchlorid	$Al_n(OH)_mCl_{3n-m}$	40%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Polyester resin	Polyesterharz		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Polyglykol	Polyglykol (Polyethylenglykol)		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Polyole	Polyole		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Polyvinyl acetate, solid	Polyvinylacetat, fest	$H(CH_2CHOOCCH_3)_nH$	H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	-
				120	-	-	-	-
Polyvinyl alcohol, solid	Polyvinylalkohol, fest	$H(CH_2CHO)_nH$	H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	-
				120	-	-	-	-
Potassium	Kalium	K		20	-	-	-	-
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Potassium acetate	Kaliumacetat	CH_3COOK	≤ GL	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Potassium aluminium sulfate (alum)	Kalium-Aluminiumsulfat (Alaun)	$Al_2(SO_4)_3 \times K_2SO_4 \times 24H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium aluminium sulfate (alum)	Kalium-Aluminiumsulfat (Alaun)	$Al_2(SO_4)_3 \times K_2SO_4 \times 24H_2O$	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Potassium bichromate	Kaliumbichromat	$K_2Cr_2O_7$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium borate	Kaliumborat	K_3BO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium bromate	Kaliumbromat	$KBrO_3$	≤ GL	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	+/-(o)	+/-(o)	+	+
				80	-	+/-(o)	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium bromate	Kaliumbromat	$KBrO_3$	10%	20	+	+	+	+
				40	+/-(o)	+/-(o)	+	+
				60	+/-(o)	+/-(o)	+	+
				80	-	+/-(o)	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium bromide	Kaliumbromid	KBr	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium bromide	Kaliumbromid	KBr	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium carbonate	Kaliumcarbonat	K_2CO_3	50%	40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
				20	+	+	+	+
Potassium carbonate (Potash)	Kaliumcarbonat (Pottasche)	K_2CO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium carbonate (Potash)	Kaliumcarbonat (Pottasche)	K_2CO_3	30%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium chlorate	Kaliumchlorat	$KClO_3$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	+	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium chlorate	Kaliumchlorat	$KClO_3$	VL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	+	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Potassium chloride	Kaliumchlorid	KCl	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium chloride	Kaliumchlorid	KCl	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium chlorite	Kaliumchlorit	$KClO_2$	5%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium chlorite	Kaliumchlorit	$KClO_2$	50%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium chromate	Kaliumchromat	K_2CrO_4	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium cyanide	Kaliumcyanid	KCN	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium dichromate	Kaliumdichromat	$K_2Cr_2O_7$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium dichromate	Kaliumdichromat	$K_2Cr_2O_7$	VL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	+	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium ferricyanide	Ferricyankalium (Kaliumhexacyaonaferrat)	$K_3[Fe(CN)_6]$	VL	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Potassium ferrocyanide	Kaliumeisencyanid	$K_4[Fe(CN)_6]$ x $3H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium ferrocyanide (II)	Kaliumhexacyanoferrat(II) (gelbes Blutlaugensalz)	$K_4[Fe(CN)_6]$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Potassium ferrocyanide (III)	Kaliumhexacyanoferrat(III) (rotes Blutlaugensalz)	$K_3[Fe(CN)_6]$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium fluoride	Kaliumfluorid	KF	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium formate	Kaliumformiat	KCOOH	55%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Potassium hydrogen carbonate	Kaliumhydrogencarbonat (Kaliumbicarbonat)	$KHCO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium hydrogen phosphate	Kaliumdihydrogenphosphat	KH_2PO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium hydrogen sulfate	Kaliumhydrogensulfat	$KHSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium hydrogen sulfite	Kaliumhydrogensulfit	$KHSO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium hydroxide	Kalilauge (Kaliumhydroxid)	KOH	50%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium hydroxide	Kalilauge (Kaliumhydroxid)	KOH	30%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium hydroxide	Kalilauge (Kaliumhydroxid)	KOH	5%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium hydroxide	Kalilauge (Kaliumhydroxid)	KOH	4%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Potassium hydroxide	Kalilauge (Kaliumhydroxid)	KOH	2%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium hydroxide	Kalilauge (Kaliumhydroxid)	KOH	<1%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium hypochlorite	Kaliumhypochlorit	KClO	≤ GL	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium hypochlorite	Kaliumhypochlorit	KClO	VL	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Potassium iodate	Kaliumiodat	KIO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium iodate	Kaliumiodat	KIO_3	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium iodide	Kaliumiodid	KI	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium Iodine (Lugol's-solution)	Iod-Iodkalium (Lugols-Lösung)	$KI + I_2$	< 3%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+/-(q)	+
				80	-	+/-(s)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Potassium metaborate	Kaliummetaborat	KBO_2	1%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium nitrate	Kaliumnitrat	KNO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium nitrite	Kaliumnitrit	KNO_2	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Potassium perborate	Kaliumperborat	$K_2B_2O_6$ x H_2O	≤ GL	20	+	+	+	+
	(Kaliumperoxoborat)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium perchlorate	Kaliumperchlorat	$KClO_4$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium permanganate	Kaliumpermanganat	$KMnO_4$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium permanganate	Kaliumpermanganat	$KMnO_4$	6%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium permanganate	Kaliumpermanganat	$KMnO_4$	10%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium permanganate	Kaliumpermanganat	$KMnO_4$	18%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium permanganate	Kaliumpermanganat	$KMnO_4$	20%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium permanganate	Kaliumpermanganat	$KMnO_4$	50%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+	+
				80	-	-	+/-(o)	+
				100	-	-	-	+/-(o)
				120	-	-	-	-
Potassium persulfate	Kaliumpersulfat	$K_2S_2O_8$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium phosphate	Kaliumphosphat	K_3PO_4	VL	20	+	+	+	+
	(Trikaliumphosphat)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium sulfate	Kaliumsulfat	K_2SO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Potassium sulfite	Kaliumsulfit	K_2SO_3 x H_2O	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Potassium tatrate	Kaliumtartrat	$K_2(CHOHCOO)_2$ x $2H_2O$	≤ GL	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)
Potassium tetracyanocuprate	Kaliumtetracyanocuprat	$K_3[Cu(CN)_4]$	≤ GL	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)
Potassium tripolyphosphate	Kaliumtripolyphosphat	$K_5P_3O_{10}$	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Propane, gaseous	Propan, gasförmig	C_3H_8	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propane, liquid	Propan, flüssig	C_3H_8	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propanol	Propanol	C_3H_7OH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propargyl alcohol	Propargylalkohol	$CH{=}CCH_2OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propargyl alcohol	Propargylalkohol	$CH{=}CCH_2OH$	7%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propionic acid	Propionsäure	CH_3CH_2COOH	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propionic acid	Propionsäure	CH_3CH_2COOH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Propionic acid ethyl ester	Propionsäureethylester	$CH_3CH_2COOC_2H_5$	TR	20	+/-(q)	+/-(q)	+	+
	(Ethylpropionat)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propionic acid methyl ester	Propionsäuremethylester	$CH_3CH_2COOCH_3$	TR	20	+/-(q)	+/-(q)	+	+
	(Methylpropionat)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propyl acetate	Essigsäurepropylester	$CH_3COOCH_2CH_2CH_3$	TR	20	+	+	+	+
	(Propylacetat)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Propyl chloride	Propylchlorid	$CH_3CHClCH_3$	TR	20	+/-(q)	+/-(q)	+	+
	(Isopropylchlorid)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propylamine	Propylamin	$CH_3CH_2CH_2NH_2$	TR	20	+/-(q)	+/-(q)	+	+
	(Aminopropan)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	-	+
				100	-	-	-	+
				120	-	-	-	-
Propylene carbonate	Propylencarbonat	$OCH(CH_3)CH_2OCO$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propylene dibromide	Dibrompropan	$CH_3CHBrCH_2Br$	TR	20	+/-(q)	+/-(q)	+	+
	(1,2 Propylendibromid)			40	-	-	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Propylene glycol	Propylenglykol	$HOCH_2CH_2CH_2OH$	TR	20	+/-(q)	+/-(q)	+	+
	(1,2-Propandiol)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Propylene oxide	Propylenoxyd	C_3H_6O	TR	20	+/-(o)	+/-(o)	+/-(o)	+/-(o)
	(1,2-Epoxypropan)			40	-	-	-	+/-(o)
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Prussic acid	Blausäure	HCN	TR	20	+	+	+	+
	(Cyanhydroxyde)			40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	+	+	+
				120	-	-	-	-
Pseudocumene	Pseudocumen	$C_6H_3(CH_3)_3$	TR	20	+/-(o)	+/-(o)	+/-(o)	+/-(o)
				40	-	-	+/-(o)	+/-(o)
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	+/-(o)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
p-Toluenesulfonic acid	p-Toluolsulfonsäure	$C_7H_8O_3S$ x H_2O	TR	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Pyridine	Pyridin	C_5H_5N	TR	20	+	+/-(q)	-	+/-(q)
				40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Pyridine	Pyridin	C_5H_5N	5%	20	+	+/-(q)	-	+/-(q)
				40	+/-(q)	+/-(q)	-	+/-(q)
				60	+/-(q)	+/-(q)	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Pyrogallol	Pyrogallol (1,2,3-Trihydroxybenzen)	$C_6H_3(OH)_3$	< 50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	+	+/-(q)
				120	-	-	-	-
Quinine	Chinin (6-Methoxycinchonan, Palmitylalkohol)	$C_{20}H_{24}O_2N_2$ x H_2O	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Rapsmethyl ester	Rapsmethylester (Biodiesel)		TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Raw oil	Rohöl		H	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Resin dispersion	Kunstharzdispersion		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Resorcin	Resorcin	$C_6H_6O_2$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Rubber dispersion	Kautschukdispersionen		TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Salicylic acid	Salicylsäure	HOC_6H_4COOH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+/-(q)
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Salicylic acid methyl ester	Salicylsäuremethylester	$HOC_6H_4COOCH_3$	TR	20	+/-(q)	+/-(q)	+	+
	(Methylsalicylat)			40	+/-(q)	+/-(q)	+	+/-(q)
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Salicylic aldehyde	Salicylaldehyd	$HOCC_6H_4OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+/-(q)
				60	+/-(q)	+/-(q)	+/-(q)	+/-(q)
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Sea water	Meerwasser		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Selenium acid	Selensäure	H_2SeO_4	30%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	-
Selenium acid	Selensäure	H_2SeO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(s)	+	+
				100	-	-	+	+
				120	-	-	-	-
Silane	Silan	Si_nH_{2n+2}	TR	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Silicic acid	Kieselsäure	$SiO_2(H_2O)_n$	≤ GL	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+/-(s)
				100	-	-	+/-(s)	+/-(s)
				120	-	-	-	+/-(s)
Silicon oil	Siliconöl		TR	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Silicon oil	Siliconöl		VL	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Silicon tetrachloride	Siliziumtetrachlorid	$SiCl_4$	TR	20	+/-(o)	+/-(o)	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Silver acetate	Silberacetat	CH_3COOAg	≤ GL	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Silver cyanide	Silbercyanid	AgCN	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Silver nitrate	Silbernitrat	$AgNO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Silver nitrate	Silbernitrat	$AgNO_3$	8%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Silver salts	Silbersalze		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Silver sulfate	Silbersulfat	$AgSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Soap solution	Seifenlösung		all	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium	Natrium	Na		20	-	-	-	-
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Sodium acetate	Natriumacetat	CH_3COONa	≤ GL	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Sodium benzoate	Natriumbenzoat	C_6H_5COONa	≤ GL	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Sodium bicarbonate	Natriumbicarbonat	$NaHCO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium bisulfate	Natriumbisulfat	$NaHSO_4$	10%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sodium bisulfite	Natriumbisulfit	$NaHSO_3$	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium borate	Natriumborat	Na_3BO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium bromate	Natriumbromat	$NaBrO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(o)	+/-(o)	+	+
				80	-	-	+/-(o)	+
				100	-	-	+/-(o)	+
				120	-	-	-	-
Sodium bromide	Natriumbromid	NaBr	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium carbonate	Natriumcarbonat	Na_2CO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium carbonate	Natriumcarbonat	Na_2CO_3	15%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium carbonate	Natriumcarbonat	Na_2CO_3	10%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium chlorate	Natriumchlorat	$NaClO_3$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium chlorate	Natriumchlorat	$NaClO_3$	33%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium chloride	Natriumchlorid	NaCl	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium chlorite	Natriumchlorit	$NaClO_2$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sodium chromate	Natriumchromat	Na_2CrO_4	VL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium cyanide	Natriumcyanid	NaCN	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium dichloroisocyanurate	Natriumdichlorisocyanurat	$C_3HCl_2N_3O_3Na$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium dichromate	Natriumdichromat	$Na_2Cr_2O_7$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium dihydrogenphosphate	Natriumdihydrogenphosphat	NaH_2PO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium disulfite	Natriumdisulfit	$Na_2S_2O_5$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium dithionite (Hydrosulfite)	Natriumdithionit (Hydrosulfite)	$Na_2S_2O_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium dodecylbenzene-sulfonate	Natriumdodecylbenzolsulfonat (Lutensit, Phenylsulfonat)	$H_{25}C_{12}C_6H_{14}SO_3Na$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	-	-
				120	-	-	-	-
Sodium fluoride	Natriumfluorid	NaF	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium fluorosilicate	Natriumfluorsilikat	Na_2SiF_6	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium hexafluorosilicate	Natriumhexafluorsilikat	Na_2SiF_6	3%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sodium hydrogencarbonate	Natriumhydrogencarbonat	$NaHCO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium hydrogensulfate	Natriumhydrogensulfat	$NaHSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium hydrogensulfide	Natriumhydrogensulfid	NaHS	VL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Sodium hydrogensulfide	Natriumhydrogensulfid	NaHS	50%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium hydrogensulfide	Natriumhydrogensulfid	NaHS	20%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium hydrogensulfite	Natriumhydrogensulfit	$NaHSO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium hydroxide	Natronlauge	NaOH	50%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hydroxide	Natronlauge	NaOH	45%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hydroxide	Natronlauge	NaOH	up to 40%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hydroxide	Natronlauge	NaOH	30%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hydroxide	Natronlauge	NaOH	up to 10%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sodium hydroxide	Natronlauge	$NaOH$	4%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+/-(s)	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hypochlorite (active chlorine 12.5%)	Natriumhypochlorit (aktives Chlor 12,5%)	$NaOCl$		20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hypochlorite (active chlorine 12.5%)	Natriumhypochlorit (aktives Chlor 12,5%)	$NaOCl$		20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hypochlorite (active chlorine 12.5%)	Natriumhypochlorit (aktives Chlor 12,5%)	$NaOCl$		20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium hypochlorite (active chlorine 12.5%)	Natriumhypochlorit (aktives Chlor 12,5%)	$NaOCl$		20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sodium iodide	Natriumiodid	NaI	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium lactate	Natriumlactat	$CH_3CHOHCOONa$	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Sodium nitrate	Natriumnitrat	$NaNO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium nitrite	Natriumnitrit	$NaNO_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium oxalate	Natriumoxalat	$Na_2C_2O_4$	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Sodium palmitic	Natriumpalmitat	$CH_3(CH_2)_{14}COONa$	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sodium perborate	Natriumperborat	$Na_2B_2O_6$ x $3H_2O$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium perchlorate	Natriumperchlorat (Irenat)	$NaClO_4$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium peroxide	Natriumperoxid	Na_2O_2	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium peroxide	Natriumperoxid	Na_2O_2	10%	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+/-(o)	+
				60	-	-	+/-(o)	+/-(o)
				80	-	-	-	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Sodium persulfate	Natriumpersulfat	$Na_2S_2O_8$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium phosphate	Natriumphosphat	Na_3PO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium silicate	Natriumsilikat (Wasserglas)	Na_2SiO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium sulfate	Natriumsulfat	Na_2SO_4	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium sulfide	Natriumsulfid	Na_2S	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium sulfide	Natriumsulfid	Na_2S	10%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium sulfide	Natriumsulfid	Na_2S	5%	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sodium sulfite	Natriumsulfit	Na_2SO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium tartrate	Natriumtartrat	$Na_2C_4H_4O_6$ x $2H_2O$	≤ GL	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80		+/-(q)	+/-(q)	+
				100			+/-(q)	+
				120	-	-	-	-
Sodium tetraborate	Natriumtetraborat (Borax)	$Na_2B_4O_7$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium thiocyanate	Natriumthiocyanat (Natriumrhodanid)	NaSCN	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Sodium thiosulfate	Natriumthiosulfat	$Na_2S_2O_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Soja bean oil	Sojabohnenöl		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Spindle oil	Spindelöl		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Starch glue	Stärkekleber		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Starch solution	Stärkelösung		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Starch syrup	Stärkesirup		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Stauffer fat	Staufferfett		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Stearic acid	Stearinsäure	$C_{17}H_{35}COOH$	TR	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Stearic acid butyl ester	Stearinsäurebutylester	$C_{17}H_{35}COOC_4H_9$	TR	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Stearoyl chloride	Stearoylchlorid	$(CH_3)(CH_2)_{16}COCl$	TR	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Stilbene	Stilben	$C_6H_5CH{=}CHC_6H_5$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Styrene	Styren	$C_6H_5CH{=}CH_2$	TR	20	-	-	+	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Succinic acid	Bernsteinsäure	$COOHCH_2CH_2COOH$	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Sugar acid	Zuckersäure	$HOOC(CHOH)_4COOH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Sugar beet juice	Zuckerrübensaft		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Sugar syrup	Zuckersirup		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Sulfamic acid	Amidoschwefelsäure (Amidosulfonsäure)	NH_2SO_3H	18%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Sulfamic acid	Amidoschwefelsäure (Amidosulfonsäure)	NH_2SO_3H	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sulfaminic acid	Sulfaminsäure	H_3SO_3N	≤ GL	20	+/-(s)	+/-(s)	+	+
	(Amidoschwefelsäure,			40	+/-(s)	+/-(s)	+/-(s)	+
	Sulfamidsäure)			60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	-	+/-(s)
				120	-	-	-	-
Sulfochromic acid	Schwefelchromsäure	$CrO_3 + H_2SO_4 + H_2O$	40%	20	-	-	+/-(s)	+/-(s)
				40	-	-	+/-(s)	+/-(s)
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Sulfoethylmethacryalate	Sulfoethylmethacryalat		TR	20	+/-(q)	+/-(q)	+	+
	(SEM)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Sulfonic acid	Sulfonsäure	$R-SO_2-OH$	60%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Sulfonic acid	Sulfonsäure	$R-SO_2-OH$	VL	20	+	+	+	+
				40	+	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	-
Sulfur	Schwefel	S		20	-	-	-	-
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Sulfur dichloride	Schwefelchlorid	SCl_2	≤ GL	20	-	-	+/-(q)	+
	(Schwefeldichlorid)			40	-	-	-	+
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Sulfur dioxide, anhydrous	Schwefeldioxid, trocken	SO_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Sulfur dioxide, aqueous	Schwefeldioxid, feucht	SO_2	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Sulfur dioxide, liquid	Schwefeldioxid, flüssig	SO_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Sulfur trioxide	Schwefeltrioxid	SO_3	TR	20	-	-	-	+/-(s)
				40	-	-	-	-
				60	-	-	-	-
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sulfuric acid	Schwefelsäure	H_2SO_4	3%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	10%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	40%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	60%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	78%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	85%	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	+/-(s)	+/-(s)	+
				100	-	-	+/-(s)	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	90%	20	-	-	+/-(s)	+
				40	-	-	+/-(s)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	96%	20	-	-	+/-(s)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sulfuric acid	Schwefelsäure	H_2SO_4	98%	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	+
				120	-	-	-	+
Sulfurous acid	Schwefelige Säure	H_2SO_3	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	-	+	+
				100	-	-	+	+
				120	-	-	-	+
Sulfuryl chloride	Sulfurylchlorid	SO_2Cl_2	≤ GL	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Sulfuryl fluoride	Sulfuryldifluorid	SO_2F_2	≤ GL	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Surfactants	Netzmittel		up to 5%	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(s)	+
				80	-	-	+/-(s)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
1,1,1,2-Tetrafluoroethane	1,1,1,2-Tetrafluorethan (Freon 134a)	F_3CCH_2F	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
1,2,3-Trichloropropane	Trichlorpropan (Trichlorhydrin)	$CH_2ClCHClCH_2Cl$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
1,2,3-Trihydroxybenzene	1,2,3-Trihydroxybenzen	$C_6H_3(OH)_3$	50%	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
1-Tetradecanamine	1-Tetradecanamin	$C_{14}H_{31}N$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
4-Toluene sulfonyl chloride	Toluol-4-sulfonylchlorid	$CH_3C_6H_4SO_2Cl$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
4-Toluensulfonic acid	Toluolsulfonsäure	$C_7H_8O_3S$	70%	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
4-Toluensulfonic acid	Toluolsulfonsäure	$C_7H_8O_3S$	30%	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
4-Toluensulfonic acid	Toluolsulfonsäure	$C_7H_8O_3S$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Tall oil	Tallöl		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Tallow	Talg			20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Talpa oil	Talpaöl		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Tannic acid	Tanninsäure	$C_{76}H_{52}O_{46}$	TR	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Tanning extracts from plants	Gerbextrakte, pflanzliche		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Tar	Teer		H	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Tartaric acid (2,3-Dihydroxybutanedioc acid)	Weinsäure (2,3-Dihydroxybutandisäure)	$(CHOH)_2(COOH)_2$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	-
t-Butanol, 2-Methyl-2-propanol (tert. Butylalkohol)	t-Butanol, 2-Methyl-2-propanol (tert. Butylalkohol)	$(CH_3)_3COH$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
t-Butylmethether SP UV	t-Butylmethether SP UV		TR	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Tellus oils	Tellusöle		H	20	+/-(q)	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Tenside	Tenside		H	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	+/-(q)	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Tert-butyl alcohol	Tert-butylalkohol (2-methyl-2-propanol)	$(CH_3)_3COH$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Tert-butylcyclohexyl acetate	Essigsäurebutylcyclohexylester	$CH_3COOC_6H_{10}C(CH_3)_3$	TR	20	+	+	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Tetrabromethane	Tetrabromethan	$Br_2CHCHBr_2$	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetrachlorodifluoroethane	Tetrachlordifluorethan (Freon R 113)	CCl_3CClF_2	18%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetrachloroethane	Tetrachlorethan	$Cl_2CHCHCl_2$	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetrachlorophenole	Tetrachlorphenol	C_6HCl_4OH	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetraethyl lead	Bleitetraethyl (Tetraetylblei)	$(CH_3CH_2)_4Pb$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Tetrafluoroboric acid	Tetrafluorborsäure	HBF_4	< 50%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetrahydrofurane	Tetrahydrofuran	C_4H_8O	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetrahydronaphthalene	Tetrahydronaphthalin	$C_{10}H_{12}$	TR	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetrahydronaphthalene	Tetrahydronaphthalin	$C_{10}H_{12}$	90%	20	-	-	+	+
				40	-	-	+/-(s)	+
				60	-	-	+/-(s)	+
				80	-	-	-	+/-(s)
				100	-	-	-	-
				120	-	-	-	-
Tetramethylammoniumhydroxide	Tetramethylammoniumhydroxid (TMAH)	$C_4H_{13}NO$	50%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Tetramethylammoniumhydroxide	Tetramethylammoniumhydroxid (TMAH)	$C_4H_{13}NO$	28%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Tetramethylammoniumhydroxide	Tetramethylammoniumhydroxid (TMAH)	$C_4H_{13}NO$	10%	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Tetramethylthiourea	Tetramethylthioharnstoff	$(CH_3)_2NCSN(CH_3)_2$	TR	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Tetramethylurea	Tetramethylharnstoff	$(CH_3)_2NCON(CH_3)_2$	TR	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	+
Thioglycolic acid	Thioglykolsäure	$HSCH_2COOH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Thioglycolic acid	Thioglykolsäure	$HSCH_2COOH$	80%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Thioglycolic acid	Thioglykolsäure	$HSCH_2COOH$	40%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Thionyl chloride	Thionylchlorid	$SOCl_2$	TR	20	-	-	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Thiophen	Thiophen	C_4H_4S	TR	20	-	-	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Thiophosphoric chloride	Thiophosphorylchlorid	$PSCl_3$	TR	20	-	-	+/-(o)	+
				40	-	-	-	+
				60	-	-	-	+/-(o)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Thioureadioxide	Formamidinsäure (Thioharnstoffdioxid)		TR	20	+/-(q)	+/-(q)	+	+
				40	-	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Tin(II) chloride	Zinnchlorid (II)	$SnCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Tin(IV) chloride	Zinnchlorid (IV)	$SnCl_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Titanium sulfate	Titansulfat	$Ti_2(SO_4)_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Titanium tetrachloride	Titaniumtetrachlorid	$TiCl_4$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Toloyl bromide	Toloylbromid	$C_6H_4CH_3Br$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Toluendiisocyanate	Toluoldiisocyanat	$C_9H_6N_2O_2$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	-
				100	-	-	-	-
				120	-	-	-	-
Toluene	Toluol	$C_6H_5CH_3$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	+/-(q)	-
				100	-	-	-	-
				120	-	-	-	-
Tomato juice	Tomatensaft		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Transformer oil	Transformatorenöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Tributhyl amine	Tributylamin (2-Amino-2-methylpropan)	$(CH_3)_3CNH_2$	TR	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	+/-(q)	+/-(q)	-	+
				80	-	+/-(q)	-	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Tributyl ester	Tributylester		TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	-	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Tributyl phosphate	Tributylphosphat (Phosphorsäuretributylester)	$(C_4H_9)_3PO_4$	TR	20	+	+	+	+
				40	+/-(q)	+	+	+
				60	-	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Trichloroacetalaldehyde	Trichloracetalaldehyd (Chloral)	CCl_3CHO	TR	20	-	-	-	+
				40	-	-	-	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichloroacetic acid	Chloressigsäure (TRI)	Cl_3CCOOH	10%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Trichloroacetic acid	Chloressigsäure (TRI)	Cl_3CCOOH	50%	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Trichloroacetic acid	Chloressigsäure (TRI)	Cl_3CCOOH	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+/-(q)	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	-
				120	-	-	-	-
Trichloroacetyl chloride	Trichloressigsäurechlorid	CCl_3COCl	TR	20	+	+	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichlorobenzene	Trichlorbenzol	$C_6H_3Cl_3$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichlorobutane	Trichlorbutan	$C_4H_7Cl_3$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichloroethane (1,1,1)	Trichlorethan (1,1,1) (Methylchloroform)	CH_3CCl_3	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichloroethane (1,1,2)	Trichlorethan (1,1,2) (Methylchloroform)	$CHCl_2CHCl_2$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichloroethylene	Trichlorethylen (Ethylentrichlorid, Acetylentrichlorid)	$Cl_2C{=}CHCl$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Trichloroisocyanuric acid	Trichlorisocyanursäure	$C_3Cl_3N_3O_3$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichloromethansulfonyl chloride	Trichlormethansulfonylchlorid (Perchlormethylmercaptan)	Cl_3CSCl_2	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichlorophenole	Trichlorphenol	$C_6H_2Cl_3OH$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trichlorosilane	Trichlorsilan (Siliconchloroform)	$SiHCl_3$	TR	20	-	-	+/-(q)	+
				40	-	-	+/-(q)	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Tricresyl phosphate	Trikresylphosphat	$(H_3CC_6H_5O)_3PO_4$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Triethanolamine	Triethanolamin	$C_6H_{15}NO_3$	5%	20	+	+	-	+
				40	+/-(q)	+/-(q)	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Triethanolamine	Triethanolamin	$N(CH_2CH_2OH)_3$	TR	20	+	+	-	+
				40	+/-(q)	+/-(q)	-	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Triethyl amide	Triethylamid		TR	20	+	+	+/-(q)	+
				40	+	+	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Triethyl amine	Triethylamin	$N(CH_2CH_3)_3$	TR	20	+	+	+	+
				40	+	+	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	+
				100	-	-	-	-
				120	-	-	-	-
Triethylenglykol	Triethylenglycol (Triglykol)	$C_6H_{14}O_4$	5%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Triethylentetramine	Triethylentetramin		TR	20	+	+	+/-(q)	+
				40	+	+	-	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Trifluoroacetic acid	Trifluoressigsäure	CF_3COOH	TR	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trifluoroacetic acid	Trifluoressigsäure	CF_3COOH	80%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trifluoroacetic acid	Trifluoressigsäure	CF_3COOH	50%	20	+/-(q)	+/-(q)	+/-(q)	+
				40	+/-(q)	+/-(q)	+/-(q)	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Triiodinemethane in methanol	Triiodmethan in Methanol	CHI_3	50%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Triisopropanolamine	Triisopropanolamin	$((CH_3)_2COH)_3N$	10%	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Trimethyl borate	Borsäuremethylester	$B(OCH_3)_3$	TR	20	+/-(q)	+/-(q)	+	+
	(Trimethoxyboran,			40	+/-(q)	+/-(q)	+	+
	Trimethylborat)			60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Trimethyl phosphate	Trimethylphosphat	$(CH_3)_3PO_4$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Trimethylacetyl chloride	Trimethylacetylchlorid	$(CH_3)_3CCOCl$	TR	20	-	-	+/-(q)	+
	(Pivaloylchlorid)			40	-	-	+/-(q)	+
				60	-	-	-	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Trimethylammonium chloride	Trimethylammoniumchlorid		TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	+
Trimethylpropane	Trimethylpropan	C_6H_{14}	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Trioctyl phosphate	Trioctylphosphat	$(C_8H_{17})_3PO_4$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Triphenyl borate	Borsäurepenthylester (Triamylborat, Triphenylborat)	$(C_5H_{11}O)_3B$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	-	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Triphenyl phosphite	Triphenylphosphit	$(C_6H_5O)_3P$	TR	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Trishydroxymethylpropane	Trishydroxymethylpropan (Trimethylolpropan)	$CH_3CH_2C(CH_2OH)_3$	10%	20	+	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	-
				120	-	-	-	-
Turpentine	Terpentin		H	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Turpentine oil	Terpentinöl		H	20	+/-(s)	+/-(s)	+/-(s)	+
				40	+/-(s)	+/-(s)	+/-(s)	+
				60	-	-	+/-(s)	+/-(s)
				80	-	-	+/-(s)	+/-(s)
				100	-	-	-	+/-(s)
				120	-	-	-	-
Two stroke oil	Zweitaktöl		H	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Uranyl nitrate	Uranylnitrat	$UO_2(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Urea	Harnstoff	H_2NCONH_2	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Uric acid	Harnsäure (2,6,8-Trihydroxypurin)	$C_5H_4O_3N_4$	TR	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Vaseline	Vaseline	$C_{22}H_{46}$ / $C_{23}H_{48}$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Vaseline oil	Vaselineöl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Vegetable oils and fats	Öle und Fette, vegetabil		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Vinegar	Essig		H	20	+	+	+	+
	(Weinessig)			40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+/-(q)	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	-	+
				120	-	-	-	-
Vinyl acetate	Vinylacetat	CH_2=$CHOOCCH_3$	TR	20	+/-(q)	+/-(q)	+	+
	(Ethenylester)			40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Vinyl chloride	Vinylchlorid	CH_2=CHCl	TR	20	-	-	+	+
				40	-	-	+/-(q)	+/-(q)
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Vinylidene bromide	Ethylendibromid	CH_2CBr_2	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Viscose spinning solution	Viscose-Spinnlösung		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Vitamin preparations	Vitaminpräparate		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Vitrea oil	Vitrea öl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Voluta oil	Voluta öl		H	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Washing agents, synthetic	Waschmittel, synthetische		H	20	+/-(s)	+/-(s)	+	+
				40	+/-(s)	+/-(s)	+	+
				60	+/-(s)	+/-(s)	+/-(q)	+
				80	-	+/-(s)	-	+
				100	-	-	-	-
				120	-	-	-	-
Washing liquids	Spülmittel		H	20	+	+	-	+
				40	+	+	-	+
				60	+	+	-	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Waste gases containing bromine	Abgase bromhaltig	Br_2	all	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+
				100	-	-	+/-(q)	+/-(q)
				120	-	-	-	+/-(q)
Waste gases containing carbon dioxide	Abgase kohlenstoffdioxidhaltig	CO_2	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Waste gases containing carbon monoxide	Abgase kohlenstoffmonoxidhaltig	CO	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Waste gases containing cyanur chloride	Abgase cyanurchloridhaltig	$C_3N_3Cl_3$	traces	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Waste gases containing hydrogen chloride	Abgase chlorwasserstoffhaltig	HCl	all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+
Waste gases containing hydrogen fluoride	Abgase fluorwasserstoffhaltig	HF	traces	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)
Waste gases containing nitrous gases	Abgase nitrosehaltig	NO_x	traces	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	-	+
				100	-	-	-	+
				120	-	-	-	-
Waste gases containing sulfur dioxide	Abgase schwefeldioxidhaltig	SO2	traces	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Waste gases containing sulfuric acid	Abgase schwefelsäurehaltig	H_2SO_4	traces	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Waste gases containing sulfuric trioxide	Abgase schwefeltrioxidhaltig	SO3	traces	20	-	-	+/-(s)	+
				40	-	-	-	+
				60	-	-	-	+
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Waste water, traces of ethanol + butanol	Abwasser, Spuren von Ethanol + Butanol		traces	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	+/-(q)

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Waste water, without organic solvent	Abwasser, ohne organische Lösungsmittel		traces	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Water destilled	Wasser destilliertes entionisiertes und vollentsalztes			20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Water waste water without organic solvent	Wasser, Abwasser ohne organische Lösungsmittel			20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Water, condensed	Wasser, Kondensatwasser			20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Wax alcohol	Wachsalkohol	$C_{31}H_{63}OH$	TR	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	-	-	+	+
				80	-	-	+/-(q)	+/-(q)
				100	-	-	-	+/-(q)
				120	-	-	-	-
Whey	Molke		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Wine vinegar	Weinessig		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+/-(q)	+/-(q)	+
				100	-	-	+/-(q)	+
				120	-	-	-	-
Wines, red and white	Weine, rot und weiß		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Wolframhexafluoride	Wolframhexafluorid (Wolfram(VI)fluorid)	WF_6	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	-
Xylene	Xylol (Dimethylbenzen)	$C_6H_4(CH_3)_2$	TR	20	-	-	+	+
				40	-	-	+	+
				60	-	-	+/-(q)	+/-(q)
				80	-	-	-	-
				100	-	-	-	-
				120	-	-	-	-
Yeast	Hefe		all	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Yeast wort	Stellhefenwürze		H	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc acetate	Zinkacetat	$(CH_3COO)_2Zn \times 2H_2O$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+/-(q)	+	+	+
				80	-	+/-(q)	+	+
				100	-	-	+	+
				120	-	-	-	-
Zinc bromide	Zinkbromid	$ZnBr_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc carbonate	Zinkcarbonat	$ZnCO_3$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc chloride	Zinkchlorid	$ZnCl_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc chromate	Zinkchromat	$ZnCrO_4$	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Zinc cyanide	Zinkcyanid	$Zn(CN)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc nitrate	Zinknitrat	$Zn(NO_3)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc oxide	Zinkoxid	ZnO	≤ GL	20	+/-(o)	+/-(o)	+	+
				40	+/-(o)	+/-(o)	+	+
				60	-	-	+/-(o)	+
				80	-	-	+/-(o)	+/-(o)
				100	-	-	-	-
				120	-	-	-	-
Zinc phosphate	Zinkphosphat	$Zn_3(PO_4)_2$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+
Zinc salts	Zinksalze		≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+

Medium_EN	Medium_DE	Chemical formula	C [%]	T [°C]	PE	PP	PVDF	ECTFE
Zinc stearate	Zinkstearat	$Zn(C_{17}H_{35}COO)_2$	≤ GL	20	+/-(q)	+/-(q)	+	+
				40	+/-(q)	+/-(q)	+	+
				60	+/-(q)	+/-(q)	+	+
				80	-	-	+/-(q)	+
				100	-	-	-	+/-(q)
				120	-	-	-	-
Zinc sulfate	Zinksulfat	$ZnSO_4$	≤ GL	20	+	+	+	+
				40	+	+	+	+
				60	+	+	+	+
				80	-	+	+	+
				100	-	-	+	+
				120	-	-	-	+