REDLEAF
RESOURCES, INC.

Document Date 3/6/2014

DWQ-2014-003741

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Utah Division of Water Quality

CONSTRUCTION PERMIT ISSUED BY
Utah Department of Environmental Quality
Utah Division of Water Quality
Date: 30 May 2014
Review Engineer: TWG
Director:

March 6, 2014

Dan Hall
Manager, Ground Water Protection Section
Utah Division of Water Quality
Utah Department of Environmental Quality
195 North 1950 West
P.O. Box 144870
Salt Lake City, UT 84114-4870

Subject: Red Leaf Resources, Inc., Ground Water Discharge Construction Permit Application – Proprietary and/or Business Confidential

Dear Mr. Hall:

Red Leaf Resources, Inc. ("Red Leaf") hereby submits a construction permit application associated with our Ground Water Discharge Permit No. UGW470002 for your review and approval. The enclosed application supplants our previous submission.

The enclosed specifications and drawings contain proprietary and confidential information and data and are submitted to the Utah Division of Water Quality (UDWQ) with the understanding that they shall be managed as proprietary and confidential by UDWQ. Drawings, information, and/or data considered to have proprietary or confidential information have been stamped with the words "confidential business information" in accordance with R317-8-3.3.

Further, this letter serves as a statement of reasons supporting Red Leaf's confidentiality claim. Utah's Government Record Access and Management Act ("**GRAMA**") provides that certain records including "trade secrets" as defined in Utah's Uniform Trade Secrets Act can be protected from public disclosure. Utah Code Section 63G-2-305. Red Leaf has followed the requirements under Utah Law to preserve the confidentiality of its Ecoshale™ In-Capsule Technology and related processes in the attached application. The company's trade secrets and commercially-sensitive information are stamped "confidential" and Red Leaf requests that UDWQ preserve this confidence. *See* Utah Code Section 63G-2-309.

The Ecoshale™ In-Capsule Technology qualifies for protection under GRAMA as a "trade secret." This term is defined in Utah's Uniform Trade Secrets Act to include information such as formulae, patterns, techniques or processes where the owner or operator derives independent economic value from its secrecy and takes steps to protect the secret. Utah Code Section 13-24-2. The text marked as confidential in the application refers to such proprietary and confidential information. These trade secrets are independent from the associated which have

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been filed by Red Leaf in the United States and internationally.[1] The information is also subject to confidentiality agreements with Red Leaf's joint venture partners and vendors.

Commercial information is subject to protection if "disclosure of the information could reasonably be expected to result in unfair competitive injury to the person submitting the information" and the company's interest in protecting its information exceeds the public's interest in obtaining access to it. Utah Code Section 63G-2-305(2). Red Leaf is subject to confidentiality agreements and has protected its processes under trademark and trade secret law. The UDWQ has been allowed to review the protected process under the terms of GRAMA. Therefore, this information should be protected from public disclosure, subject to restricted government review for environmental compliance.

Should you have any questions about this application or if additional information is required, please contact Jay Vance at 801-878-8100.

Sincerely,

Lance Lehnhof
General Counsel

Enclosures

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

[1] The Ecoshale™ In-Capsule Technology has been trademarked in the United States and Australia and patents for the technology are pending or have been issued in the United States and internationally including in Algeria, ARIPO, Armenia, Australia, Brazil, Canada, Chile, China, Congo, Egypt, Estonia, Eurasia, European Union, Georgia, India, Indonesia, Israel, Jordan, Libya, Madagascar, Malaysia, Mexico, Mongolia, Morocco, OAPI, Peru, Russian Federation, South Africa, Syria, Tunisia, Ukraine and Venezuela.

Utah Ground Water Discharge Construction Permit Application
for
Red Leaf Resources, Inc.
Southwest #1 Project

Background

Red Leaf Resources, Inc., ("Red Leaf") has received a Ground Water Discharge Permit (GWDP), Permit No. UGW470002, from the Utah Division of Water Quality (DWQ). This application for construction relates to that GWDP for the Early Production System (EPS) capsule and includes confidential engineering design plans and specifications that are submitted for approval by DWQ. To facilitate the public comment period, graphics and public-review versions of specifications and documents are being provided herewith.

Construction Drawings and Specifications

The following construction drawings and specifications are submitted with this application:

Drawings (CONFIDENTIAL)

- EPS Project Containment System Overview – Drawing Number: RL-EPS-W-0001
- EPS Project Containment System Cross Sections – Drawing Number: RL-EPS-W-0002
- EPS Project Containment System Details – Drawing Number: RL-EPS-W-0003
- EPS Project Containment System Monitoring Bulkhead & Sampling Overview – Drawing Number: RL-EPS-W-0004

Specifications (Portions are CONFIDENTIAL)

- Standard Technical Specification – Fill Materials – H335458-0310-15-123-0001
- Standard Technical Specification – Geomembrane Liner – H335458-0310-15-123-0002
- Technical Specification – Liquid Collection System Floor Pan – RLSR-MCC-01-TSP-0003
- Standard Technical Specification – Geosyntetics – H335458-0310-15-123-0004

Graphics

- EPS Overview
- EPS Cross Section
- Monitoring Bulkhead & Sampling Overview

Discussion

Design. Bentonite amended soil (BAS) is the primary barrier to prevent water from infiltrating into the capsule. A BAS layer envelops the capsule and is used in the roof, walls, and floor. The geotextile, geogrid, and geomembrane are included to ensure geotechnical performance of the BAS during operation for purposes other than water protection. Insulation materials are placed as thermal insulation to protect the BAS during operation. Other materials are used for capsule walls and cover. (See Graphics.)

EPS Monitoring. The following monitoring approaches are provided in the capsule:

- Collection Pan
- Lower Containment Layer
- Bedrock Under Capsule

A drain that is used during operation to collect oil will be used following operations for liquids that infiltrate to the collection pan. For the Lower Containment Layer monitoring, piping is placed to convey liquids that infiltrate to the lower BAS liner that flow to the bulkhead. For monitoring Bedrock Under Capsule, a drain provides for monitoring of fluids which collect above the bedrock. The drain for the bedrock and for the Lower Containment layer may be combined.

Specifications. The Standard Technical Specification for Fill Materials outlines standard tests, definitions, material descriptions, mixing and placement, and quality control related to fill materials for the capsule. Specifications for Geomembrane Liner and Geosynthetics are also included.

IGES Report (Portions are CONFIDENTIAL). A report from IGES regarding BAS testing using a sealed double-ring infiltrometer is also included. Testing shows low hydraulic conductivity of BAS.

Standard Technical Specification

Fill Materials

H335458-0310-15-123-0001

Note: Some information in this specification has been redacted for purposes of business confidentiality. Areas where this occurs are marked with the following label:

Confidential business information Proprietary

			[signature]	[signature]	[signature] for	
2014-01-24	C	Preliminary	G. Qu	S. Hinchberger	M. Campanelli	Samuel Lethier
2013-11-21	B	Client Review	G. Qu	S. Hinchberger	M. Campanelli	Samuel Lethier
2013-10-30	A	Internal Review	G. Qu	S. Hinchberger	M. Campanelli	-
DATE	REV.	STATUS	PREPARED BY	CHECKED BY	APPROVED BY	APPROVED BY
				Discipline Lead	Functional Manager	Client

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Table of Contents

1. General

1.1 Work Included

1.1.1 The work to be done under this section consists of the supply of labor, plant, material, supervision and the performance of all Work necessary to (a) produce or supply, transport and stockpile fill materials and to (b) load, transport, place, spread and compact fill materials as shown on the Drawings and as specified herein.

1.1.2 Approvals, acceptability, and/or definitions related to this specification shall be made by Owner's Engineer. Owner's Engineer reserves the right to revise, updated, or otherwise alternate these material specifications to comply with environmental and performance requirements. Owner's Engineer may also specify similar, revised, or replacement methods/standards for those in this specification.

1.2 Related Sections

1.2.1 N/A.

1.3 Standards

1.3.1 The Work covered under this section shall be done in accordance with the following standards:

Table 1 Summary of Test Standard

Test	Test Method	Title of Test
Standard Proctor Test	ASTM D-698	Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort
Modified Proctor Test	ASTM D-1557	Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort
Moist Content	ASTM D-2216	Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
Density Test	ASTM D-7263	Standard Test Methods for Laboratory Determination of Density (Unit Weight) of Soil Specimens
In-Situ Density and Water Content Test	ASTM D6938	Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods
Particle Size Test (Sieve Analyses)	ASTM D-6913	Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

Test	Test Method	Title of Test
Particle Size Test (Hydrometer Analyses)	ASTM D-421 or D-422	Standard Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants Or Standard Test Method for Particle-Size Analysis of Soils
Particle Size Test for Run of Mine	ASTM D-5519	Standard Test Method for Particle Size Analysis of Natural and Man-made Rip Rap Materials.
Hydraulic Conductivity Test	ASTM D-5084	Hydraulic Conductivity of Saturated Porous Material Using a Flexible Wall Permeameter
Specific Gravity Test	ASTM D-854	Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer

1.4 Definitions

1.4.1 **Owner**: Red Leaf Resources, Inc. (Red Leaf).

1.4.2 **Owner's Engineer**: Owner's engineer shall be a Utah registered professional engineer, appointed by Red Leaf. Identification of Owner's engineer shall be documented in writing.

1.4.3 **Contractor**: Refers to the company supplying labor, materials and equipment and performing the work necessary as per this Section.

1.4.4 **Transport:** The work necessary to haul materials from the mine or quarries to stockpiles and then to site locations where such materials will be placed.

1.4.5 **Ore Grade:** For the purpose of this specification, ore grade refers to the gallons of oil per ton in the ore as determined from retort compression tests and Fisher Assay tests.

1.4.6 **High Pay Material:** A material with an ore grade exceeding 10 gallons per ton.

1.4.7 **Low Pay Material:** A material with an ore grade below 10 gallons per ton.

1.4.8 **Testing Organization:** A qualified independent geotechnical testing company retained to perform field quality-control testing.

1.4.9 **Lot:** A portion of the material or section of the work that has been constructed or produced under essentially uniform conditions during the same shift or batch and contains material of essentially uniform quality and composition.

1.4.10 **Run of Mine:** Rock fill material produced from normal drill and blast mining operations.

1.4.11 **BAS (Bentonite Amended Soil):** An engineered soil mixture consisting of crushed and screened low grade shale, bentonite and water.

1.4.12 **GBAS (Glycerine and Bentonite Amended Soils):** An engineered soil mixture consisting of crushed and screened low grade shale, bentonite and a water-glycerine mixture.

1.4.13 **Matrix Soil:** Consists of the crushed screened low grade ore that is to be mixed with bentonite and water to create BAS or bentonite and water-glycerine to create GBAS.

1.4.14 **Bedding Layers:** Layers of 3/8 inch minus aggregate materials that when placed and compacted provide suitable bedding surface for geomembrane placement.

1.4.15 **Choking Layers:** Layers of 8 inch minus (if required) and 1 inch minus aggregate materials that are used to fill the voids in 'Run of Mine' rock fill layers to create a smooth and uniform surface for placement of bedding or geosynthetics materials.

1.4.16 **Convective Barrier:** A zone of granular material with sufficient particle size and pore size distribution to retard convective heat flow within that material.

2. Materials

2.1 General

2.1.1 The fill materials required for the EPS capsule gas containment layer are:

Type 1 Fill: Bentonite Amended Soil (BAS)
    Type 1A Fill: BAS with a standard bentonite content (see 2.4)
    Type 1B Fill: BAS with a high bentonite content (see 2.4)
Type 2 Fill: Glycerine and Bentonite Amended Soil (GBAS)
Type 3 Fill: (BAS and GBAS matrix material)
Type 4 Fill:
    Type 4A Fill: Low pay
    Type 4B Fill: High pay
Type 5 Fill:
    Type 5A Fill: Low pay
    Type 5B Fill: High pay
Type 7 Fill: Jaw Run Rockfill
Type 9 Fill: Run of Mine Rockfill

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2.1.2 The fill materials shall be produced from ore derived from the mining operations. Type 1, 2 and 3 fills (BAS and GBAS related materials) should be low pay materials. The source of Type 7 and 9 fills are the low pay rockfills from the mining operations.

2.1.3 Ensure fill materials are free from excessive moisture, snow, ice, debris, organics (other than kerogen in rockfill) and other deleterious materials.

2.1.4 Stockpile materials in a manner that prevents segregation.

2.1.5 Stockpile BAS and GBAS materials in a manner that prevents drying, desiccation and wetting due to water infiltration.

2.1.6 All materials shall conform to the gradations listed in the following section, and as shown on the Drawings.

2.2 Grain Size Specifications

2.2.1 The grain size specifications are provided in the following sections. The materials shall be within the specified limits or as approved by Owner's Engineer.

2.2.2 Bentonite (Sure Seal 80 or equivalent as approved by Owner's Engineer).

Table 2: Grain Size Distribution for Bentonite

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2.2.3 Type 1A, 1B and 2 Fill – BAS and GBAS Material.

Table 3: Grain Size Distribution for Type 1A, 1B Fill

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2.2.4 Type 3 Fill

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2.2.5 Type 4 Fill

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2.2.6 Type 5 Fill

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Proprietary

2.2.7 Type 7 Fill

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2.2.8 Type 9 Fill

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2.3 Bentonite Properties

2.3.1 Bentonite will be required to produce Type 1 and 2 fills. The Bentonite shall have high swelling and ultra-low permeability. It shall have the following properties

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2.4 BAS Mix (Type 1 Fill) Properties

2.4.1 Type 1A Fill shall consist of:

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2.4.2 Type 1B Fill shall consist of:

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2.5 GBAS Mix (Type 2 Fill) Properties

2.5.1 Type 2 Fill shall consist of:

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3. Execution

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Confidential business information
Proprietary

Confidential business information
Proprietary

4. Quality Control

4.1 General

4.1.1 Owner's Engineer will establish direct and continuous quality control over fill materials throughout the period of construction and shall provide guidance on definitions, provide approvals, and make necessary determinations for completion of requirements outlined in this specification.

4.1.2 The Contractor shall provide a mobile testing facility to enable testing of the fill materials, including, but not limited to, grain size distribution and moist content. Other tests may be added and specified by Owner's Engineer.

4.1.3 The Owner or Owner's Engineer may delegate a Testing Organization to undertake third party testing to ensure conformance with these specifications.

4.1.4 If a third-party Testing Organization is used, the Contractor shall coordinate and cooperate with the Testing Organization to allow the sampling and testing of fill material as well as the use of Contractor's mobile test facility.

4.2 In Situ Density and Moisture Content

4.2.1 Type 1 (BAS) materials: Perform in situ density and moisture content measurements according to ASTM D6938-10 with corrections made to account for organic content in the shale.

4.2.2 Within each lift, performed one density and moisture content test as per the requirement in Table 9, or as directed by Owner's Engineer.

Table 9: Recommended In-situ Tests

Parameter	Fill Materials	Recommended Test Method	Minimum Testing Frequency
In-situ Moisture and Density	Type 1 and Type 2 in **Capsule Floor or Roof**	ASTM D-6938 or equivalent*	2 per 1000 yd^3 or 4 per 10,000 sq. ft/lift or 4 tests per material lot, whichever is greatest
In-situ Moisture and Density	Type 1 and Type 2 in **Side Walls**	ASTM D-6938 or equivalent*	2 per 250 yd^3 or 2 per 100 ft/lift, whichever is greatest
In-situ Moisture and Density	Type 4 (if compaction required)	ASTM D-6938 or equivalent*	1 per 1000 yd^3 or 1 per 20,000 sq. ft/lift, whichever is greatest

Note: *The depth of measurement shall be Equivalent method(s) shall be approved by Owner's Engineer.

4.3 Material Tests

4.3.1 Tests shall be performed at a rate that complies with Table 10, or as directed by Owner's Engineer.

Table 10: Recommended Materials Tests

Parameter	Fill Materials	Test	Minimum Frequency
Percent of Fines	Types 1, 2	ASTM D-1140	For the capsule floor and roof, 1 per 1000 yd^3 or 1 per 20,000 sq ft/lift or 4 tests per material lot, whichever is greatest
			For the capsule side walls, 3 per 1000 ft/lift or when compaction conditions changes, whichever is greatest
Percent of Bentonite	Type 1 and Type 2	Methylene Blue Test (Alther, 1983) or Equivalent*	For the capsule floor and roof, 1 per 1000 yd^3 or 1 per 20,000 sq ft/lift or 4 tests per material lot, whichever is greatest
			For the capsule side walls, 1 per 300 ft/lift or when compaction conditions changes, whichever is greatest
Particle Size Distribution	Types 1, 2, 3, and 4	ASTM D-1557 or ASTM D-5084 (TBD)	For the capsule floor and roof, 1 per 2000 yd^3 or 1 per 40,000 sq ft/lift, or 1 per source, whichever is greatest
			For the capsule side walls, 1 per 600 ft/lift, or 1 per source, whichever is greatest
	Types 5	ASTM D-1557 or	1 per 5000 yd^3 or 1 per source, whichever is greatest
	Types 7 and 9	ASTM D-1557 or equivalent*	1 per source
	Bentonite	ASTM D-5084	1 per shipment
Proctor Test	Type 1 and Type 2	ASTM D-1557	1 per 10,000 yd^3
Liquid and Plastic Limit	Type 1 and Type 2	ASTM D-4318	1 per 1000 yd^3 or 4 tests per material lot, whichever is greatest
Hydraulic Conductivity/ Gas Permeability	Type 1 and Type 2	ASTM D-5084	1 per 20,000 sq ft / lift**

Notes: * Equivalent method(s) shall be approved by Owner's Engineer.

**The Shelby tube sampling shall be performed as per specified frequency. The test frequency shall be directed by Owner's Engineer.

For Tables 9 and 10, after sufficient testing and data collection has been performed, testing frequency may be adjusted based on statistical analysis, as directed and determined sufficient by Owner's engineer.

END OF SECTION

HATCH

REDleaf RESOURCES

Standard Technical Specification

Geomembrane Liner

H335458-0310-15-123-0002

			[signature]	[signature]	[signature]	
2013-11-21	B	Client Review	S. PerrettJG. Qu	for S. Hinchberger	by M. Campanelli	
2013-10-30	A	Internal Review	S. PerrettJG. Qu	S. Hinchberger	M. Campanelli	
DATE	REV.	STATUS	PREPARED BY	CHECKED BY	APPROVED BY	APPROVED BY
				Discipline Lead	Functional Manager	Choose Approver

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1. General

1.1 Scope

1.1.1 This section covers the manufacture, supply and installation of a geomembrane liner for the Red Leaf Experimental Oil Shale Capsule Project as shown on the Drawings and described herein.

1.1.2 Contractor shall furnish, install and test the geomembrane liner in accordance with this Specification and subject to the terms and conditions of the manufacturer's requirements.

1.1.3 The following sections cover Subgrade Preparation, Sheet Specifications, Liner Installation, Cover Material requirements, Inspection and Quality Control, and Manufacturer, Fabricator, Installer Qualification.

1.1.4 Approvals, acceptability, and/or definitions related to this specification shall be made by Owner's Engineer. Owner's Engineer reserves the right to revise, updated, or otherwise alternate these material specifications to comply with environmental and performance requirements. Owner's Engineer may also specify similar, revised, or replacement methods/standards for those in this specification.

1.2 Qualifications

1.2.1 Manufacturer and Installer shall be competent and experienced in the production and installation of geomembrane and liners having at least five years continuous experience in the manufacture and installation, respectively. These parties shall have at least ten million square feet of acceptable manufacture and installation experience.

1.2.2 Installation Supervisors must have worked in a similar capacity on projects of similar size and complexity to the project described in the Contract Documents.

1.2.3 Installer shall provide a minimum of one Master Seamer for the Work with a minimum of one million square meters of geomembrane installation experience and associated seaming work using the type of seaming apparatus proposed for this Project.

1.3 Standards

1.3.1 Pertinent provisions of the following American Society for Testing and Materials (ASTM) Standards shall apply to the Work (or alternative standards may be used as determined by Owner's Engineer):

- D 570-98 – Standard Test Method for Water Adsorption of Plastics.
- D 638-98 - Test Method for Tensile Properties of Plastics.
- D746-13 – Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact.
- D751-06 – Standard Test Methods for Coated Fabrics.

- D882-12 – Standard Test Method for Tensile Properties of Thin Plastic Sheeting.
- D 1004-94a - Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
- D1044-13 – Standard Test Method for Resistance of Transparent Plastics to Surface Abrasion.
- D1149-07 – Standard Test Methods for Rubber Deterioration-Cracking in an Ozone Controlled Environment.
- D1203-10 – Standard Test Methods for Volatile Loss from Plastics using Activated Carbon Methods.
- D 1204-94 - Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperatures.
- D 1238-98 - Test Methods for Flow Rates of Thermoplastics by Extrusion Plastometer.
- D 1505-98 - Test Method for Density of Plastics by the Density-Gradient Technique.
- D1593-13 – Standard Specification for Nonrigid Vinyl Chloride Plastic Film and Sheeting.
- D1603-12 – Standard Test Method for Carbon Black Content in Olefin Plastics.
- D1693-13 – Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics.
- D2136-02 – Standard Test Method for Coated Fabrics – Low Temperature Bend Test.
- D 4218-96 - Test Method for Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.
- D 4437-84 (1998) - Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes.
- D 4833-88 (1996) - Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products.
- D4873-02 – Standard Guide for Identification, Storage and Handling of Geosynthetic Rolls and Samples.
- D 5199-98 - Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
- D 5397-95 - Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test.
- D 5514-94 - Test Method for Large Scale Hydrostatic Puncture Testing of Geosynthetics.
- D 5596 – Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
- D 5617-94 - Test Method for Multi-Axial Tension test for Geosynthetics.

- D 5596-94 - Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
- D5641-94 – Standard Practice for Geomembrane Seam Evaluation by Vaccum Chamber.
- D6392-12 – Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced using Thermo-Fusion Methods.
- D6693 – Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes.
- D6747-12 – Standard Guide for Selection of Techniques for Electrical Detection of Leaks in Geomembranes.
- D7007-09 – Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials.
- D7176-06 – Standard Specification for Non-Reinforced Polyvinyl Chloride (PVC) Geomembranes Used in Buried Applications.
- D7240-06 – Standard Practice for Leak Location using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique.
- D7408-12 – Standard Specification for Non Reinforced PVC (Polyvinyl Chloride) Geomembrane Seams.
- D7700-12 – Standard Guide for Selecting Test Methods for Geomembrane Seams.
- D7872-13 – Standard Practice for Use of an Electrically Conductive Geotextile for Leak Location Surveys.
- D7865-13 – Standard Guide for Identification, Packaging, Handling, Storage and Deployment of Fabricated Geomembrane Panels.

1.3.2 Pertinent provisions of the following Geosynthetic Research Institute (GRI) publications have been utilized:

- GRI GM 13 Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.

1.4 GRI GM 17 Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes Related Sections

Section S31 23 23 – Fill Materials.

Section: S31 32 19 – Geosynthetics.

1.5 Definitions

1.5.1 **Owner**: Red Leaf Resources, Inc.

1.5.2 **Owner's Engineer:** The engineering firm retained by Owner to supervise the Work.

1.5.3 **Contractor**: Refers to the general company contracted to perform the earthworks portion of the Red Leaf Oil Shale Capsule Project.

1.5.4 **Liner Installer:** Refers to the subcontractor retained to install the geomembrane liner.

1.5.5 **Lot:** A quantity of resin used in the manufacture of geomembranes. Finished rolls will be identified by a roll number traceable to the resin lot used.

1.5.6 **Manufacturer:** The party responsible for manufacturing the geomembrane rolls.

1.5.7 **Panel:** Unit area of a geomembrane that will be seamed in the field and is larger than $9.3m^2$.

1.5.8 **Patch:** Unit area of geomembrane that will be seamed in the field and is smaller than $9.3m^2$.

1.5.9 **Subgrade Layer:** Soil layer which immediately underlies the geosynthetic material(s).

1.6 Submittals

1.6.1 Contractor shall provide a manufacturer's certificate warranting compliance with these Specifications. The certificate shall identify the liner material, quantity, batch number and date of manufacture.

1.6.2 Contractor shall submit samples of the proposed liner material to the Owner's Engineer with manufacturer's literature including minimum average roll values and expected average roll values of the physical properties of the geomembrane liner for information.

1.6.3 Manufacturer and Installer are required to provide a list of references detailing their relevant project experience.

1.6.4 Liner Installer shall submit to the Owner's Engineer the qualification of its welding personnel to perform the work and tested sample results from each welder and welding machine prior to commencement of the work.

1.6.5 Liner Installer shall submit to the Owner's Engineer his proposed work plan for installation of the liner including sizes for the factory assembled panels and an Installation Layout Drawing showing the sequence of installation including field seams, details and the quantity of membrane in square yards.

1.6.6 Liner Installer shall be responsible for providing Quality Control and Assurance. As such, submit to the Owner's Engineer a proposed Quality Control and Assurance Plan that complies with these specifications. The plan should include mechanical tests on membrane materials, field and factory patches and seams, and undertaking leak detection tests on installed liner materials.

1.6.7 Liner Installer shall submit a construction completion report no later than 14 days after completion of the liner installation. The report shall include:

1. Daily weld property average reports containing: Date of weld; Location of Weld; Welding machine number; Welder's name; Test sample numbers and locations; Test sample results; Weld temperatures; Documentation and locations of repairs; and Air temperatures and weather conditions.
2. As built Drawings.

2. Materials

2.1 Polyethylene

2.1.1 All materials used in the fabrication of liner roles and panels must be of good quality and should be furnished by the same Manufacturer to ensure uniform composition.

2.1.2 All resin should be of the same make and type with excellent toughness, cold temperature performance, environmental stress cracking and UV resistance properties.

2.1.3 Sheet compounds used to manufacture the membrane shall be formulated from a premium quality, virgin, unblended, polyethylene film grade resin prepared by the polymerization of no less than 85% ethylene and containing no less than 95% by weight of total olefins.

2.1.4 **Natural resin shall meet the following requirements: Density (ASTM D 1505) ≥ 0.932 g/cc; Melt Flow Index (ASTM D 1238) ≤ 1.0 g/10 minutes; OIT (ASTM D 3895) ≥ 100 minutes.**

2.1.5 The unpigmented resin shall not contain more than 0.1% by weight of particulate matter or pyrolization.

2.1.6 The compound to be pigmented with finely dispersed carbon black of particle size less than 20 nanometers. The pigment masterbatch must be made from the same virgin polyethylene resin as is used to manufacture the geomembrane.

2.2 Polyvinyl Chloride

2.2.1 Polyvinyl Chloride (PVC) resins shall comply with ASTM D7176-06.

2.3 Sheets

2.3.1 No rework or scrap material shall be used in the manufacture of the geomembrane sheets.

2.3.2 The sheet surface is to be smooth on both sides except as noted on the Drawings.

2.3.3 The sheeting shall be free of die lines, gels, streaks, blisters, contaminants, agglomerates, poorly dispersed ingredients, pinholes or other manufacturing defects.

2.3.4 All sheets shall be free from holes, tears, scratches, cracks, creases or any handling damage. The edges of the sheeting are to be free of nicks and cuts visible to the unaided eye.

2.3.5 The maximum sheet temperature at roll wind-up shall be 35 degrees celsius. The minimum inside roll diameter shall be 6". Rolls should be wound up with less than 1" +/- telescoping.

2.3.6 Sheets shall lay flat when rolled out with a minimum amount of curl or waves on edge. Sheets shall be straight and not curve or wander.

2.4 Geomembrane Properties

2.4.1 **High Density Polyethylene (HDPE)**

2.4.1.1 Where specified on the Drawings, HDPE liners shall consist of high density polyethylene sheet, 1.52mm (60 mils) thick for the floor of the EPS Capsule and 2.03mm (80mills) thick for the roof.

2.4.1.2 Material shall be smooth or textured as shown on the Drawings.

2.4.1.3 The HDPE liner shall conform to the following properties:

- Density (ASTM D1505): Greater than 0.94 gm/cc.
- Thickness (ASTM D1505): 60mil; 1.52mm +/- 10%; 80 mill; 2.03mm +/- 10%.
- Carbon Black Content (ASTM D1603): 2-3% by weight.
- Carbon Black Dispersion (ASTM D5596): 9 of 10 views shall be Category 1 or 2; No more than 1 view from Category 3.
- Membrane Tensile Properties (ASTM D638):
  a. Minimum Tensile Yield Stress: 2400 psi average.
  b. Minimum Tensile Break Strength: 3800 psi average.
  c. Minimum Elongation at yield: 8%.
  d. Minimum Elongation at break: 700%.
- Minimum Tear Resistance (ASTM D1004): 42 lbs (60 mil); 55 lbs (80 mil).
- Minimum Puncture Resistance (ASTM D 4833): 108 lbs (60 mil); 144 lbs (80 mil).
- Low Temperature Brittleness (ASTM D746; Procedure B): Min. -40 degrees Celsius.
- Environmental Stress Crack Resistance (ASTM D1693; Condition C): Zero Failures in 2000 hrs.
- UV Resistance (ASTM 626): Less than 10% decrease in tensile properties at 10,000 hrs Xenon Arc.
- Dimensional Stability (ASTM D1204; 100°C, 1hr): ±1%.
- Water Adsorption (ASTM D570): 0.1% weight change.

- Maximum Volatile Loss of Resin (ASTM D 1203 Method A): 0.12.
- Ozone Resistance (ASTM D1149): No Cracks at 7x Magnification (7 days 1ppm 104 degrees F).
- Abrasion Resistance (ASTM D1044): 1-5mg/1000 Taber Rev.

2.4.2 All main seams shall be wedge welded to the following minimum properties:

- Shear Strength (ASTM D 882): 2400 psi.
- Elongation at Break (ASTM D822): 200%.
- Peal Strength (AE-PL2-85): 1800 psi.
- Peel separation (AE-PL2-85): 25% of fused interface width.

2.4.3 PVC Geomembranes

2.4.3.1 Material to be used shall be HAZGARD 5000 HT or equivalent **as approved by the Owner's** Engineer.

2.4.3.2 Minimum Thickness (ASTM D1593): 0.68 mm (0.27 in).

2.4.3.3 Minimum Tensile Properties (ASTM D751): Machine direction and perpendicular to machine direction average values on the basis of five (5) test specimens each direction:

- Break Strength: 2670 N (600 lbs).
- Break Elongation: 25%.

2.4.3.4 Minimum Tear Resistance (ASTM D751): 556 N (125 lbs).

2.4.3.5 Minimum Puncture Resistance (ASTM D4833): 142 N (32 lbs), 213 N (48 lbs), 271 N (61 lbs).

2.4.3.6 Adhesion – Dielectric Weld (ASTM D751): 3.1 kN/m (35 lbs/in).

2.4.3.7 Hydrostatic Resistance (ASTM D751): 3400 kPa (500 psi).

2.4.3.8 Bursting Strength (ASTM D751 Ball Tip): 3560 N (800 lbs).

2.4.3.9 Low Temperature (ASTM D2136): -30°C (-22°F).

2.4.3.10 Shop Seam Properties (ASTM D6392):

- Shear Strength: 36.7 kN/m (210 lbs/in).
- Peel Strength: 3.5 kN/m (20 lbs/in).

2.4.3.11 Field Seam Properties (ASTM D6392):

- Shear Strength: 24.5 kN/m (140 lbs/in).

- Peel Strength: 2.6 kN/m (15 lbs/in).

3. Execution

3.1 Material Labeling, Delivery, Storage, and Handling

3.1.1 Materials shall be delivered to the site only after the required submittals have been approved by Owner's Engineer.

3.1.2 During delivery and storage, protect geosynthetics from ultraviolet rays, excessive heat, mud, dirt, dust, debris, and rodents according to ASTM D4873 and D7865.

3.1.3 Deliver, store, handle and clean materials in accordance with the manufacturer's written instructions.

3.1.4 All materials delivered should be inspected for damage. Material damaged during handling and installation shall be disposed of offsite by the Liner Installer and replaced by the Liner Installer at no additional cost to the Owner.

3.1.5 Delivered panels and rolls shall be labelled or tagged to provide product identification sufficient for inventory and quality control purposes. As a minimum, packaging should be labelled with:

- Manufacturer's Name.
- Material type.
- Dimensions (thickness, length and width).
- Stock code or Product Identification Number.
- QC number.
- Panel number.
- Unfolding and deployment directions.

3.1.6 Cleaning solvents shall not be used unless product is approved by membrane manufacturer.

3.1.7 Panels shall be furnished skid mounted with suitable wrapping to protect against damage during shipping and extended ultraviolet light exposure prior to placement.

3.1.8 Schedule fabrication, delivery and installation such that rolls are unloaded directly onto their proper location on the site to minimize potential handling damage. Take care to orient the rolls and panels correctly with respect to the liner layout.

3.1.9 Use water and rags for all cleaning. If soap is used for cleaning rinse with clean water and dry before welding.

3.1.10 The on-site storage location for geomembrane material shall be sufficient to protect the geomembrane form punctures, abrasions, and excessive dirt, moisture and UV exposure should have the following characteristics:

- Level.
- Smooth.
- Dry.
- Protected from theft and vandalism.
- Adjacent to the area to be deployed.

3.1.11 Rolls shall be stored in a way that prevents sliding or rolling from stacks.

3.1.12 The above requirements for packaging and storage of the liner panels are minimum requirements.

3.2 Subgrade Layer Preparation

3.2.1 Ensure subgrade layer is acceptable for geomembrane installation in accordance with manufacturer's written instructions.

3.2.2 Subgrade layers and cover soils shall comprise Type 3 or 4 Fill placed in layers.

3.2.3 Subgrade layers shall provide a firm, unyielding surface with no sharp changes or abrupt breaks in grade.

3.2.4 Subgrade layers shall be compacted to 98% Standard Proctor Maximum Dry Density (ASTM D-698) using uniform effort to achieve stable earthworks that are not subject to slides, excessive settlement, or excessive erosion.

3.2.5 Subgrade layers shall be visually inspected (with the Owner's Engineer present) and if conditions are deemed unacceptable then corrective action must be taken.

3.2.6 Particular care should be taken to backfill and re-compact trenches or other excavations in lifts of 6 inches or less thickness to 98% of Standard Proctor Maximum Dry Density (ASTM D-698). Excavation may be slightly crowned to allow for a small degree of settlement.

3.2.7 Anchor liners at the top of fill lifts or fill stages in a V-shaped trench with a minimum depth of 18 inches located at least 18 inches from the edge of fill. Compact backfill material to 95% SPMDD.

3.2.8 Subgrade layers should be finish graded to provide a smooth bearing surface without windows or hummocks of loose soil.

3.2.9 For placement on flat ground, compact subgrade fill using smooth drum vibratory rollers.

3.2.10 For placement of membranes on steep slopes, create a smooth subgrade layer using hydraulic excavators equipped with vibratory plate tamper attachments or other method that produce equivalent effect.

3.2.11 Geomembrane subgrade layer and support layers shall be free of any wood, metal or other sharp projections that could puncture the membrane material.

3.3 Installation

3.3.1 Geomembrane

3.3.1.1 Maintain area of installation free of water, ice and snow accumulations.

3.3.1.2 Repair excessively soft supporting subgrade material as directed by the Owner's Engineer.

3.3.1.3 Do not proceed with panel placement and seaming when ambient temperatures are below -5ºC or above 40°C, during any precipitation, in presence of excessive moisture (e.g., fog, dew), nor in presence of high winds.

3.3.1.4 Place and seam panels in accordance with manufacturer's recommendations on graded surface in orientation and locations indicated.

3.3.2 Install the liner tight with allowances for expansion and contraction having no folds or excess wrinkles present. The amount of slack will be limited to that recommended by the manufacturer to ensure the service life of the liner.

3.3.2.1 Do not permit passage of any vehicle directly on the membrane at any time. Vehicular traffic will be permitted on the liner only after the full granular base materials are provided.

3.3.2.2 Ballast used to prevent uplift by wind must not damage the geomembrane. A continuous load is recommended along the edges of panels to eliminate the risk of wind uplift.

3.3.2.3 Provide sufficient thermal slack during placement to ensure that harmful stresses do not occur in service.

3.3.3 Where possible, place only as much liner as can be covered during a shift.

3.3.3.1 Under no circumstances should high ground pressure rolling equipment be allowed onto liner panels. Ensure personnel working on geomembrane do not use damaging footwear. When it is necessary for workmen to walk on the panels, clean soft-soled shoes shall be worn.

3.3.4 Field Seaming

3.3.4.1 Keep seam area clean and free of moisture, dust, dirt, debris and foreign material.

3.3.4.2 Welding operations should not be carried out when precipitation is falling unless the weld area can be kept dry by the use of shelters. Welding will only be performed in cold weather below 32°F when qualification weld tests indicate that the welding procedure used is producing peel test film tear bond quality welds.

3.3.4.3 To the maximum extent possible, orient seams down-slope and not across-slope.

3.3.4.4 All sheet welding is to be lapped and welded using the hot wedge method to produce two welds separated by an air channel. An average overlap of 6 inches should be used at all field seams between panels.

3.3.4.5 The panel edges to be joined should be thoroughly cleaned and dried using a clean cloth until the edges are free from foreign matter and water.

3.3.4.6 Extrusion Welding: Hot-air track adjacent pieces together using procedures that do not damage the geomembrane; prepare geomembrane surfaces by disc grinder or equivalent; and purge welding apparatus of heat-degraded extrudate before welding.

3.3.4.7 Where areas to be extrusion welded are roughened by grinding or equivalent, roughening marks shall be in the normal direction of the seam. All roughening debris will be blown or wiped off the surface prior to welding. The welding shall take place the same day the surface has been prepared or the surface will be re-prepared as specified above.

3.3.4.8 Hot Wedge Welding: Welding apparatus shall be a self-propelled device equipped with an electronic controller that displays applicable temperatures; clean seam area of dust, mud, moisture and debris immediately ahead of the hot wedge welder; and protect against moisture build-up between sheets.

3.3.4.9 No third party material will be allowed on main seams. Seams will be fused by the melt action of actual sheet to sheet under compression. No glues, tapes or other temporary holding techniques will be used in the area of seams.

3.3.4.10 Joints shall be continuous with no creases, inclusions or unbounded segments.

3.3.4.11 Punctures in the general liner should be repaired by covering the damaged area with a patch of at least 12inches square such that an overlap of at least 3 inches is achieved on all sides of the damage. The patch will be bonded to the liner using an extrusion fillet weld.

3.3.4.12 A seam where two liner sections which have seams in different direction have to be joined is referred to as a butt seam. Butt seams shall be run with the wedge welder. To ensure a good seal, the T-intersections between seams are extrusion welded.

3.3.5 Qualification Seams

3.3.5.1 A qualification seam will be run prior to any field seams.

3.3.5.2 A qualification seam is made with separate pieces of geomembrane using the same material and equipment that will be used for production welding and under the same surface (i.e., subgrade) and environmental (i.e. ambient temperature) conditions as the production welds.

3.3.5.3 Machine conditions, and operator used for welding must be the same as those used for the qualification weld.

3.3.5.4 Qualification seams must be tested in shear and peel, and meet the specified requirements for the material as stated in the materials section. Run a minimum of two qualification welds per day, per welding apparatus and operator; one made prior to the start of a shift and one completed at mid shift.

3.3.5.5 A qualification seams must be rerun whenever the operator is changed, the equipment adjusted, or at least every four (4) hours.

3.4 Cover Material

3.4.1 Cover all liner materials with either Type 1, Type 3 or Type 4 fill material as shown on the Drawings or as directed by Owner's Engineer.

3.4.2 Cover soil should be placed on the liner by dumping rather than blading so that tensile forces are not transmitted to the liner. Level dumped material with low ground pressure equipment.

3.4.3 Soil cover should be placed on slopes in an upslope direction.

3.4.4 Under no circumstance should equipment be allowed on the liner without sufficient cover material to ensure that no damage occurs to the liner. The depth of cover soil will depend on the type of cover material and the ground pressure of the equipment. Contactor shall perform compaction trials to ensure suitable methods and equipment are employed.

3.4.5 Equipment should not accelerate, decelerate, turn or perform manoeuvers which would transmit excessive stress to the liner. Placement operation should be planned out in a manner that minimizes activity of equipment on liner areas.

3.4.6 The Liner Installer shall provide a Senior Project Supervisor or Foreman to supervise the work.

3.5 Repairs

3.5.1.1 Inspect seams and non-seam areas for defects, holes, blisters, and undispersed raw materials.

3.5.1.2 Identify any sign of foreign matter contamination.

3.5.1.3 Repair all through-thickness defects.

3.5.1.4 The liner manufacturer shall provide written certification that the liner has been vacuum box tested at all panel thermal welded joint locations and all panel material has been visually inspected with deficiencies noted and corrected prior to purchasing. When a membrane liner is field seamed, spliced, modified or repaired, the part so fabricated shall be subject to the same performance test prescribed by the manufacturer and shall consist of visual inspection, vacuum and tensile testing. Repair areas shall be reported to the Owner's Engineer.

3.5.1.5 Repair minor tears and pinholes by patching until vacuum testing is successful. Patches to be round or oval in shape, made of the same geomembrane material, and extend to a minimum of 100 mm beyond the edge of the defect. Repaired areas shall be recorded and submitted to the Owner's Engineer.

3.5.1.6 Defective Seams: Cap strip or replace.

3.5.1.7 Small Holes or Tears: Patch and seal round holes or sharp ends of tears on slope or stressed area prior to patching.

3.5.1.8 Repair blisters, large cuts and undispersed raw materials with patch.

3.5.1.9 Secure Patches by Adhesive Seam (Chemical Weld) or Hot Air Welding:

3.5.1.10 Chemical Weld

- Follow the instructions supplied with the adhesive.
- Align the patch on the damaged area, ensuring that it conforms to the bonding surface. Apply solvent with a brush between the damaged material and the patch material.
- Roll out the patch from the center to the edges using a small roller, or press the patch down and smooth using a rag.
- Allow 24 hours curing time (at 20 0C) before testing the seam.

3.5.1.11 Hot Air Welding

- Hand hot air welding is permitted for patching HAZGARD 5000.
- Clean area to be patched.
- Hand weld the patch with a hot air gun and suitable roller.

3.5.1.12 Patches: Round or oval, of same geomembrane. Extend minimum 100mm (3 in) beyond the edge of the defect.

3.5.1.13 Verification of Repairs: All repairs to be non-destructively tested using:

- Air Lance Test, ASTM D4437 Method 7.2.
- Vacuum Box Test ASTM D5641.

3.5.1.14 Keep records of all repairs and the results of repair testing.

3.6 Quality Control

3.6.1 Liner Materials

3.6.1.1 Perform inspections of the subgrade layer that the liner is to be placed on jointly with the Liner Installer, Contractor and Owner's Engineer.

3.6.1.2 Liner panels shall be installed on subgrade layers only after Owner's Engineer has inspected such layers and approved the base preparation.

3.6.1.3 Liner Manufacturer shall provide the Liner Installer and Owner with the mill run certificates and specified test results for each shift and batch.

3.6.1.4 Inspect all liner panels for shipping damage prior to installation. Repair materials that can be patched or discard irreparable materials.

3.6.1.5 When placement and field welding is completed, Owner's Engineer and Contractor shall inspect the liner to ensure that materials, factory joints, field joints, repairs, and anchors are installed in accordance with these Specifications.

3.6.1.6 The following Quality Control data shall be provided by the manufacturer:

a. Resin Properties (Density, Melt Index, Resin Number, Batch Number).

b. Sheet Properties (Density, Melt Index, Tensile Properties, Thickness, Microtome Sections.

c. Role Identification: Operator ID, Batch Number, Date Made, Roll Length, Roll Thickness.

3.6.1.7 One unseamed and one factory seamed sample of each liner panel that is delivered to the site shall be given for laboratory testing prior to installation of the liner to ensure the panel sheets and seams meet these Specifications. Any panels for which the tested sample fails to meet the required minimum physical properties of this specification may be rejected by Owner upon confirmation of the test results.

3.6.1.8 Rejected liner panels shall be replaced by Contractor prior to field installation at no additional cost to Owner. Any liner panels found to not meet these specifications as a result of further testing during installation may also be rejected by Owner and require replacement by Contractor at no additional cost to Owner.

3.6.1.9 At the start of each daily run, provide a qualification weld for each machine and operator. A record should be taken with the following data:

a. Ambient temperature.

b. Precipitation.

c. Wind.

d. Machine Speed.

e. Welder temperature.

3.6.1.10 The qualification weld must produce film tear bond failures at all weld edges prior to the start of production welding.

3.6.1.11 A field peel test device should be on site at all times. Samples should be peel tested on every seam to ensure that the seam is being properly fused.

3.6.1.12 Provide a laboratory quality portable tensometer for field seam testing. Conduct periodic tensometer tests to ensure that field peel tests are valid.

3.6.1.13 The sampling of production welds for destructive testing shall be taken from the start or end of each seam. Tests shall be conducted according to the following test standards:

a. Tensile Test – 95% of yield strength of parent material (ASTM D882).

b. Peel Test – 80% of yield strength of parent material (ASTM D882).

3.6.1.14 All field seams shall be air pressure tested to a minimum of 175 kPa for 1 hour (or alternative testing times and air pressures **as approved by the Owner's Engineer**). The test procedure shall comprise:

- Seal off both ends of the seam with heat and pressure.
- Attach a pressure gauge assembly.
- Pressurize the air channel with a compressor attached to a gauge assembly.
- Allow the pressure to stabilize in the air channel.
- Observe the pressure gauge. There should be no observable pressure drop for a time period of one minute per 20m of seam length.
- If a rapid pressure drop occurs, perform a visual inspection of the seam. If a flaw is detected in the seam, pressure-test the seam on either side of the flaw. Repair the flaw using extrusion welding and test the extrusion weld using the vacuum test.
- Record the results of the test.

3.6.1.15 All patches shall be vacuum box tested to ensure no leakage will occur. Air vacuum test procedure shall comprise:

- Trim off any flaps from the wedge welder and coat the seam with a dilute soap solution.
- Place the vacuum chamber and depressurize with a vacuum pump to 20 kPa vacuum.
- Observe the weld inside the vacuum chamber. Any leaks will allow atmospheric pressure air from beneath the liner to enter the vacuum chamber. Soap bubbles will form at the leak.
- Mark any leaks that are found, repair and retest.
- Record the results of the test.
- During this test the underside of the liner must be dry, the test will not work if water is present on the underside of the liner.

3.6.1.16 Use the following guidelines for developing Quality Control and Assurance Plan:

Property	Test Method	Frequency
Thickness	ASTM D5199	Every Roll
Density	ASTM D1505	90,000 kg
Tensile Properties	ASTM D6693	9,000 kg
Tear Resistance	ASTM D1004	20,000 kg
Puncture Resistance	ASTM D4833	20,000 kg
Carbon Black Content	ASTM D1603	9,000 kg
Carbon Black Dispersion	ASTM D5397	20,000 kg

3.6.2 Field Seams

3.6.2.1 Field seams will be sampled for testing in a way that does not compromise the installed liner.

3.6.2.2 One sample to be tested for every 150 m (500 ft) of field seam.

3.6.2.3 Test samples are to be removed from the ends of seams, from the anchor trench, or other location that does not introduce a defect into the liner.

3.6.2.4 Samples to be approximately 100 mm (4 in) long to permit testing of one shear and two peel specimens (ASTM D6392).

3.6.2.5 Test samples immediately after seaming.

3.6.2.6 Record date, location and pass/fail description.

3.6.2.7 Vacuum testing shall be performed on all field seams in accordance with ASTM D 5641.

3.6.2.8 Conduct Air Pressure Testing in accordance with ASTM D 5820.

3.6.3 Leak Detection

3.6.3.1 Conduct leak detection testing on all sections of the geomembrane using a suitable electrical based leak detection method (i.e. ASTM D7007-09). Include leak detection plans and procedures in the Quality Control and Insurance Plan.

3.6.3.2 Conduct surveys after the geomembrane is covered. The expected minimum sensitivity is 1.5mm diameter holes.

END OF SECTION

REDLEAF RESOURCES, INC.	**Seep Ridge EPS Project**	RLSR_MCC_01_TSP_0003
Technical Specification: Liquid Collection System – Floor Pan		**Issue Date:** 3/6/2014
		Revision : A

3/6/2014	A	Issued for Permit	K. Johns	S. Lethier	S. Packard
Date	**Rev**	**Status**	**Prepared by**	**Reviewed by**	**Approved by**

General

The work to be done under this specification consists of the supply of labor, plant, material, supervision and the performance of all work necessary for the supply and installation of the floor pan; including transportation, loading and unloading, handling, surface preparation in advance of installation, as shown on the drawings and as directed by the Owner's Engineer and as specified herein.

Approvals, acceptability, and/or definitions related to this specification shall be made by Owner's Engineer. Owner's Engineer reserves the right to revise, updated, or otherwise alternate these material specifications to comply with environmental and performance requirements. Owner's Engineer may also specify similar, revised, or replacement methods/standards for those in this specification.

Reference Standards

The Work covered under this section shall be done in accordance with the following standards:

- ASTM A1011 - Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
- ASTM A749 - Standard Specification for Steel, Strip, Carbon and High-Strength, Low-Alloy, Hot-Rolled, General Requirements for

Definitions

Owner: Red Leaf Resources, Inc.

Owner's Engineer: Owner's Engineer shall be a Utah registered professional engineer, appointed by Red Leaf. Identification of Owner's Engineer shall be documented in writing.

Contractor: Refers to the company supplying all labor, materials and equipment and performing all the work necessary as per this Section.

Mechanical Design

The purpose of the floor pan is to collect the fluids (retort water and oil) that are produced during operation of the capsule. It will be located at the bottom of the capsule in an area that is lower than any material subjected to temperature conditions that will cause the shale to retort and release fluids.

The floor pan design shall specify the required slope of the substrate and the floor pan sheet layout, so fluids will flow to a collection area at the lowest point.

The floor pan is not designed to act as a structural member. The floor pan is to be installed on a designed substrate that will provide the required structural integrity.

The minimum thickness of the floor pan will be 22 gauge unless otherwise noted.

To assist with transport and installation, material shall be furnished with a suitable method for lifting and traveling members to avoid distortion of the material during handling.

Installation

The floor pan shall be installed on substrate that is installed per H335458-0310-15-123-001, Standard Technical Specification - Fill Materials.

The floor pan will be covered with backfill that is installed per H335458-0310-15-123-001, Standard Technical Specification - Fill Materials.

The floor pan shall be installed to the dimensions and within the tolerances specified.

If the floor pan is damaged prior to or during installation, the damaged area shall be discarded and not used or it shall be repaired prior to use.

Submittals

Submit to the Owner's Engineer manufacturer's instructions, printed product literature and data sheets received from the material supplier.

Material Certificates for each steel coil shall be submitted to the Owner's Engineer.

Quality Assurance

Contractor must follow the documented installation plan and work procedures approved by the Owner's Engineer.

All coils of steel shall be marked with the following information:

- Name of Manufacturer
- ASTM Designation
- Unique Material Identification Designator that is traceable to certification (such as heat or coil number)
- Grade

Quality Control

The Owner's Engineer, or designee, will establish and direct and quality control throughout the period of construction and shall provide guidance on definitions, provide approvals, and make necessary determinations for completion of requirements outlined in this specification.

The Owner or Owner's Engineer may delegate a Testing Organization to undertake third party testing to ensure conformance with the specifications.

If a third-party Testing Organization is used, the Contractor shall coordinate and cooperate with the Testing Organization to allow the sampling and testing.

Material Tests and Verifications

Tests shall be performed by the Owner's Engineer, or designee, as follows:

- Visual Inspection for damage and defects – each sheet
- Visual Inspection for required overlap of sheets – each sheet
- Visual Inspection for proper termination at edges – each sheet, both ends

END OF SECTION

Standard Technical Specification

Geosynthetics

H335458-0310-15-123-0004

			GC for	W. Hyle	W. Hyle	
2013-11-21	B	Client Review	S. Perrett	for S. Hinchberger	for M. Campanelli	As Required
2013-10-30	A	Internal Review	S. Perrett	S. Hinchberger	M. Campanelli	As Required
DATE	REV.	STATUS	PREPARED BY	CHECKED BY	APPROVED BY	APPROVED BY
				Discipline Lead	Functional Manager	Choose Approver

Table of Contents

1. General

1.1 Description of Work

1.1.1 The Work to be performed under this Section shall consist of supplying all labor, materials and plant, and performing all work necessary for the supply and installation of geotextiles and geogrid earth reinforcements; including loading, transporting, unloading, handling and undertaking the required surface preparation, in advance of installation, as shown on the Drawings and as directed by the Owner's Engineer and as specified herein.

1.1.2 Approvals, acceptability, and/or definitions related to this specification shall be made by Owner's Engineer. Owner's Engineer reserves the right to revise, updated, or otherwise alternate these specifications to comply with environmental and performance requirements. Owner's Engineer may also specify similar, revised, or replacement methods/standards for those in this specification.

1.2 Related Sections

1.2.1 Section S31 23 23 – Fill Material.

1.2.2 Section S31 05 19 – Geomembrane Liner

1.3 References

1.3.1 American Society for Testing and Materials International, (ASTM):

- ASTM D638 – 10, Standard Test Method for Tensile Properties of Plastics
- ASTM D696 - 08e1, Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between −30°C and 30°C with a Vitreous Silica Dilatometer
- ASTM D751 – Standard Test Method for Coated Fabrics
- ASTM D792-08, Standard Test Method for Specific Gravity (Relative Density) and Density of Plastics by Displacement.
- ASTM D1004-09, Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
- ASTM D1204-08, Standard Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature.
- ASTM D1505-10, Standard Test Method for Density of Plastics by the Density-Gradient Technique.
- ASTM 1593 – Specification for Non-rigid Vinyl Chloride Plastic Sheeting (thickness)
- ASTM D1603-06, Test Method for Carbon Black in Olefin Plastics.

- ASTM D1693 - 13 Standard Test Method for Environmental Stress Cracking of Ethylene Plastics
- ASTM D1790-08, Standard Test Method for Brittleness Temperature of Plastic Sheeting by Impact.
- ASTM D2136-02, Standard Test Method for Coated Fabrics-Low-Temperature Bend Test
- ASTM D3786 – 09, Standard Test Method for Bursting Strength of Textile Fabrics.
- ASTM D4218 – 96, Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique.
- ASTM D4329 - 05 Standard Practice for Fluorescent UV Exposure of Plastics
- ASTM D4355 – 07, Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus.
- ASTM D4437-08, Standard Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes
- ASTM D4437-08, Standard Practice for Non-Destructive Testing (NDT) for determining the Integrity of Seams used in Joining Flexible Polymeric Sheet Membranes.
- ASTM 4491 – 99a, Standard Test Methods for Water Permeability of Geotextiles by Permittivity.
- ASTM D4533 – 11, Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
- ASTM D4632 – 08, Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
- ASTM D4643-08, Standard Test Method for Determination of Water (Moisture) Content of Soil by Microwave Oven Heating.
- ASTM D4751 – 04, Standard Test Method for Determining Apparent Opening Size of a Geotextile.
- ASTM D4759 – Standard practice for Determining the Specification Conformance of Geosynthetics
- ASTM D4833, Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products.
- ASTM D4873 - 02 Standard Guides for Identification, Storage, and Handling of Geosynthetic Rolls and Samples.
- ASTM D5084-10, Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.
- ASTM D5199-12, Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.

- ASTM D5321-08, Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.
- ASTM D5262 - 07 Standard Test Method for Evaluating the Unconfined Tension Creep and Creep Rupture Behavior of Geosynthetics.
- ASTM D5397-07, Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test.
- ASTM D5617 - 04(2010) Standard Test Method for Multi Axial Tension Test for Geosynthetics
- ASTM D5641, Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.
- ASTM D5596-03, Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
- ASTM D5885 - Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry.
- ASTM D5887-09, Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter.
- ASTM D5890-11, Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners.
- ASTM D5891-02(2009), Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners.
- ASTM D6213 – 97, Standard Practice for Tests to Evaluate the Chemical Resistance of Geogrids to Liquids.
- ASTM D6243-09, Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method.
- ASTM D6392-08, Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.
- ASTM D6496-04a, Standard Test Method for Determining Average Bonding Peel Strength Between the Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners.
- ASTM 6497 – Standard Guide for Mechanical Attachment of Geomembrane to Penetrations or Structures
- ASTM D6637 – 11, Standard Test Method for Determining Tensile Properties of Geogrids by the Single or Multi-Rib Tensile Method.
- ASTM D6638 - 11 Standard Test Method for Determining Connection Strength Between Geosynthetic Reinforcement and Segmental Concrete Units (Modular Concrete Blocks).

- ASTM D6693-04(2010), Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes.
- ASTM D6768-04, Standard Test Method for Tensile Strength of Geosynthetic Clay Liners.
- ASTM D7556 – 10, Standard Test Methods for Determining Small-Strain Tensile Properties of Geogrids and Geotextiles by In-Air Cyclic Tension Tests.

1.4 Definitions

1.4.1 **Owner**: Red Leaf Resources Inc.

1.4.2 **Owner's Engineer**: TBD

1.4.3 **Contractor**: Refers to the company supplying all labor, materials and equipment and performing all the work necessary as per this Section.

1.4.4 **Geosynthetics**: Geosynthetics are generally polymeric products including woven geotextiles, non-woven geotextiles and geogrids.

1.5 Submittals

1.5.1 Product Data: Submit to the Owner's Engineer manufacturer's instructions, printed product literature and data sheets for geotextiles and geogrids, and include product characteristics, performance criteria, physical size, finish and limitations.

1.5.2 Shop Drawings: Submit to the Owner's Engineer shop drawings indicating installation details, including fabricated and field seams, anchor trenches and protrusion details.

1.5.3 Samples: Submit to the Owner's Engineer samples four weeks minimum before beginning work samples as follows;

1.5.4 Certificates

- Submit to the Owner's Engineer copies of manufacturer's mill test data and specification sheets at least two weeks prior to start of work.
- Submit to the Owner's Engineer certificates, including test results, at least two weeks prior to delivery to job site.

1.6 Quality Assurance

1.6.1 Submit certified test reports showing compliance with specified performance characteristics and physical properties.

1.7 Delivery, Storage, Handling and Cleaning

1.7.1 During delivery and storage, protect geosynthetics from direct sunlight, ultraviolet rays, excessive heat, mud, dirt, dust, debris, and rodents (ASTM D4873).

1.7.2 Deliver, store, handle and clean materials in accordance with the **manufacturer's** written instructions.

1.7.3 Cleaning solvents shall not be used unless product is approved by manufacturer.

1.7.4 Use water and rags for all cleaning. If soap is used for cleaning rinse with clean water and dry before welding.

1.7.5 Delivery of materials to site should be in packaging labelled with;

- Material type
- Dimensions
- Stock code
- Sales order number
- QC number
- Panel number
- Unfolding and deployment directions

1.7.6 During delivery and storage, protect geosynthetics from direct sunlight, ultraviolet rays, excessive heat, mud, dirt, dust, debris and rodents.

1.7.7 All materials delivered should be inspected for damage. Any damaged or defective materials should be replaced with new materials.

1.7.8 Rolls shall be stored in a way that prevents sliding or rolling from stacks.

1.7.9 The extent to which geosynthetics are dragged on the ground shall be minimized.

2. Products

2.1 Materials

2.1.1 ***Geotextile (Non-Woven)***

2.1.1.1 Geotextile to consist of a non-woven synthetic fiber fabric, supplied in rolls with a minimum width of 15 ft (4.5 m) and a minimum length of 300 ft (90 m).

2.1.1.2 Geotextile is to be a 100% continuous filament polypropylene non-woven needle punched engineering fabric which is resistant to freeze-thaw, soil chemicals and ultraviolet light (Layfield LP7 or an approved equivalent). Geotextiles shall be supplied in rolls. The geotextile shall equal or exceed the following minimum average roll values.

- Physical properties:

- Grab tensile strength and elongation (in any principal direction): to ASTM D-4632.
  - Grab tensile strength: 190 lbs (800 N)
  - Grab elongation: 50%
- Mullen burst to ASTM D-3786: 2400 kPa.
- Puncture Strength to ASTM D-4833: 105 lbs (467 N).
- Trapezoidal Tear to ASTM D-4533: 333 N.
- UV Resistance to ASTM D-4355: 70% @ 500 hours.

- Hydraulic properties:
  - Apparent opening size (AOS) to ASTM D-4751: 70 sieve (212 μm).
  - Permittivity to ASTM D-4491: 1.4 sec^{-1}.
  - Flow Rate to ASTM D-4491: 100 gpm/ft^2 (67.9 $L/s/m^2$).

2.1.1.3 Petroleum resistant Layfield LP7 or an approved equivalent for use around dyke sumps and where indicated on the drawings within the secondary containment dyke construction as reinforcement.

2.1.2 Geotextile(Woven)

2.1.2.1 Geotextile to consist of a woven synthetic fiber fabric, supplied in rolls with a minimum width of 15 ft (4.5 m) and a minimum length of 300 ft (90 m) .

2.1.2.2 Woven geotextile shall be made of polyester.

2.1.2.3 Geotextiles shall be supplied in rolls. The geotextile shall equal or exceed the following minimum average roll values.

- Physical properties:
  - Wide width tensile strength: to ASTM D-4595.
    - Strength @5% Strain (MD): 3600 lbs/ft (52.5kN/m).
    - Strength @Ultimate Strain (MD): 10000lbs/ft.(150kN)

      Creep Reduced Strength (MD): 6170 lbs/ft (90kN/m)..

- Hydraulic properties:
  - Apparent opening size (AOS) to ASTM D-4751: 20 US Sieve (0.85 mm).
  - Permittivity to ASTM D-4491: 0.2 sec^{-1}.

2.1.2.4 The product "PET150" manufactured by Mirafi or an approved equivalent shall be used in construction.

2.1.3 Geogrids Type A

2.1.3.1 Uni-axial geogrids shall be used. Geogrids shall be made of sheets of an extruded polyolefin, preferably polypropylene.

2.1.3.2 Geogrids shall be suitably formulated from first quality polymeric materials. The material shall be free of water soluble compounding ingredients and must be resistant to mildew and bacterial degradation. It shall also be resistant to chemical attack of diesel fuel and other corrosive matter.

2.1.3.3 Physical Properties:

- Polymer Type: Polypropylene.
- Structure: Single layer of extruded uni-axial geogrid.
- pH Resistance range: 2 to 13.
- Carbon Black Content (ASTM D4218): 1%.

2.1.3.4 Tensile Strength @ 5% Strain (ASTM D6637): 90 kN/m.

2.1.3.5 The supplied geogrid rolls shall have a minimum width of 3.5 m and a minimum length of 50 m. Aperture dimensions shall be greater than 25 mm.

2.1.3.6 The product "E'GRID 90R" manufactured by Layfield or an approved equivalent shall be used in construction.

2.1.4 Geogrids Type B

2.1.4.1 Biaxial or triaxial geogrids shall be used. Geogrids shall be made of sheets of an extruded polyolefin, preferably polypropylene.

2.1.4.2 Geogrids shall be suitably formulated from first quality polymeric materials. The material shall be free of water soluble compounding ingredients and must be resistant to mildew and bacterial degradation. It shall also be resistant to chemical attack of diesel fuel and other corrosive matter.

2.1.4.3 Physical Properties:

- Polymer Type: Polypropylene.
- Structure: Single layer of extruded biaxial or triaxial geogrid.
- pH Resistance range: 2 to 13.
- Carbon Black Content (ASTM D4218): 1%.

2.1.4.4 Ultimate Tensile Strength (ASTM D6637): 20 kN/m.

2.1.4.5 Tensile Strength @ 2% Strain (ASTM D6637): 8 kN/m.

2.1.4.6 Tensile Strength @ 5% Strain (ASTM D6637): 15.4 kN/m.

2.1.4.7 Junction Strength (GRI-GG2): 19 kN/m.

2.1.4.8 Aperture Stability (@ 5kg-cm torque): 3.4 kg-cm/deg.

2.1.4.9 Radial Stiffness @ 0.5% Strain: 285 kN/m.

2.1.4.10 The supplied geogrid rolls shall have a minimum width of 3.8 m and a minimum length of 50 m. Aperture dimensions shall be greater than 25 mm.

2.1.4.11 The product "TBX2000" manufactured by Terrafix or an approved equivalent shall be used in construction.

2.2 Fabricator

2.2.1 Fabricator must be ISO 9001 registered or follows ISO 9001 compliance procedures.

3. Execution

3.1 Preparation

3.1.1 ***Geotextile and Geogrid***

3.1.1.1 Prepare the surface on which the geotextile or geogrid is placed to a smooth surface and remove obstruction, debris, depressions, erosion features, or vegetation. Remove any irregularities to ensure continuous contact of the geotextile or geogrid with the entire surface. Remove any loose material, soft or low density pockets of material, and grade erosion features such as rills, gullies etc. out of the surface before geotextile or geogrid placement.

3.2 Installation

3.2.1 Geotextile

3.2.1.1 Place geotextile material by unrolling onto graded surface in orientation, manner and locations indicated on the Drawings or as directed by the Owner's Engineer. Remove all snow and ice prior to placing material.

3.2.1.2 Geotextile will be rejected if it has defects, rips, holes, flaws, deterioration or damage incurred during manufacturing, transportation, storage, handling or installation. Replace damaged geotextile to the approval of the Owner's Engineer.

3.2.1.3 Place geotextile material smooth and free of tension stress, folds, wrinkles and creases.

3.2.1.4 Place geotextile material on sloping surfaces in one continuous length from toe of slope to upper extent of geotextile.

3.2.1.5 Overlap each successive strip of geotextile 500 mm over previously laid strip.

3.2.1.6 Protect installed geotextile material from displacement, damage or deterioration before, during and after placement of fill material layers.

3.2.1.7 Place and compact soil layers over the geotextile in accordance with Section S31 12 12 – Placement of Fill.

3.2.1.8 Vehicular traffic not permitted directly on geotextile.

3.2.2 Geogrid

3.2.2.1 Place geogrid material by unrolling onto graded surface in orientation, manner and locations indicated on the Drawings or as directed by the Owner's Engineer. Remove all snow and ice prior to placing material.

3.2.2.2 Geogrid will be rejected if it has defects, rips, flaws, deterioration or damage incurred during manufacturing, transportation, storage, handling or installation. Replace damaged geogrid to the approval of the Owner's Engineer.

3.2.2.3 Place geogrid material free of tension stress, folds, wrinkles and creases.

3.2.2.4 If geogrid does not have equal aperture dimensions, for road and railway applications unroll geogrid in a way that the long axis of the roll is parallel with traffic patterns.

3.2.2.5 Except for very soft subgrades, it is not necessary to mechanically tie successive or adjacent strips together. If subgrade is very soft, use plastic cable ties to prevent relative movement of strips.

3.2.2.6 Overlap successive or adjacent strips of geogrid between 0.3 to 0.9 m depending on the subgrade strength. Use the following table to estimate the required overlap:

Subgrade Strength	Overlap (m)
$CBR \leq 0.5$	0.9
$0.5 < CBR \leq 2$	0.6 – 0.9
$2 < CBR \leq 4$	0.3 – 0.6
$4 \leq CBR$	0.3

3.2.2.7 Protect installed geogrid material from displacement, damage or deterioration before, during and after placement of fill material layers.

3.2.2.8 Place and compact soil layers over the geogrid in accordance with Section S31 12 12 – Placement of Fill.

3.2.2.9 Fill placement shall proceed in such a manner that it minimized development of wrinkles in and/or movement of the geogrid.

3.2.2.10 Geogrid material could become brittle in cold climate. Vehicular traffic and excessive dynamic loads shall not be not permitted directly on geogrid.

3.2.2.11 A minimum loose lift thickness of 15 cm is required before operating tracked vehicles over the geogrid placement area. Under all circumstances, turning of tracked equipment shall be avoided while over the geogrid placement area.

3.2.2.12 In cases of extremely soft subgrade, aggregate placement methods designed to avoid damage to the geogrid shall be developed under the direction of the Owner's Engineer.

3.3 Repairs

3.3.1 Geotextile and Geogrid

3.3.1.1 A damaged geotextile or geogrid can be repaired by placing an entirely new panel of the same material over the damaged panel. It is not necessary to remove the damaged panel.

3.3.1.2 The new geotextile or geogrid will need to be anchored in the same manner as the original damaged panel.

END OF SECTION

IGES®

Intermountain GeoEnvironmental Services, Inc.
4153 Commerce Drive, Salt Lake City, UT 84107
Ph: 801.270.9400, Fx: 801.270.9401

Field Scale Hydraulic Conductivity Evaluation of Compacted Bentonite Amended Soil by Sealed Double Ring Infiltration Testing

EcoShale™ Early Production System (EPS)
Seep Ridge, Uintah County, Utah

IGES Job No. 01109-018

March 3, 2014

Prepared for:

REDleaf Resources, Inc.
10808 South River Front Parkway
Suite 200
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IGES®

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Field Scale Hydraulic Conductivity Evaluation of Compacted Bentonite Amended Soil by Sealed Double Ring Infiltrometer Testing

Uintah County, Utah

IGES Job No. 01109-018
EcoShale™ Early Production System (EPS)
Seep Ridge, Uintah County, Utah

Submitted March 3, 2014
IGES, Inc.

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Table of Contents

1.0 EXECUTIVE SUMMARY

This report presents the results of field scale hydraulic conductivity testing of compacted BAS using two Sealed Double Ring Infiltrometer tests for proposed EPS capsule. The purpose for the hydraulic conductivity testing of compacted BAS was to evaluate a prototype liner that could be used to provide a minimal flow barrier below the EPS capsule during and after operations.

2.0 INTRODUCTION

2.1 PURPOSE AND SCOPE OF WORK

This report presents the results of two Sealed Double Ring Infiltrometer (SDRI) tests (ASTM D5093 – Standard Test Method for Field Measurement of Infiltration Rate using Double-Ring Infiltrometer with Sealed Inner-Ring) performed on a test pad comprised of bentonite amended soil (BAS) at the REDleaf project operations site located in Uintah County, Utah. The scope of work performed by IGES Inc. included:

- The observation, documentation, monitoring, and testing of the SDRI test pad.
- Collect representative disturbed and undisturbed test specimens of the constructed fill for laboratory testing.
- Installation of SDRI test equipment.
- Initiation SDRI testing and monitor field performance over a minimum of 30-45 day period.
- Conduct laboratory testing for hydraulic conductivity as a means of comparison with the test pad performance.
- Reduce and interpret the field SDRI test data.
- Remove and dismantle SDRI equipment.
- Prepare a comprehensive report documenting test pad construction, performance, and testing all laboratory test data developed.

2.2 PROJECT DESCRIPTION

The EPS capsule will consist of a single cell containing processed run of mine oil shale rubble, for which a liner is needed to prevent infiltration of surface water and condensate and to minimize the potential for subsequent groundwater contamination. The SDRI test is used to evaluate both the BAS performance and construction method suitability for the proposed capsule liner.

2.2.1 Observation and Monitoring of Test Pad Construction

Construction of the BAS test pad was observed and monitored by representatives from IGES on November 1, 2012. The parameters observed by IGES included the loose height of BAS placement (loose lift thickness), compacted height of BAS after placement, method of compaction, unit weight of compacted BAS material, and water content of BAS material.

2.2.2 Testing and Documenting Test Fill Construction

In order to evaluate the compaction performance of the BAS Test Pad, the unit weight and water content measurements were obtained using a Nuclear Density Gage. Representative disturbed and undisturbed test specimens of the constructed fill were obtained for laboratory testing. Documentation of the test pad construction was accomplished by annotating the BAS as it was loosely placed, compacted, and tested and by recording the construction process by way of a video camera. Video recordings were broken down into three disks in DVD format providing documentation of construction of the BAS test pad. This documentation was sent to Woody Campbell with the Utah Department of Environmental Quality, Division of Water Quality on December 27, 2012 for his review.

3.0 BACKGROUND

3.1 SEALED DOUBLE RING INFILTROMETER

The purpose of the SDRI test is to evaluate the vertical, one-dimensional in-situ or field scale infiltration of water through a porous material. This apparatus allows for the measurement of low infiltration rates that are generally associated with fine-grained clayey soils. The SDRI test equipment consists of both an inner and outer ring. The outer ring is open to the atmosphere, whereas the inner ring is sealed and submerged during the measurement of flow. The SDRI test configuration prior to being filled with water is shown in Figure 1.

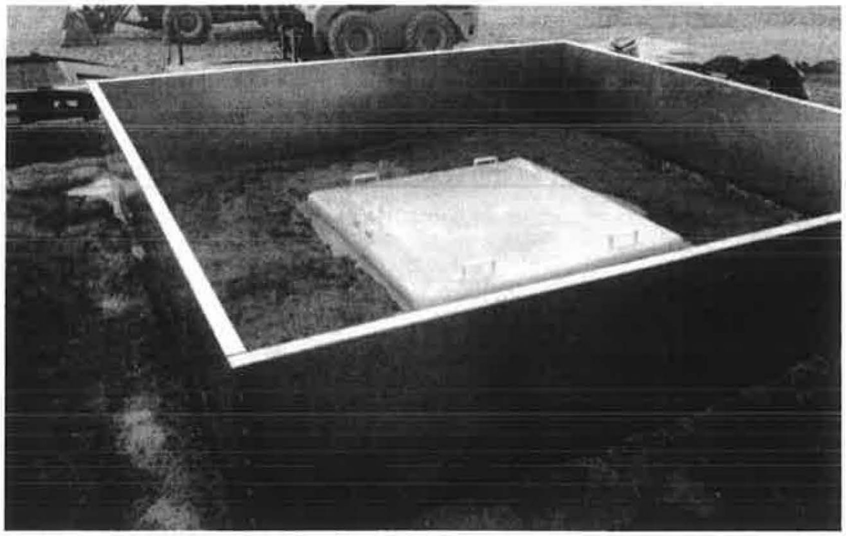

Figure 1 – SDRI test equipment installation prior to being filled with water

The sealed inner ring has three ports (see Figure 2). Two inlet ports are located on the side of the inner ring, while one port is located on top of the inner ring. Water is allowed to enter both side inlet ports while initially filling the apparatus with water. All air is allowed to exit via the top port, which is located at the highest point of the inner ring. However, during testing only one inlet port is used to allow water to enter the inner ring from flexible bags, which are connected via plastic tubing (see Figure 3). The other inlet port is plugged to prohibit any additional water to enter into the inner ring during testing. The port on top of the inner ring is used to occasionally vent and bleed air out of the inner ring.

Figure 2 – Inner ring with ports

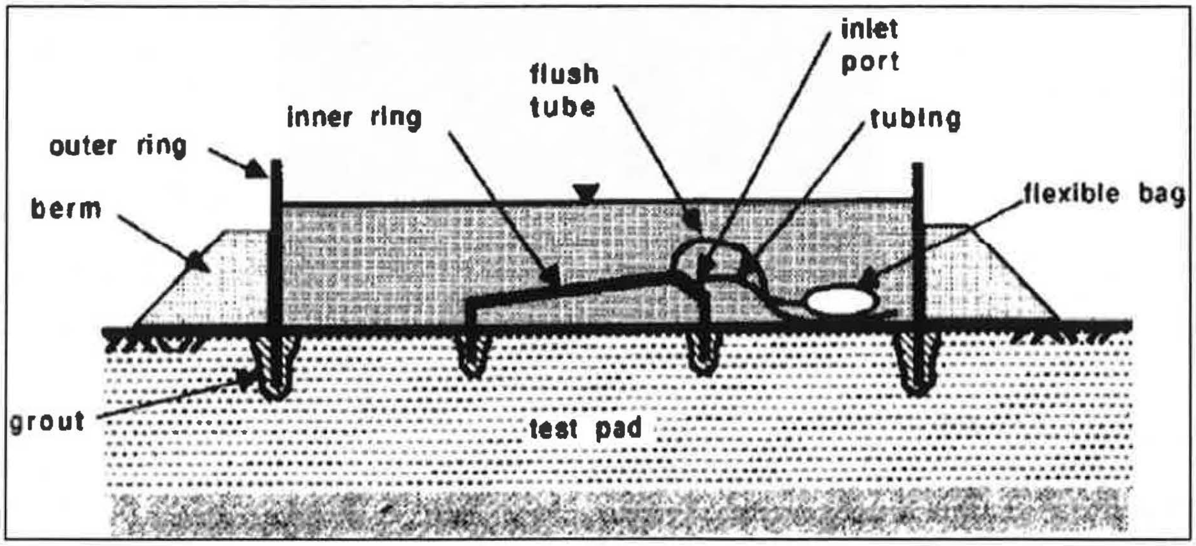

Figure 3 – Schematic of a Sealed Double Ring Infiltrometer (ASTM D5093)

During testing, two flexible bags are filled with water and connected to one of the side inlet ports of the inner ring using a tee connection and plastic tubing. The bags, and therefore the water in the inner ring, are under the same hydrostatic head as the surrounding water in the outer ring. As water begins to infiltrate the ground beneath the inner ring, an equal amount of volume of water is displaced out of the flexible bags and into the inner ring. While the ground becomes more saturated underneath the inner ring, the infiltration rate begins to decrease to a steady state condition over time. The bags are disconnected from the inner ring and weighed periodically throughout the infiltration process. The weight of each bag, the date and time the bags were disconnected and connected, and temperature of the water were recorded for each reading. When a great amount of water has been displaced out of the bags during the project, the bags were refilled for the continuation of testing.

3.2 TENSIOMETERS

Tensiometers are used to help estimate the position of the wetting front during the infiltration process. The tensiometers used on this project consisted of a sealed plastic tube with a porous tip on one end and a vacuum gage on the other. The saturated tensiometer is placed into a predrilled hole to a desired depth within the unsaturated soil. Initially when the tensiometer is placed into the soil, water will be drawn from the tube and the gage will begin to register suction (matric suction). As the wetting front passes the tip, the matric suction will decrease and water will reenter the tensiometer until the suction goes to zero at a high degree of saturation. Tensiometers were placed at depths of 6, 12, and 18 inches into the SDRI test pad.

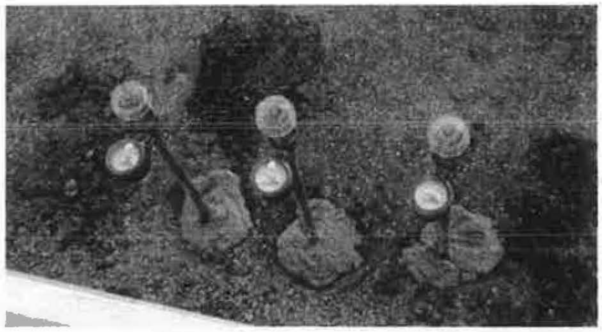

Figure 4 – Tensiometer nest at 6, 12, and 18 in. depth

3.3 SWELL GAUGES

Swell gauges are used to evaluate the magnitude of swell of the soil beneath the inner ring during infiltration. Metal fence posts were driven into BAS matrix diagonally from one another and outside of the influence of infiltration. A tensioned wire is located between the two fence posts spanning locations that are directly above the handles of the inner ring. Staff gauges are bolted to the handles of the inner ring and used to measure the change that is to occur during infiltration. The wire serves as an elevation reference point for any vertical movement of the inner ring. Swell gauges spanning a diagonal distance are shown in Figure 5.

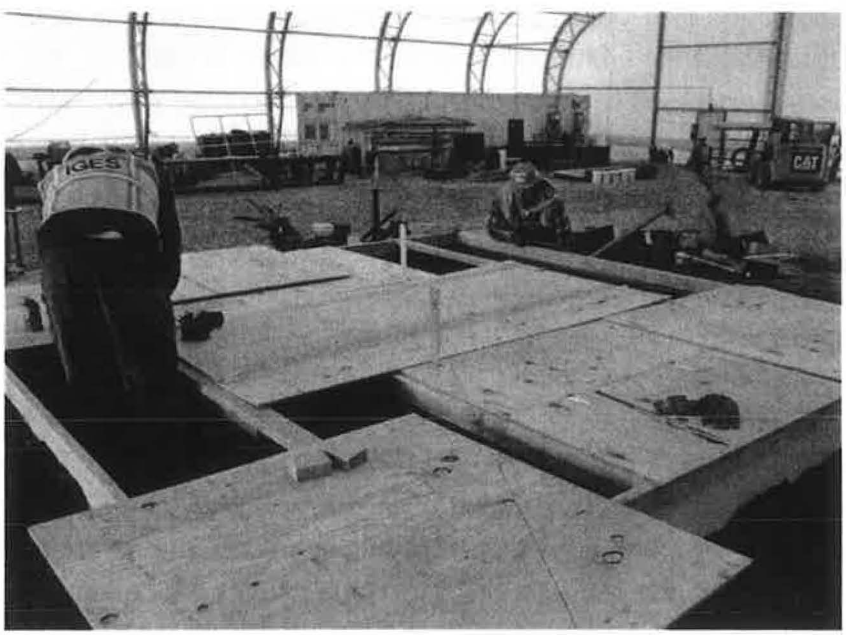

Figure 5 – Swell gauges being installed to monitor the potential vertical movement of the BAS.

4.0 METHODS OF STUDY

4.1 FIELD INVESTIGATION

The specific objectives of the field investigation performed at the REDleaf Resources project were as follows:

1. Monitoring, observing, testing, and documenting the construction a 25' x 30' BAS SDRI pad.
2. Installation two sealed double ring infiltrometer tests.
3. Monitoring, testing, and documenting the infiltration rate and hydraulic conductivity of the BAS SDRI pad using the sealed double ring infiltrometer tests.
4. Obtaining disturbed and undisturbed test specimens before and after SDRI testing for laboratory testing.

4.1.1 Construction of SDRI Pad

Construction of the test pad commenced on November 1, 2012. The first step in constructing the BAS liner for SDRI testing was to place Confidential business information Proprietary shale material (see Figure 6) on top of the existing surface and compact it using a vibratory smooth drum roller. To facilitate the quality of the SDRI testing program, the test pad was constructed inside the Kevlar structure located at the REDleaf project site.

Figure 6 – Confidential business information Proprietary material underlying the SDRI BAS test pad

The test pad consisted of an engineered soil containing Western Clay Sure Seal 80 bentonite and Confidential business information Proprietary crushed oil shale rubble meeting a target design gradation. The proportion of Western Clay Sure Seal 80 bentonite to Confidential business information Proprietary crushed oil shale rubble was Confidential business information Proprietary bentonite to Confidential business information Proprietary crushed oil shale rubble on a dry weight basis. The product of this engineered soil is denoted as a bentonite amended soil (BAS). The test pad consisting of BAS material was constructed to cover a 25' x 30' rectangular area. The area covered by BAS material supported two locations were SDRI tests could be performed. Two different methods of compaction were used to construct the BAS liner under the guidance and recommendations given to IGES from Norwest. These recommendations included the type of compaction equipment used for constructing the test pad, height of loosely and compacted BAS material during construction of the test pad, and number of passes per lift. The recommended compaction methods were observed and documented. A pass during the construction of the SDRI test pad was defined by Norwest as one complete cycle, back and forth, made by the type of compactor across the surface.

The two different compactors were used in order to observe, assess, and establish which type of compaction method would achieve the compaction specifications, while yielding the appropriate hydraulic conductivity value for the BAS during SDRI testing. A smooth drum CS74 vibratory soil compactor, which simulated the construction methods of the floor and roof of the capsule (SDRI 1) was used on the southern half of the pad as shown in Figure 7. A small Wacker Neuson RTSC2 Trench Roller, which simulated the construction methods of the walls of the capsule (SDRI 2), was used to prepare the north side of the test pad as shown in Figure 8.

Figure 7 – Smooth drum CS74 vibratory soil compactor used for compacting south side of BAS test pad

Figure 8 – Wacker Neuson RTSC2 Trench roller used for compacting north side of BAS test pad

Construction of the BAS test pad on the south side was accomplished in two lifts. Each lift consisted of loosely placing BAS material to a height of 18 inches and then compacting to a height of 12 inches using a smooth drum CS74 vibratory soil compactor (see Figure 9). Construction of the SDRI test pad on the north side was accomplished in three lifts. Each lift consisted of loosely placing the BAS material to a height of 12 inches and promptly compacting to a height of 8 inches using a Wacker Neuson RTSC2 Trench roller. The target 95% compaction of the BAS material was accomplished under a series of passes. The unit weight and water content for each test was obtained by nuclear density gauge. Construction of the test pad results for compaction type, number of passes, average total unit weight, average dry unit weight, average water content, and relative compaction are presented in Table 1. Complete compaction testing observations are provided in Appendix A.

Figure 9 – North side lift 1, 12 inch loose

Table 1 – Compaction type, number of passes, average total unit weight, average dry unit weight, average water content, and relative compaction for each test performed for each lift.

Lift No.	Test No.	Compaction Type	No. of Passes	Total Unit Weight (pcf)	Dry Unit Weight (pcf)	Water Content (%)	Relative Compaction (%)
1	1	CS74 vibratory soil compactor	2				
1	2	CS74 vibratory soil compactor	2				
1	3	CS74 vibratory soil compactor	2				
1	4	CS74 vibratory soil compactor	2				
1	5	RTSC2 Trench Roller	3				
1	6	CS74 vibratory soil compactor	2				
1	7	RTSC2 Trench Roller	3				
1	8	RTSC2 Trench Roller	3		Confidential business information Proprietary		
2	9	CS74 vibratory soil compactor	3				
2	10	CS74 vibratory soil compactor	3				
2	10A	CS74 vibratory soil compactor	3				
2	11	RTSC2 Trench Roller	3				
2	12	RTSC2 Trench Roller	3				
3	13	RTSC2 Trench Roller	3				
3	14	RTSC2 Trench Roller	3				
3	15	RTSC2 Trench Roller	3				

The majority of the test pad was covered with a plastic tarp at the future locations of SDRI 1 and SDRI 2 to help maintain the water content at which the BAS material was originally placed and compacted, as shown in Figure 10. The plastic tarp partially covering the location of SDRI 1 was removed at the onset of installation of SDRI 1, whereas the plastic tarp partially covering the location of SDRI 2 was not removed until the installation of SDRI 2.

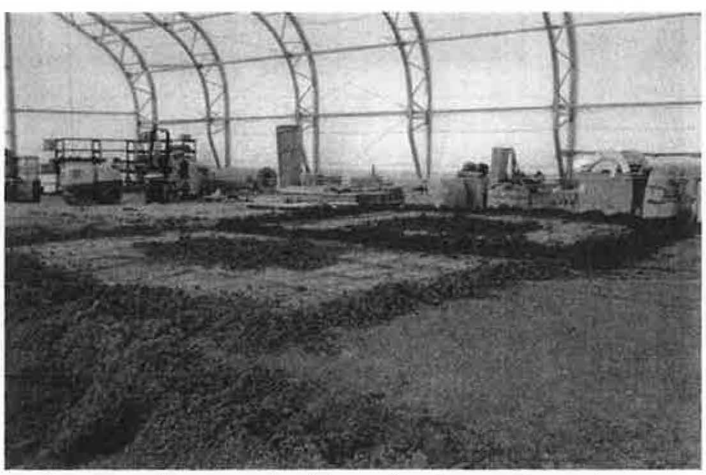

Figure 10 – Completed test pad covered with a plastic tarp in order to maintain the original water content at which the BAS was placed and compacted.

4.1.2 SDRI Intallation

The installation of SDRI 1 and SDRI 2 followed the procedure found in ASTM D5039. The installation process consists of assembling the outer rings, trenching and excavating, placement of the inner and outer ring in the trenches, covering the outer ring, and filling up the inner and outer rings with water.

The installation process begins with 4 aluminum panels, 12 feet in length and 3 feet in height, which were bolted together forming a 12' x 12' square outer ring. The outer ring was placed upon the SDRI test pad area, centered and squared. The ground was marked along the lower edge of the outer ring on all four sides. The square 5' x 5' fiberglass inner ring was centered within the outer ring area and marked on the ground along the four lower edges. Final markings of the inner and outer rings are shown in Figure 11.

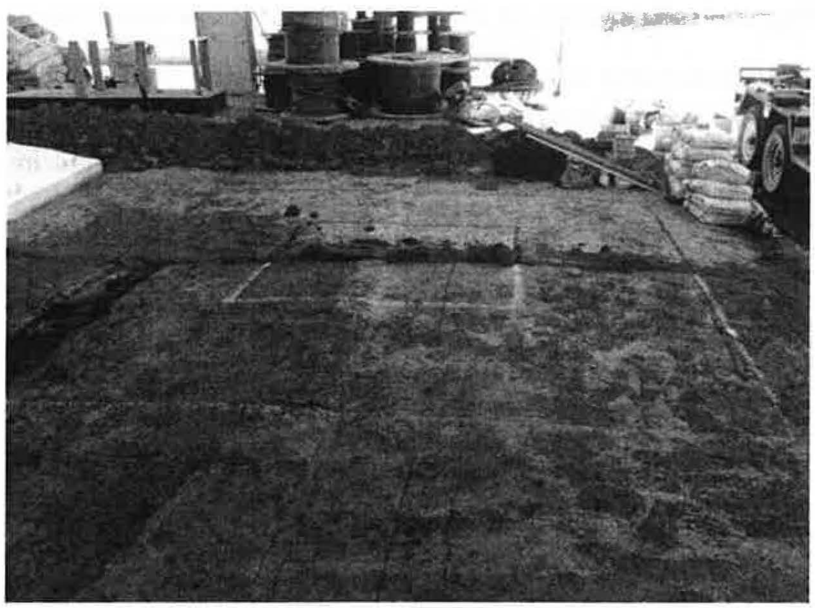

Figure 11 – Marked locations of inner and outer ring

After marking the locations of the rings, trenches for each ring were excavated using a trenching machine for the outer ring (see Figure 12) and a brick hammer for the inner ring. The trench for the outer ring was approximately 18 inches deep and 4 – 6 inches wide. The trench for the inner ring was approximately 6 inches deep and 2 inches wide. Both trenches were leveled on all four sides and at the corners of each side using a surveying level and Philadelphia rod.

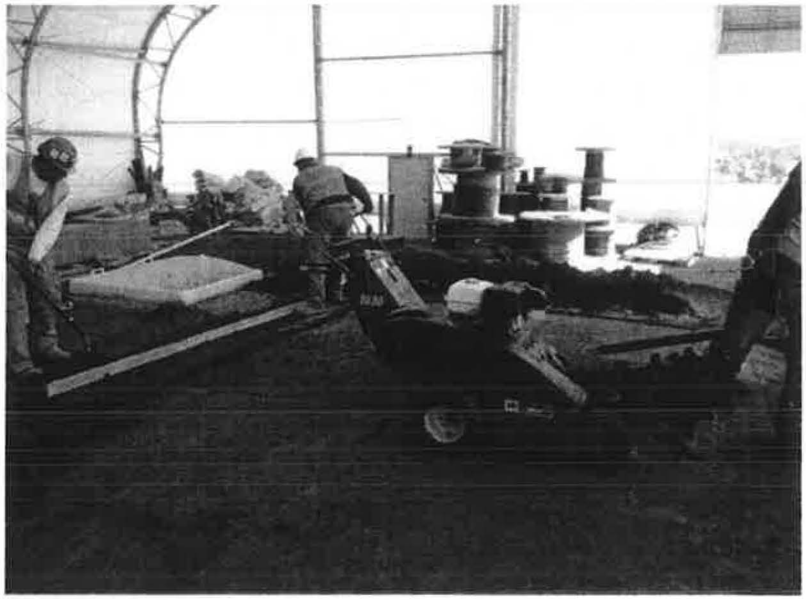

Figure 12 – Excavation of the outer trench using a trenching machine

Before placing the outer and inner ring into their respective trenches, high solids powdered bentonite grout was mixed, prepared, and placed at the bottom of each side in the excavated inner ring trench. The inner ring was embedded, sealed, and leveled in the trench before placement of the outer ring, as shown in Figure 13.

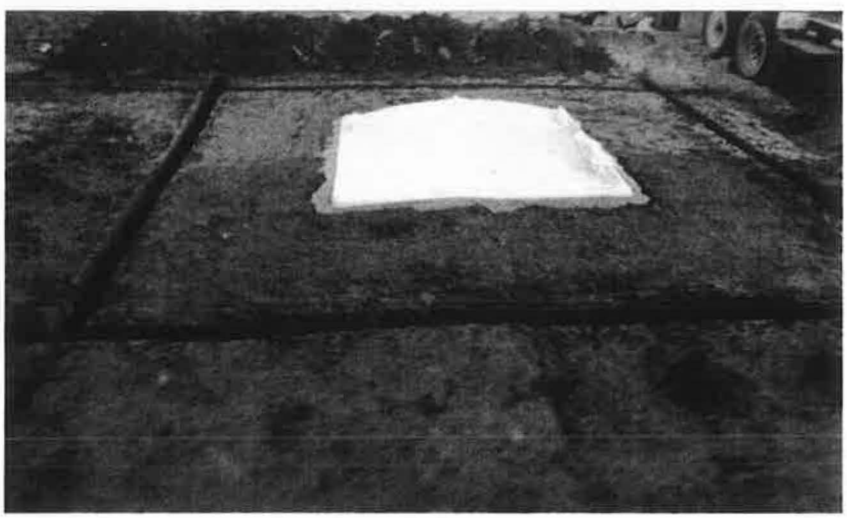

Figure 13 – Inner ring set in place with the excavated outer ring trench.

Additional amounts of grout were mixed, prepared, and placed at the bottom of the outer ring trench to an approximate depth of 8 inches. The outer ring was embedded and sealed in the trench. The remainder of the outer ring trench was filled with bentonite chips on both the inside and outside of the outer ring, as shown in Figure 14 and Figure 15. These chips were compacted and hydrated to provide a hydraulic barrier between the outer ring and the BAS test pad.

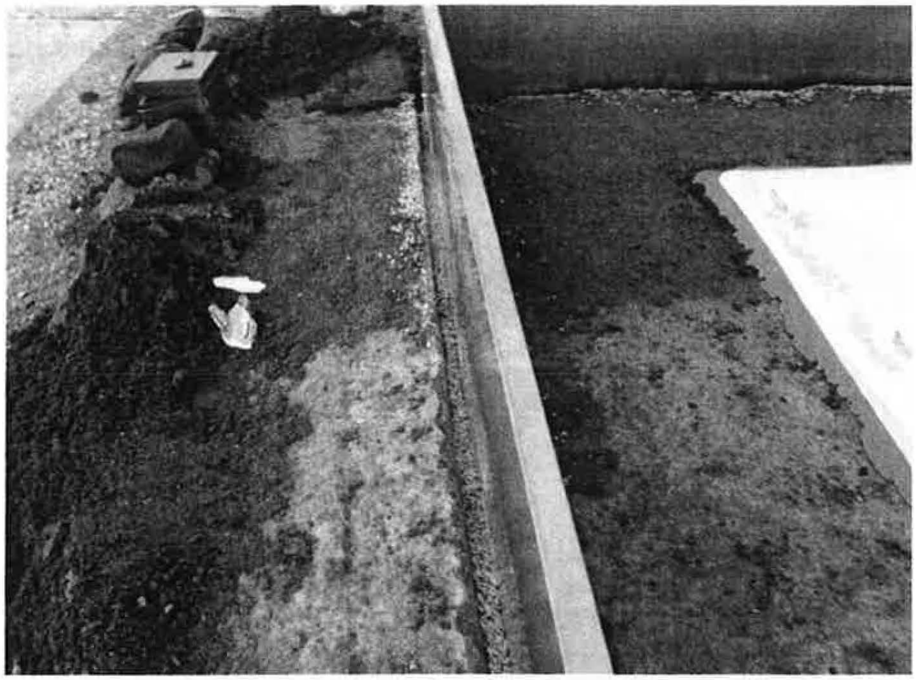

Figure 14 – Bentonite chips placed along the outside of the outer ring

Figure 15 – Bentonite chips placed along the inside of the outer ring

To help mitigate the temperature change of water within the outer ring, polystyrene insulation was placed along the sides of the exposed outer ring. Once the insulation was in place, berms were built on the inside and outside of the outer ring upon completion of placing the bentonite chips in the outer ring trench. The purpose of the berms is to keep the outer ring from bowing, provide stability to the trench, keep the grout from being pushed out the trench once the outer ring is filled with water, to insulate, and to help prevent the leakage of water from occurring. Berms were built on all four sides of the outer ring as shown in Figure 16 and Figure 17.

Figure 16 - SDRI with berms built on the inside around the periphery of the outer ring

Figure 17 – SDRI with berms built on the outside around the periphery of the outer ring

Tensiometers were advanced into pre-drilled holes within the BAS between the inner and outer rings. A total of nine tensiometers were pushed at three different locations and positioned on each non-port side of the inner ring (see Figure 18). Tensiometers were pushed to depths of 6, 12, and 18 inches below the surface of the SDRI test pad at each location.

A 12 x 12 foot insulated cover was constructed and placed upon outer ring. The purpose for covering the outer ring was to minimize a drastic temperature change of the water and to help minimize evaporation that could occur during testing. The cover was made out of plywood, 2 x 4's, and insulation (see Figure 19).

Figure 18 – Locations of Tensiometers and initial construction of the outer cover

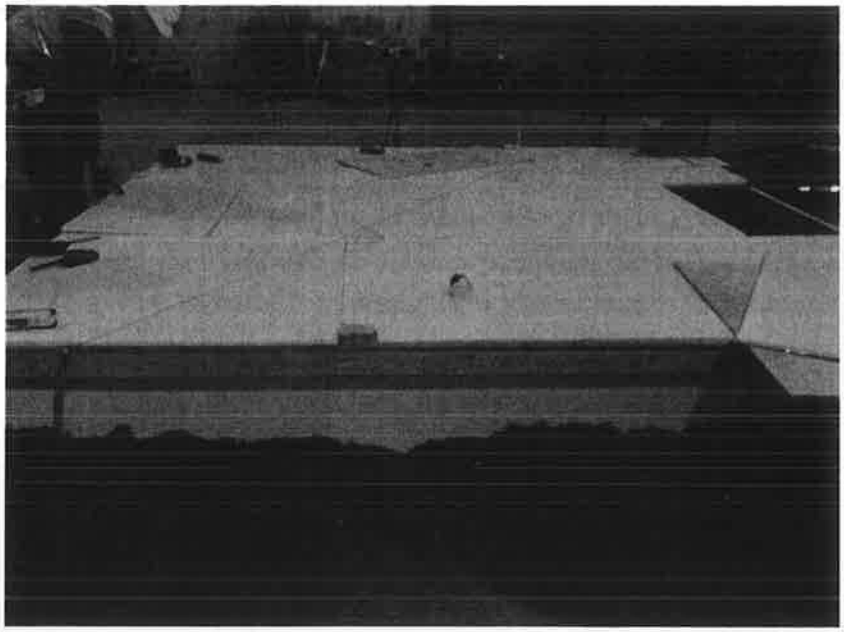

Figure 19 – Complete cover placed upon the outer ring

Water from the REDLeaf operations site was used to fill the inner and outer ring. To maintain the water at a constant temperature and keep from freezing during the periods of cold weather, an electric floating trough heater was placed in the water within the SDRI.

4.1.3 SDRI 1

Installation of SDRI 1 commenced on November 27, 2012 and was completed on November 29, 2012. SDRI 1 was located on the south corner of the SDRI test pad. Initial readings were obtained on November 29, 2012. Hydraulic conductivity testing the south side of the SDRI test pad occurred in the locations where the BAS material was compacted using a smooth drum CS74 vibratory roller. Infiltration testing for SDRI 1 continued until March 31, 2013. The disassembly and removal of SDRI 1 occurred on April 16, 2013, and subsequently moved to the SDRI 2 testing location.

4.1.4 SDRI 2

Upon completion of the SDRI 1 test, the outer ring and inner ring were uplifted from the BAS material and moved to the north side of the SDRI test pad. The installation of SDRI 2 commenced on April 16, 2013 and was completed on April 18, 2013. Initial readings for SDRI 2 began on April 18, 2013. Hydraulic conductivity testing for the north side of the SDRI test pad where the material was compacted using a Wacker Neuson RTSC2 Trench Roller. Infiltration testing for SDRI 2 continued until December 3, 2013. The disassembly and removal of SDRI 2 occurred on December 17, 2013.

4.1.5 Field Sampling

Undisturbed and disturbed soil samples were obtained at the SDRI test pad during placement and compaction of BAS material and upon completion of each SDRI test. Eight bag samples were obtained as BAS loads were brought from the pug mill mixing site to the location of the test pad. Nine undisturbed thin wall samples were obtained around the periphery of the test pad on BAS material after compaction of the BAS had occurred as shown in Table 2.

Table 2 – Sample ID, sample type, and depth of sample of samples obtained during construction of the test pad

Sample ID	Type	Depth (ft)
Load 3	Bag	NA
Load 4	Bag	NA
Load 5	Bag	NA
Load 6	Bag	NA
Load 7	Bag	NA
Load 8	Bag	NA
Western Clay 80 Mesh	Bag	NA
East Bulk	Bucket	NA
West Bulk	Bucket	NA
9	Tube	0-0.5
9A	Tube	0-0.5
10	Tube	0-0.5
10A	Tube	0-0.5
13	Tube	0-0.5
13A	Tube	0-0.5
14	Tube	0-0.5
15	Tube	0-0.5

Four undisturbed thin wall samples were obtained near each corner of the inner ring location upon completion of SDRI 1 as shown in Table 3.

Table 3 – Sample ID, type of sample, and depth of sample for samples obtained within the inner ring area of SDRI 1 upon completion of the SDRI 1 testing

Sample ID	Type	Depth (ft)
1 NW	Tube	0-0.5
2 NE	Tube	0-0.5
3 SE	Tube	0-0.5
4 SW	Tube	0-0.5

Six undisturbed thin wall samples were obtained around the periphery of the inner ring are upon completion of SDRI 2 as shown in Table 4.

Table 4 - Sample ID, type of sample, and depth of sample for samples obtained within the inner ring area of SDRI 2 upon completion of the SDRI 2 testing

Sample ID	Type	Depth (ft)
A	Tube	0-0.5
B	Tube	0-0.5
C	Tube	0-0.5
D	Tube	0-0.5
E	Tube	0-0.5
F	Tube	0-0.5

All thin wall samples collected during the field investigation for each location were obtained at a depth of 0 – 0.5 feet below the compacted BAS surface.

Field density tests were performed within the inner ring area to assess any potential density loss that may have occurred as a result of swelling. The in situ field densities of the BAS matrix within the inner ring area for SDRI 1 were obtained at the four corners using a nuclear density gauge and are provided Table 5.

Table 5 – Field density measurements within the inner ring area upon completion of SDRI 1 testing (4/16/2013)

ID	Total Unit Weight (pcf)	Dry Unit Weight (pcf)	Water Content (%)
NW Corner			
SW Corner			
SE Corner			
NE Corner			

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The in situ field densities of the BAS matrix within the inner ring area of SDRI 2 were obtained using thin wall sampling kit, and were obtained around the periphery of the inner ring. Samples obtained by way of the thin wall sampling kit were brought back to the IGES laboratory and tested. Results for field densities obtained from thin wall samples will be presented in Section 4.2.

4.2 LABORATORY INVESITGATION

BAS samples collected by IGES occurred during construction of the SDRI BAS test pad and at the time of completion of SDRI 1 and SDRI 2. Samples obtained were taken back to the IGES laboratory for material indexing testing and hydraulic conductivity testing. Basic material index testing included:

- Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (ASTM D2216)
- Liquid Limit, Plastic Limit, and Plasticity Index of Soils (ASTM D4318)
- Particle Size Analysis of Soils by Mechanical Sieving and Sedimentation Processes (ASTM D422)
- Laboratory Compaction Characteristics of Soil Using Standard Effort (ASTM D698)

A total of 9 unit weight tests and 20 water contents tests on samples obtained during construction of the test pad and completion of SDRI 1 and SDRI 2 testing. Unit weight tests were not performed on Sample IDs Load 1 through West Blk because these samples were obtained as bag samples or bucket samples. The total unit weight and water content results for the samples tested are presented in Table 6.

Table 6 – Unit weight and water content results for samples obtained during construction of the test pad and upon completion of SDRI 1 and SDRI 2 testing

Sample ID	Unit Weight (pcf)	Water Content (%)
Load 1		
Load 2		
Load 3		
Load 4		
Load 5		
Load 6		
Load 7		
Load 8		
Western Clay 80 Mesh		
East Blk	*Confidential business information Proprietary*	
West Blk		
1 NW		
2 SW		
3 SE		
4 NE		
B		
C		
D		
E		
F		

A total of 29 Atterberg limit tests were performed on samples obtained during construction or the test pad and completion of SDRI 1 and SDRI 2 testing. Results for the liquid limit, plastic limit, and plasticity index determinations are shown in Table 7. These samples classify as fat clays. Complete liquid limit, plastic limit, and plasticity index results for samples obtained during SDRI test pad construction and upon completion of SDRI 1 and SDRI 2 testing are provided in Appendix B, Appendix D, and Appendix E.

Table 7 – Liquid limit, plastic limit, and plastic index results for samples obtained during construction of the test pad and upon completion of SDRI 1 and SDRI 2 testing

Sample ID	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Sample Description
9				
9A				
10				
10A				
13				
13A				
14				
15				
Load 1				
Load 2				
Load 3				
Load 4				
Load 5	*Confidential business information*			
Load 6	*Proprietary*			
Load 7				
Load 8				
Western Clay 80 Mesh				
East Bulk				
West Bulk				
1 NW				
2 SW				
3 SE				
4 NE				
B				
C				
D				
E				
F				

A total of two laboratory compaction characteristic tests using a standard effort (ASTM D698) were performed on samples obtained during the construction of the test pad. The optimum water content (w_{opt}) and maximum dry unit weight (γ_{dmax}) for laboratory compaction tests are presented in Table 8. Complete laboratory compaction test results are provided in Appendix B.

Table 8 Laboratory compaction results for samples obtained during construction of the test pad

Sample ID	W_{opt} (%)	γ_{dmax} (pcf)
East Blk	15.2	101.5
West Blk	13.8	103.3

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To evaluate the BAS proportion of [ ] bentonite to *Confidential business information Proprietary* oil shale rubble mixture, 28 particle size analysis (ASTM D422) were performed. A combined plot with the particle size distribution results for samples previously mentioned Section 4.1.5 is shown in Figure 20. Complete particle size distribution results for samples obtained during SDRI test pad construction and upon completion of SDRI 1 and SDRI 2 testing are provided in Appendix B, Appendix D, and Appendix E.

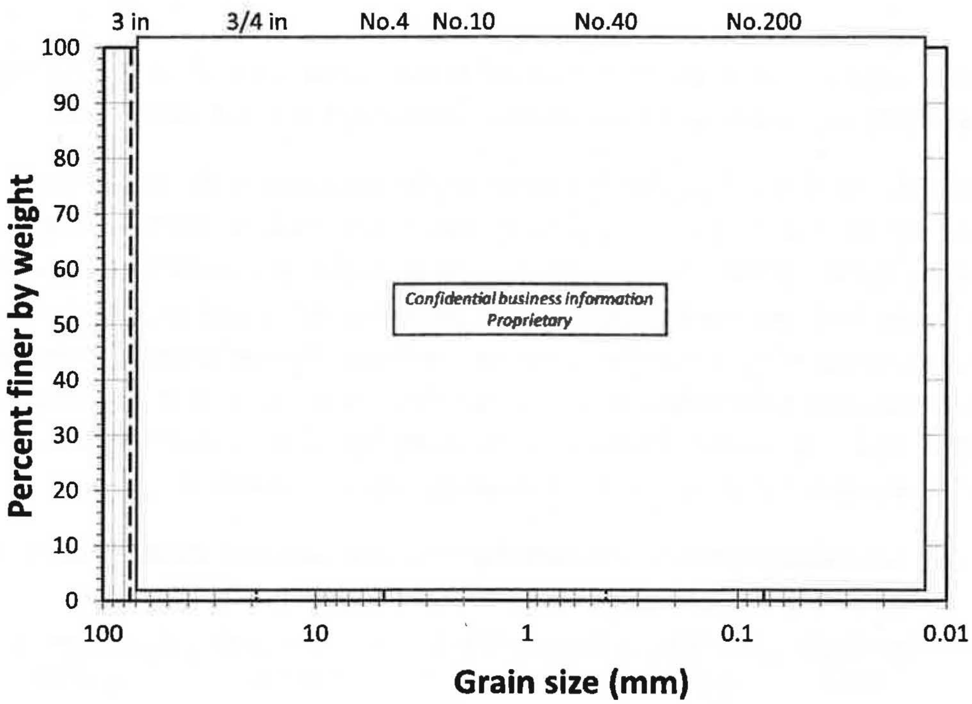

Figure 20 – Particle size distribution analysis for samples obtained during construction of the SDRI test pad and during SDRI testing

In order to evaluate the hydraulic flow characteristics of the BAS site soils for the estimation of the hydraulic conductivity following the Measurement of Hydraulic Conductivity of Saturated

Porous Materials Using a Flexible Wall Permeameter (ASTM D5084) was performed. The purpose of performing ASTM 5084 was to select BAS samples to supplement the data collected in the field. Hydraulic conductivity testing was performed on samples obtained during construction and upon completion of SDRI 1 and SDRI 2. Hydraulic conductivity results for samples obtained during the construction of the test pad are presented in Table 9.

Table 9 – Laboratory hydraulic conductivity results for samples obtained during construction of the BAS test pad

Sample ID	Depth (ft)	k (cm/sec)
9	0-0.5	4.0E-06
9A	0-0.5	8.2E-07
10	0-0.5	2.4E-07
10A	0-0.5	1.2E-06
13	0-0.5	8.2E-06
13A	0-0.5	4.7E-06
14	0-0.5	2.7E-07
15	0-0.5	5.1E-06

Suspected bypass flow along the sides of these samples resulting in the high hydraulic conductivity values shown above is discussed later in section 6.0 of this report.

The hydraulic conductivity of the thin wall samples obtained at the four corners of the inner ring area for SDRI 1 and inside the inner ring area of SDRI 2 was tested following the procedures outlined in ASTM D5084 with a slight sample preparation modification. To prevent water bypass during hydraulic conductivity testing, bentonite slurry was prepared and placed along the circumference of each sample. Effective confining stresses used to consolidate the test specimens obtained from SDRI 1 were 1, 5, and 10 ksf, with purpose of providing a baseline and upper limit hydraulic conductivity value. Laboratory hydraulic conductivity results for SDRI 1 at each effective confining stress and location are presented in Table 10.

Table 10 – Laboratory hydraulic conductivity results for samples obtained at the four corners of the inner ring area upon completion of SDRI 1

Sample ID	Depth (ft)	$k_{@1\,ksf}$ (cm/sec)	$k_{@5\,ksf}$ (cm/sec)	$k_{@10\,ksf}$ (cm/sec)
1 NW	0-0.5	1.8E-08	5.3E-09	2.8E-09
2 NE	0-0.5	9.5E-09	4.0E-09	2.0E-09
3 SE	0-0.5	1.1E-08	4.6E-09	2.5E-09
4 SW	0-0.5	2.1E-06	9.2E-09	7.7E-09

The effective confining stresses used to consolidate the test specimens were 1.44, 2.88, and 5.76 ksf. Hydraulic conductivity results for each effective confining stress inside the inner ring area of SDRI 2 are presented in Table 11. Laboratory results for hydraulic conductivity for samples obtained during construction of the test fill pad and upon completion of SDRI 1 and SDRI 2 testing are provided in Appendix B, Appendix D, and Appendix E.

Table 11 - Laboratory hydraulic conductivity results for samples obtained inside the inner ring area upon completion of SDRI 2

Sample ID	Depth (ft)	$k_{@1.44\ ksf}$ (cm/sec)	$k_{@2.88\ ksf}$ (cm/sec)	$k_{@5.76\ ksf}$ (cm/sec)
B	0-0.5	1.1E-08	9.4E-09	4.6E-09
C	0-0.5	3.2E-08	2.1E-08	9.5E-09
D	0-0.5	8.0E-09	6.3E-09	4.7E-09
E	0-0.5	1.7E-08	1.1E-08	6.7E-09
F	0-0.5	1.7E-08	1.4E-08	8.9E-09

5.0 DATA REDUCTION

5.1 SDRI DATA

Data obtained during the SDRI testing included date and time of reading, mass of bag 1 and mass of bag 2, temperature of water, the depth of water inside the outer ring, matric suction, and swell of the inner ring. Data was collected by personnel provided by REDLeaf Resources under the supervision of IGES. Data collection began on November 29, 2012 and ended on April 8, 2013 for SDRI 1 whereas, data collection for SDRI 2 began on April 18, 2013 and ended on December 6, 2013.

Data reduction involved obtaining the weight of each bag at each time and date. The weight loss between readings was converted into a quantifiable volume of water that was discharged between readings due to infiltration below the inner ring.

The infiltration rate (*I*) for each reading was determined by recording the total flow from the bags (Q_t) and dividing by the area of the inner ring (*A*) and the change in time between each readings (ΔT). The infiltration rate is denoted using the following equation:

$$I = \frac{Q_t}{A(\Delta T)}$$

The total flow from underneath the inner ring into the BAS matrix soil is a summation of the loss of water for each individual bag at each time and date the bags were weighed:

$$Q_t = \frac{(M_{1,j} - M_{1,j-1}) + (M_{2,j} - M_{2,j-1})}{\rho}$$

where:

M_1 = Mass of bag 1 in grams

M_2 = Mass of bag 2 in grams

ρ = density of water (1 gm/mL)

T_i = Time of reading at time j

T_{i-1} = Time of reading at the previous time step $j-1$

A = 25 ft^2 (2.3226 m^2).

$$\Delta t = T_i - T_{i-1}$$

The depth of water inside the outer ring was recorded for each time step in order to properly maintain a constant head above the inner ring and the flexible bags filled with water.

Hydraulic conductivity (k) can be calculated from the infiltration rate by evaluating the gradient (i) during the infiltration process. The gradient is defined as follows:

$$i = \frac{\Delta H}{L}$$

where:

ΔH = Height of water above compacted BAS material

L = Depth to the wetting front

The hydraulic conductivity can be evaluated as follows:

$$k = \frac{I}{i} = \frac{Q_t}{i(A)\Delta t}$$

The hydraulic conductivity data is normalized to a hydraulic conductivity at a standard water temperature of 20°C, k_{20}:

$$k_{20} = kR_T$$

$$R_T = \frac{2.2902(0.9842^T)}{T^{0.1702}}$$

where:

R_T = Ratio of the viscosity of water at the test temperature to the viscosity of water at 20°C

T = the average temperature over the incremental test interval

5.2 TENSIOMETER DATA

The location of the wetting front due to water infiltrating through test pad needs to be estimated during the infiltration process. Tensiometers were installed in an effort to help estimate the location of the wetting front within the test pad. Readings from the tensiometers were obtained during the hydraulic conductivity testing phase of SDRI 1 and SDRI 2 and are presented in 6.1and 6.2.

5.3 SWELL GAUGE DATA

As water infiltrated the SDRI test pad, the possibility of swelling of the test pad could occur. In order to properly monitor this movement, swell gauge readings were obtained during the SDRI 1 testing time period. Swell within the inner ring area of the test pad for SDRI 1 did not occur, thus swell gauges were not installed for SDRI 2.

6.0 RESULTS AND CONCLUSIONS

Results and conclusions for determining the steady state hydraulic conductivity of the BAS using a sealed double ring infiltrometer are presented in this section. The temperature, water depth, water tension, infiltration rate, and hydraulic conductivity, for data obtained from SDRI 1 are presented in Section 6.1. The temperature, water depth, water tension, infiltration rate, and hydraulic conductivity for data obtained from SDRI 2 are presented in Section 6.2.

The data from the tensiometers indicated that the location of the wetting front never reached the shallowest tensiometers at 6 inches. The laboratory density data were used to determine the complete phase relationships and to arrive at the porosity, *n*, of the compacted BAS at 31.7% and 32% for SDRI 1 and SDRI 2 respectively. The depth of the wetting front was then calculated at follows:

$$L = \frac{S + \int_0^t I(t)\,dt}{n}$$

where *I(t)* in the infiltration rate as a function of time.

The location of the wetting front at the end of testing was observed in the field upon dismantling the testing equipment and closely correspond to the calculated location of the wetting front using the formula as shown above.

6.1 SDRI 1

Infiltration testing for SDRI 1 lasted a total of 116 days. Water tension results for the test pad are presented in Figure 23. The hydraulic conductivity was determined to have a reached a steady state condition of 1.98E-9 cm/sec, as shown in Figure 25.

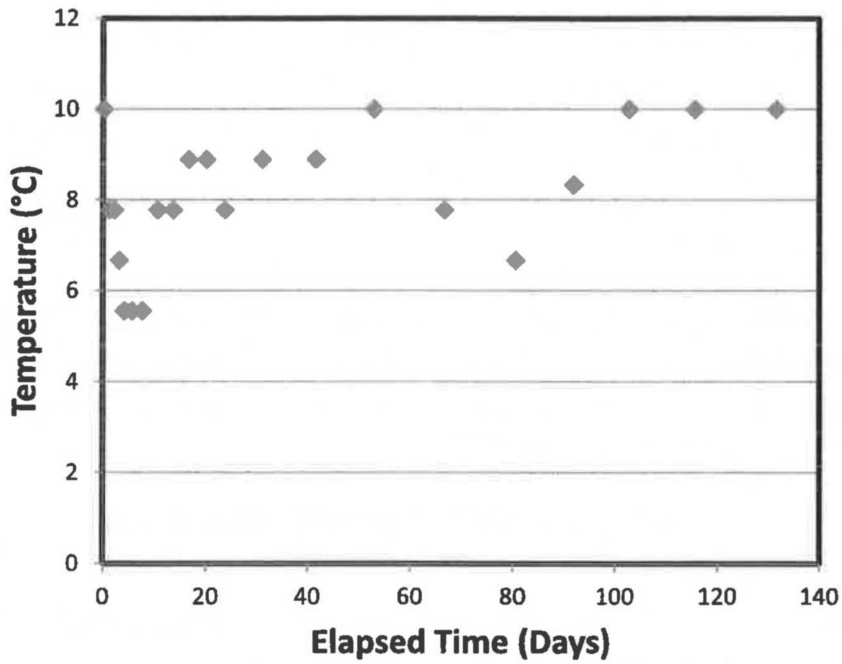

Figure 21 - Variation of temperature with elapsed time for SDRI 1

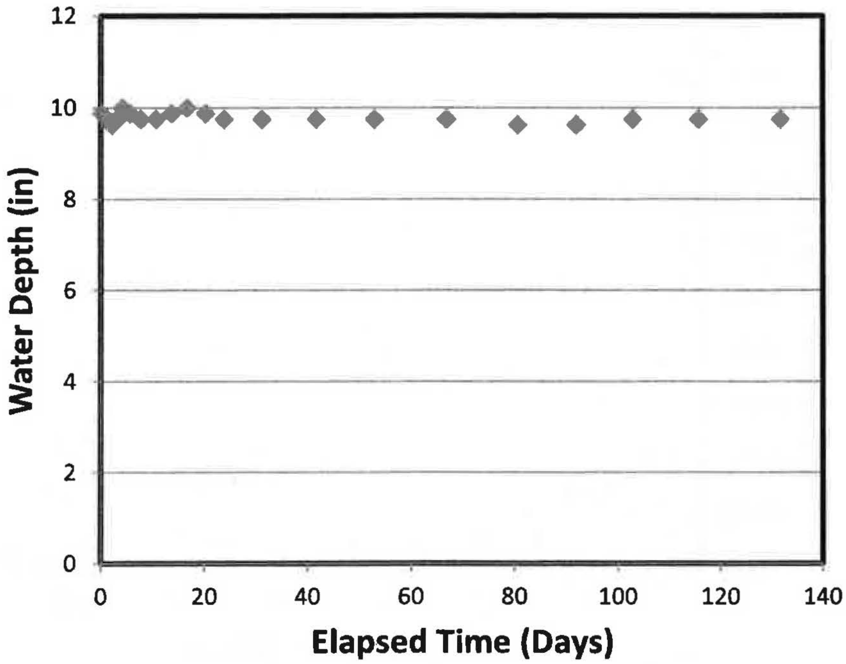

Figure 22 - Water depth with elapsed time for SDRI 1

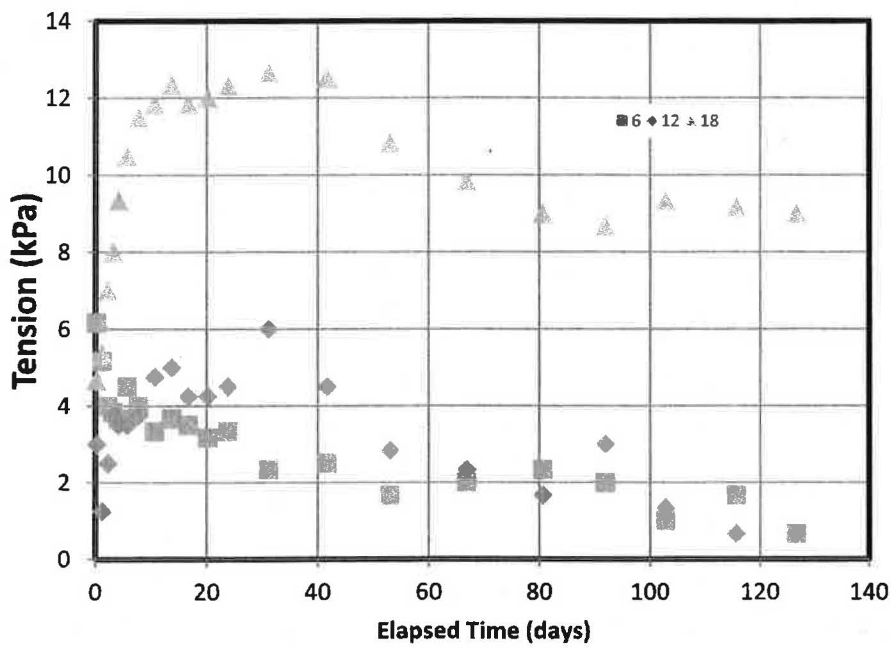

Figure 23 – Water tension with time at SDRI 2 for depths of 6, 12, and 18 inches into the SDRI test pad.

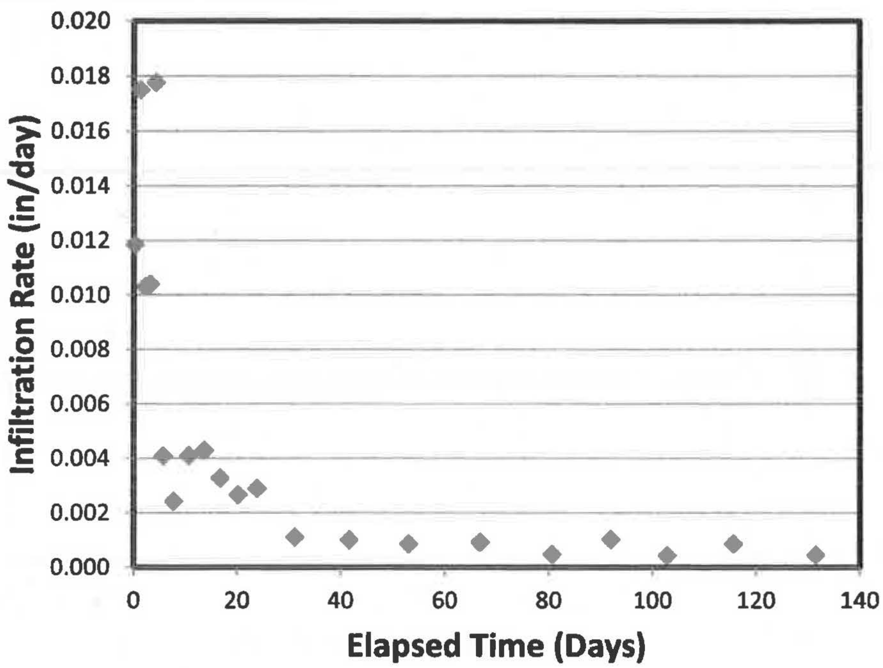

Figure 24 – Infiltration rate with time for SDRI 1

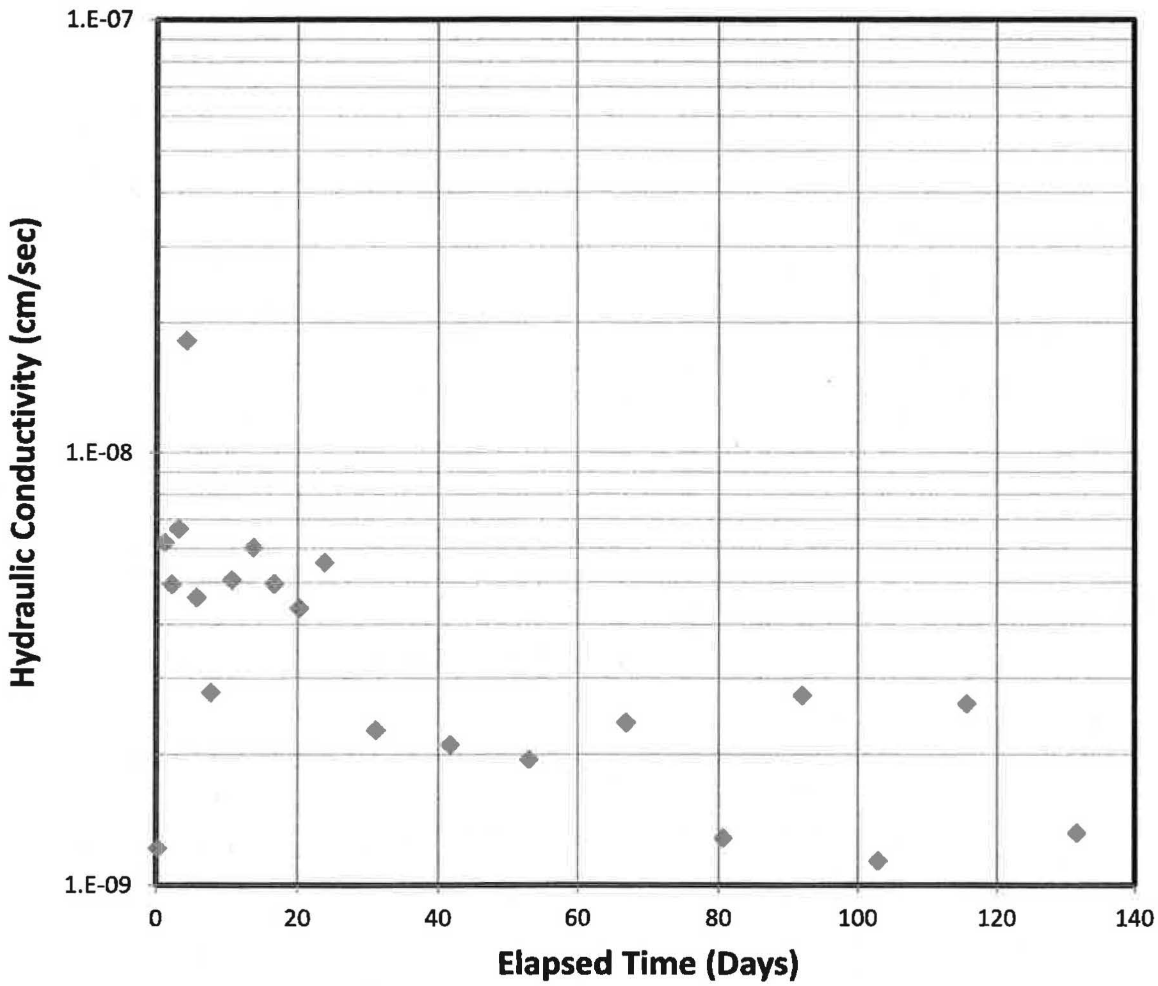

Figure 25 – Hydraulic conductivity with time for SDRI 1

6.2 SDRI 2

Hydraulic conductivity testing for SDRI 2 lasted a total of 230 days. Water tension results for the test pad for SDRI 2 are presented in Figure 28. The hydraulic conductivity was determined to have a reached a steady state condition of 3.38E-8 cm/sec as shown in Figure 30.

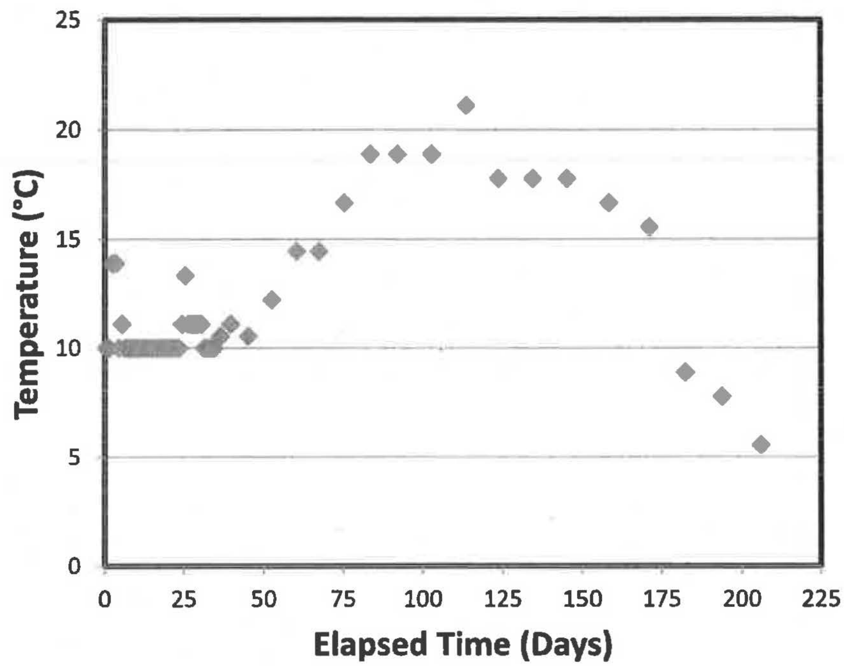

Figure 26 - Variation of temperature with elapsed time for SDRI 2

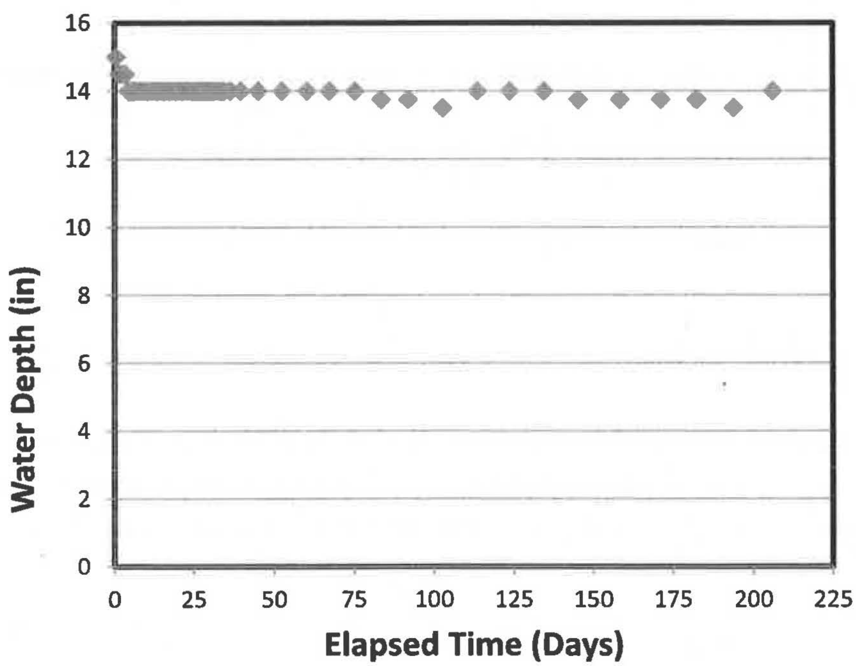

Figure 27 - Water depth with elapsed time for SDRI 2

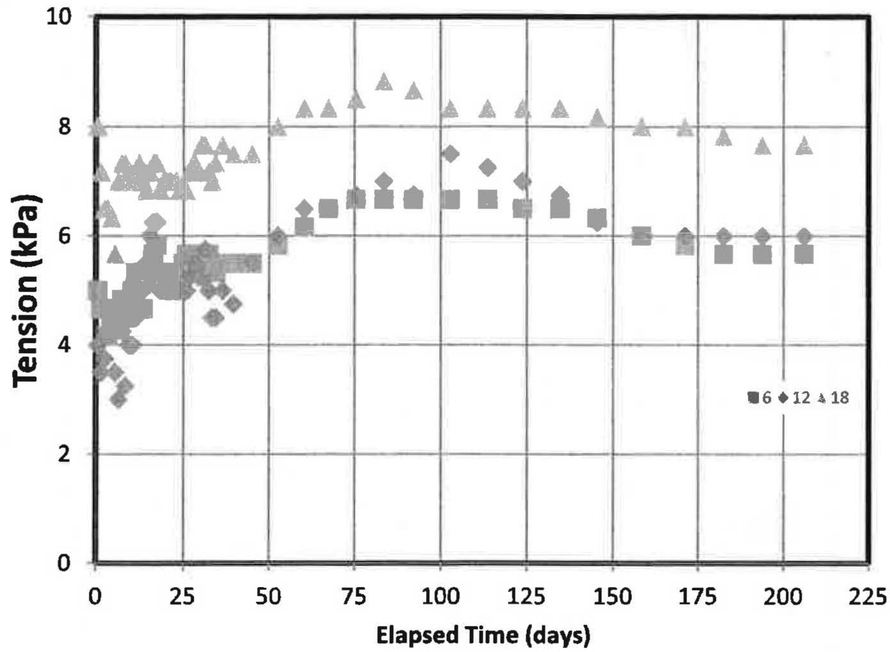

Figure 28 - Water tension with time at SDRI 2 for depths of 6, 12, and 18 inches into the SDRI test pad.

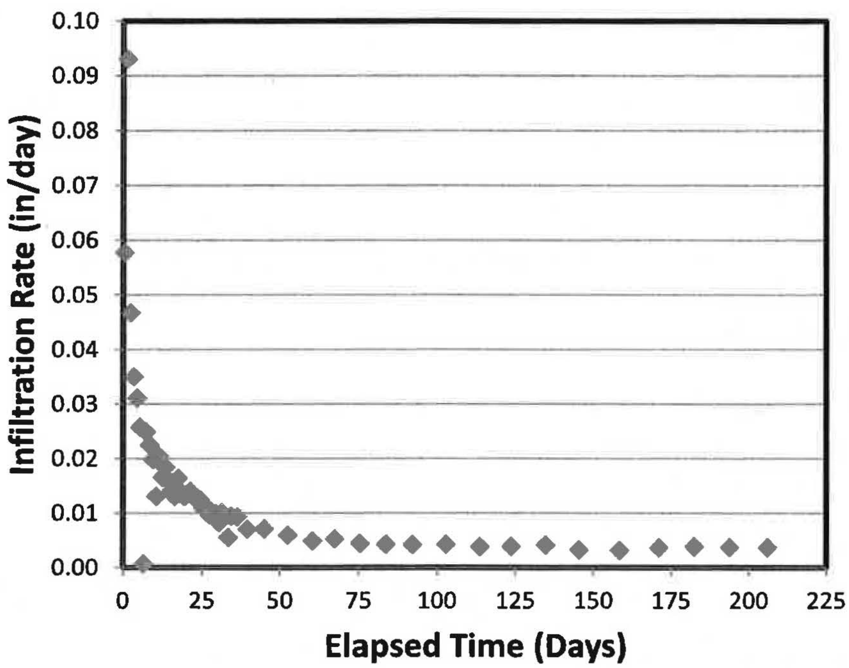

Figure 29 – Infiltration rate with time for SDRI 2

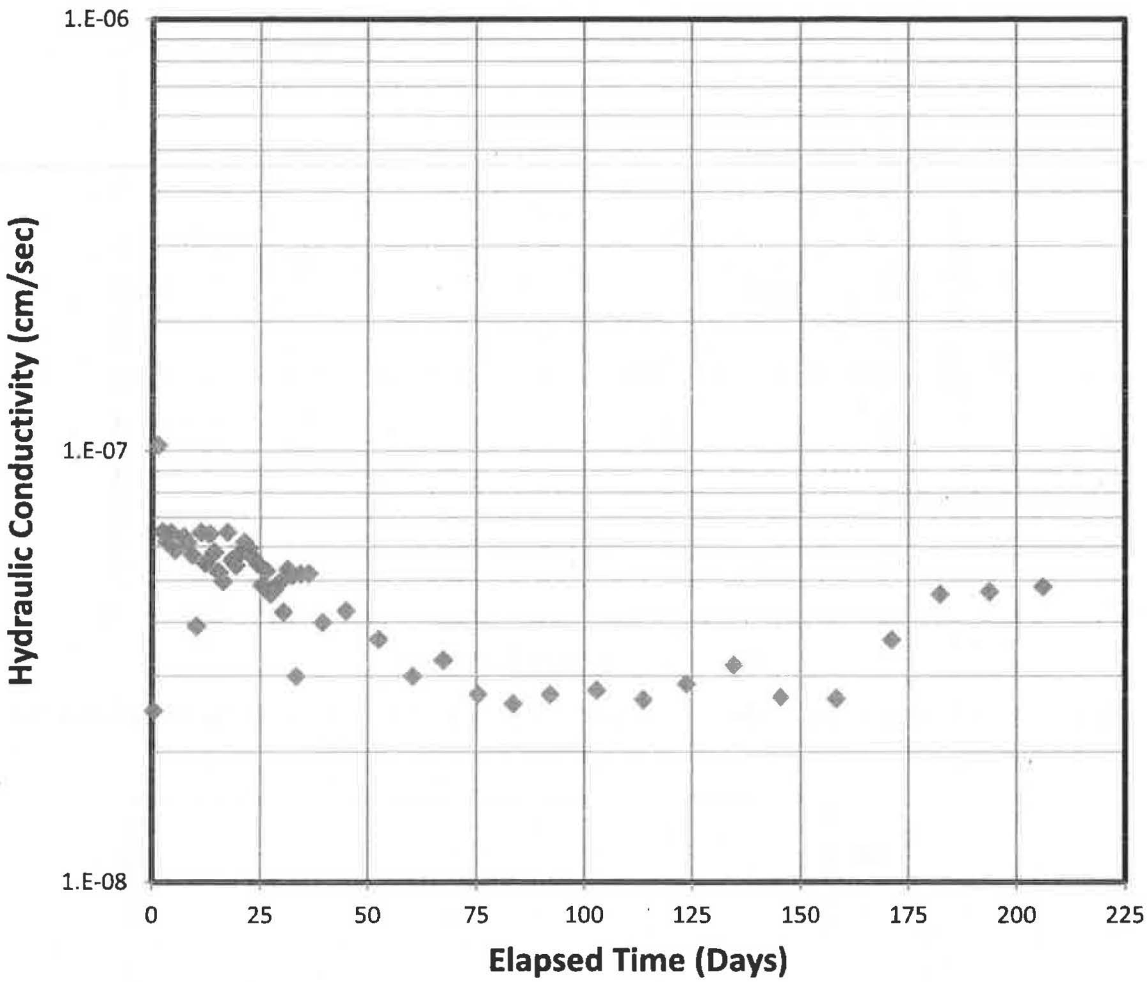

Figure 30 – Hydraulic conductivity with time for SDRI 2

6.3 CONCLUSIONS

The laboratory hydraulic conductivity tests which were initially performed and summarized in Table 9, indicated a potential of bypass flow between the membrane and the test specimen because of the coarse granular nature of the BAS material and the pathways that most likely developed attributed to the drive tube method of sampling. Bypass flow can occur with test specimens exhibiting relatively rough circumference surfaces. The in-situ samples exhibited this texture. In subsequent testing, an effort was made to mitigate this bypass flow potential by skim coating the circumference of the test specimens with a layer of hydrated bentonite prior to membrane encapsulation and testing. This sidewall treatment proved to be quite successful in mitigating this bypass flow and revealed that initial testing yielded erroneously high hydraulic conductivity values.

The results presented in Section 6.2 indicate that the SDRI field test yielded similar results with the laboratory tests. The results also indicate that the BAS produced during the fall of 2012 and corresponding construction methods yield a liner with a range of hydraulic conductivity of 2.0E-9 cm/sec (for SDRI 1, floor and roof construction methods) to 3.5E-8 cm/sec (for SDRI 2, vertical wall construction method). Companion laboratory test data also show that the increase in effective stress that the capsule base liner will be subjected to, will also result in a further decrease in hydraulic conductivity relative to that observed in SDRI 1.

Methods of BAS production and placement that would increase the hydraulic conductivity and should be avoided include:

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- Decreasing the amount of bentonite (less than ___ by weight)
- BAS matrix material gradation changes with less fines and tend towards more poorly grading.
- Lower compaction effort.
- Lower compacted water content.
- Lower compacted degree of saturation.

Conversely, methods of BAS production and placement that would decrease the hydraulic conductivity and may be acceptable (upon laboratory testing verification) include:

- Increasing amounts of bentonite by weight (greater than ___ by weight)
- Producing a more well graded BAS matrix material.

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- Higher compaction effort.
- Higher compacted water content.
- Higher compacted degree of saturation.

Any change made to the BAS material should undergo additional laboratory hydraulic conductivity testing for verification. It is highly recommended that a sidewall treatment be applied as described in this report for all additional verification testing in the laboratory.

Appendix A

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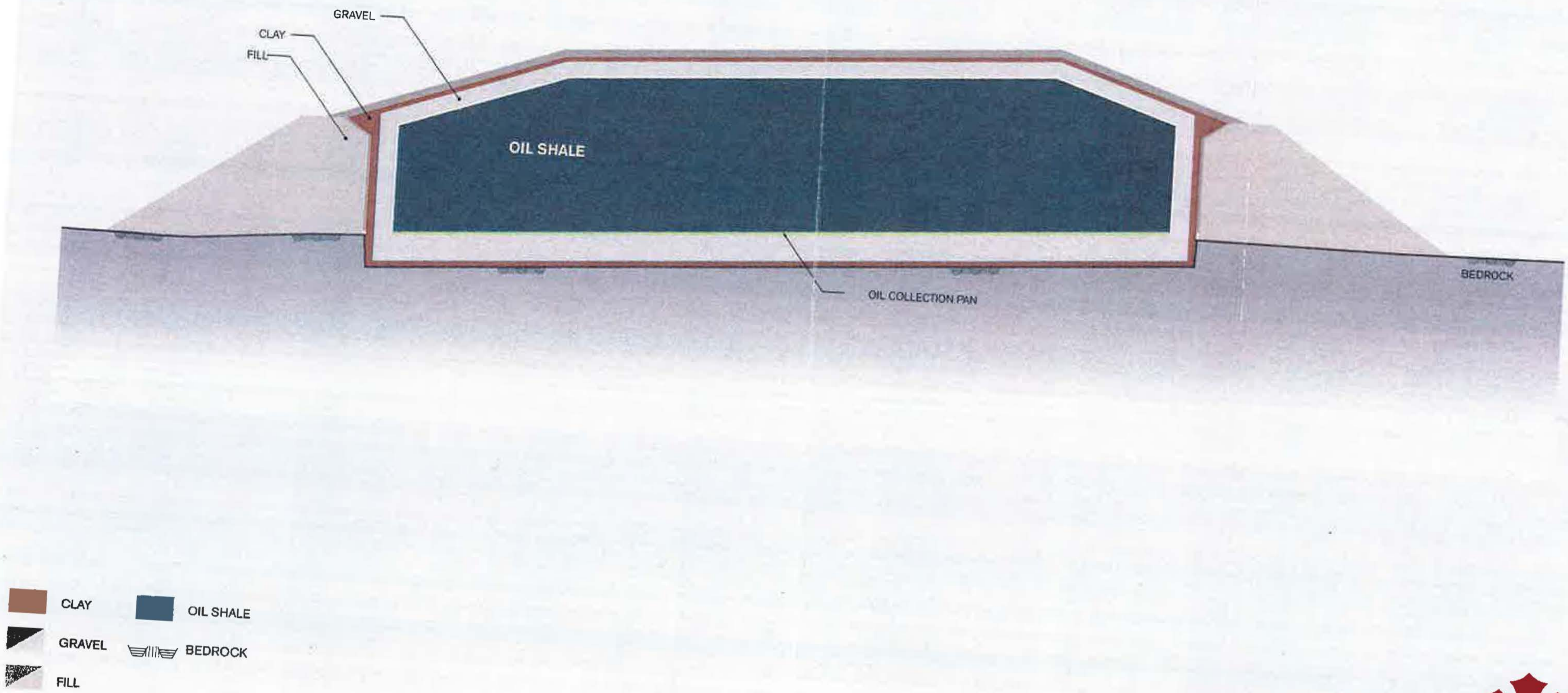
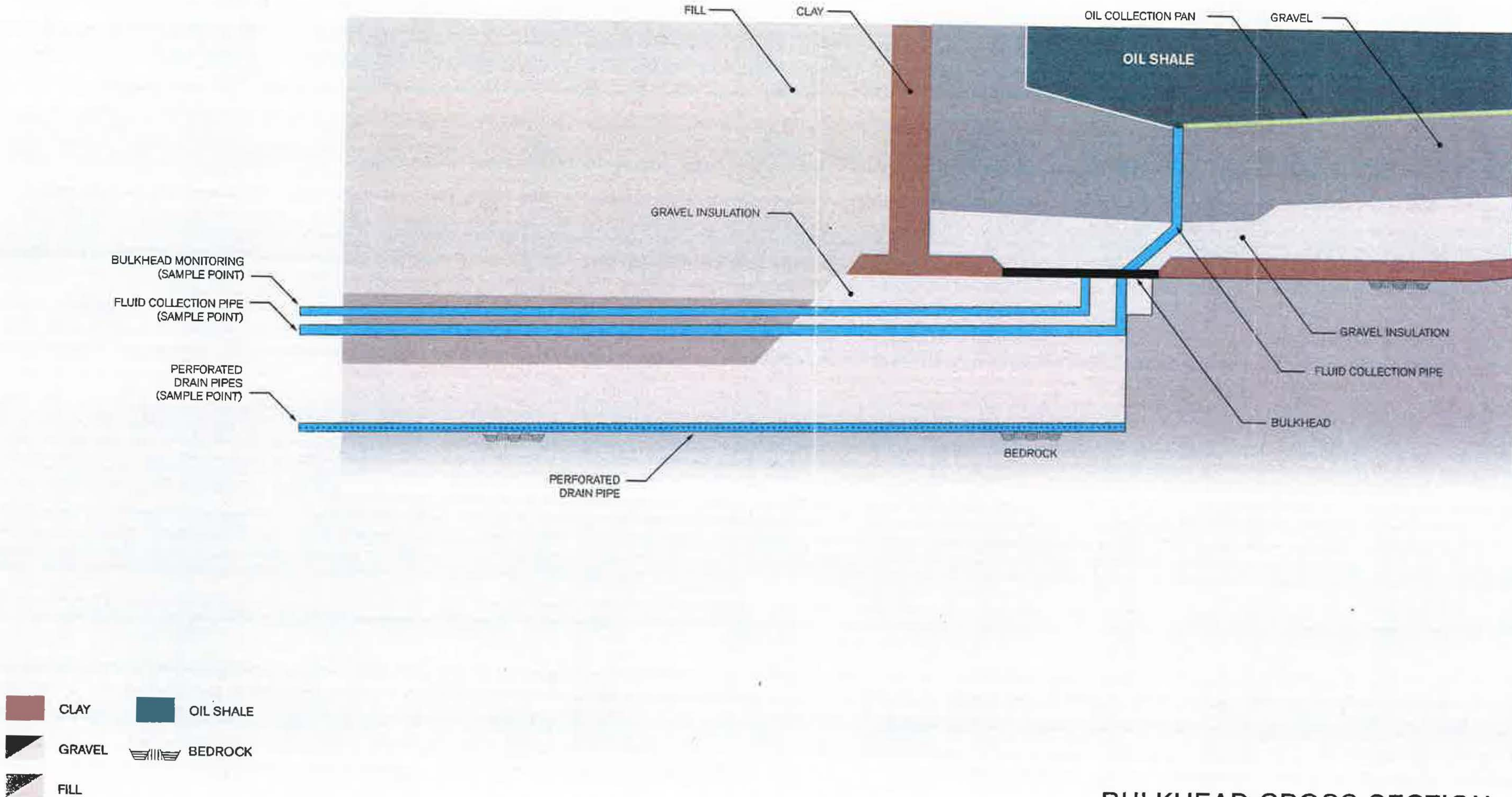


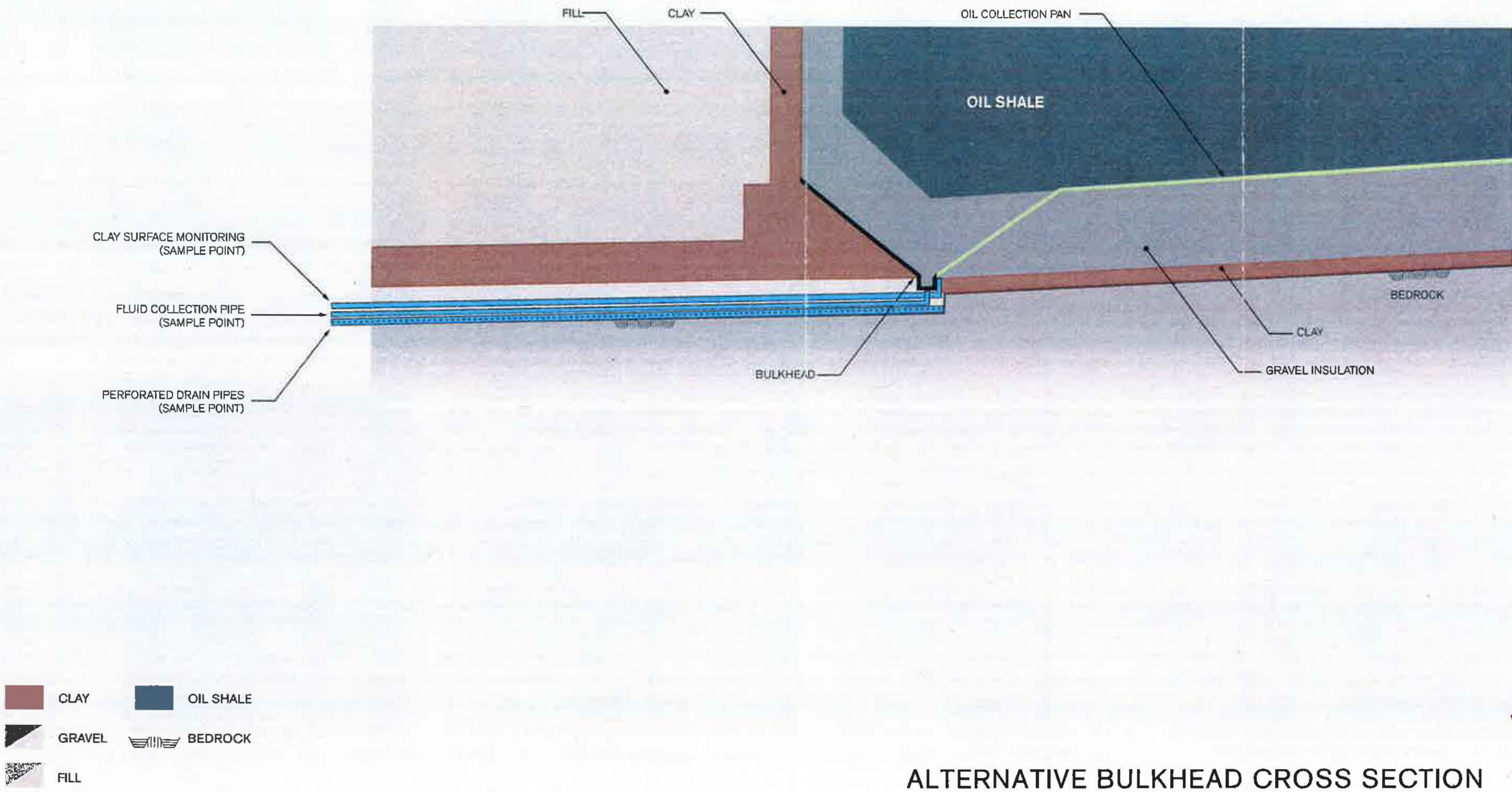
CAPSULE CROSS SECTION

REDLEAF



BULKHEAD CROSS SECTION

REDLEAF



ALTERNATIVE BULKHEAD CROSS SECTION

REDLEAF