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June 3, 2011

**VIA PDF and FEDERAL EXPRESS**

Mr. Rusty Lundberg  
Executive Secretary  
Utah Division of Radiation Control  
Utah Department of Environmental Quality  
195 North 1950 West  
Salt Lake City, UT 84116-3097

**Re: Nitrate Investigation Revised Phase 2 to 5 Work Plan -- Nitrate Investigation at the White Mesa Mill Site -- Docket No. UGW09-03**

Dear Mr. Lundberg:

Pursuant to paragraph 4 of the Tolling Agreement, Rev. 1, dated April 28, 2011 between Denison Mines (USA) Corp. ("Denison") and the Co-Executive Secretary of the Utah Water Quality Board, please find enclosed Denison's *Draft Nitrate Investigation Revised Phases 2 to 5 Work Plan, White Mesa Mill Site, Blanding Utah*.

Our proposed schedule for the nitrate investigation assumes that the Division of Radiation Control will provide any comments on this draft document by June 24, 2011. We respectfully request that DRC provide comments to Denison by that date.

Please contact me at 303-389-4132 if you have any questions on this submittal.

Yours very truly,

A handwritten signature in cursive script, reading "Jo Ann S. Tischler".

Jo Ann S. Tischler  
Director, Compliance and Permitting

Enclosure.

cc Robert D. Baird, URS



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# **NITRATE INVESTIGATION REVISED PHASES 2 THROUGH 5 WORK PLAN**

**White Mesa Mill Site**

**Blanding, Utah**

***Prepared for:***



Denison Mines (USA) Corp.  
1050 17th Street, Suite 950  
Denver, Colorado 80265

***Prepared by:***



6000 Uptown Boulevard NE, Suite 220  
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**June 3, 2011**



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## ABBREVIATIONS AND ACRONYMS

Agreement States	State agencies authorized to implement the U.S. Nuclear Regulatory Commission's licensing program under the Atomic Energy Act
Analysis Monitor	employee or agent of the Analytical Laboratory
Analytical Laboratory	contract analytical laboratory
bgs	below ground surface
CAP	Corrective Action Plan
CCD/SX	Counter Current Decant/Solvent Extraction
CIR	Contamination Investigation Report
COC	chain of custody
Co-Executive Secretary	Co-Executive Secretary of the Utah Water Quality Board of the Utah Department of Environmental Quality
Consent Agreement	Stipulated Consent Agreement Docket No. UGW09-03 dated January 27, 2009
CSM	Conceptual Site Model
$\delta$	delta
Data Users	data requestors/users
DOE	U.S. Department of Energy
DQO	data quality objectives
DRC	Utah Division of Radiation Control
DUSA	Denison Mines (USA) Corp.
EPA	U.S. Environmental Protection Agency
GWDP	Groundwater Discharge Permit
GPS	global positioning system
ID	identification
INTERA	INTERA Incorporated
LCS	laboratory control sample
LU/LC	land use/land cover
MDL	method detection limit
mg/L	milligrams per liter
Mill	White Mesa Mill
msl	mean sea level



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NAVLAP	National Voluntary Laboratory Accreditation Program
NELAP	National Environmental Laboratory Accreditation Program
New Theory	A new theory for a possible source of the nitrate and chloride contamination beneath the Mill, based on DUSA's review of the scientific literature
NRC	U.S. Nuclear Regulatory Commission
PG	Professional Geologist
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAP	Quality Assurance Plan
Request	Request for Voluntary Plan and Schedule to Investigate and Remediate Nitrate Contamination at the White Mesa Mill Site
RPD	relative percent difference
SAG	Semi Autogenous Grinding
SHP	southern high plains
Site	White Mesa Mill
SPLP	Synthetic Precipitate Leaching Procedure
Tolling Agreement	A Tolling Agreement dated December 15, 2010, between DUSA and the Co-Executive Secretary
UDEQ	Utah Department of Environmental Quality

## 1.0 INTRODUCTION

Denison Mines (USA) Corp. (“DUSA”) received a Request for Voluntary Plan and Schedule to Investigate and Remediate Nitrate Contamination at the White Mesa Mill (the “Mill”) Site, near Blanding, Utah (the “Request”) from the Co-Executive Secretary (the “Co-Executive Secretary”) of the Utah Water Quality Board, of the Utah Department of Environmental Quality (“UDEQ”) on September 30, 2008. In the Request, the Co-Executive Secretary noted that groundwater nitrate as nitrogen levels have exceeded the State water quality standard of 10 milligrams per liter (“mg/L”) in certain monitoring wells at the Mill Site. For the remainder of this document, any reference to nitrate or ammonia, whether or not the reference specifies “as N,” means the analyte “as nitrogen.”

As a result of the Request, DUSA agreed to submit a plan of action and a schedule for Co-Executive Secretary approval for completion of a Contamination Investigation Report (“CIR”) to determine the physical cause(s), location(s), transfer mechanism(s) and characteristics of all source(s) of the nitrate contamination in order to form a basis for and facilitate later submittal of a groundwater Corrective Action Plan (“CAP”) that meets the requirements of Utah Administrative Code (“UAC”) R317-6-6.15D, or to demonstrate conclusively that DUSA did not cause or contribute to the nitrate contamination in any manner and that, as a result, such a CAP is not necessary. Subsequently, in a letter dated December 1, 2009, UDEQ, noting that elevated chloride concentrations exist, apparently coincident with elevated nitrate concentrations, recommended that DUSA also address and explain the elevated chloride concentrations.

DUSA and the Co-Executive Secretary entered into a Stipulated Consent Agreement Docket No. UGW09-03, dated January 27, 2009 (“Consent Agreement”), related to nitrate contamination at the Mill. Pursuant to Item 6.A of the Consent Agreement, DUSA submitted a Nitrate CIR for the White Mesa Uranium Mill Site, Blanding, Utah, dated December 30, 2009, to the Utah Division of Radiation Control (“DRC”). By a letter dated October 5, 2010, the Co-Executive Secretary notified DUSA of his determination that the CIR is incomplete.

By an email transmitted to the Co-Executive Secretary on October 20, 2010, and pursuant to Item 11 of the Consent Agreement, DUSA requested an amendment to the deadline stipulated in item 7.C of the Consent Agreement. DUSA requested item 7.C be amended as follows:

- a. DUSA representatives would meet with the Co-Executive Secretary and his legal counsel within two weeks from the date of the email to discuss the legal responsibilities of DUSA with respect to the nitrate contamination.

- b. Once the legal responsibilities of DUSA with respect to the nitrate contamination have been determined, DUSA would, within 30 days after such a determination was made, submit to the Co-Executive Secretary for approval a plan and schedule to perform any further investigations that may be required in order to remedy any such omissions, content requirements, or failures of performance standards, and to submit a revised CIR.
- c. DUSA would perform such investigations and submit a revised CIR in accordance with the agreed upon plan and schedule.

At an October 26, 2010, meeting with the Co-Executive Secretary, DRC staff, and legal counsel, DUSA reported that it was premature to submit a schedule for submittal of performance standards and a CAP for the nitrate contamination. In turn, DUSA presented a new theory for a possible source of the nitrate and chloride contamination beneath the Mill, based on DUSA's review of the scientific literature ("New Theory"), specifically, that the nitrate contamination source is or could be caused by naturally occurring nitrate and chloride salt deposits located in the vadose zone near or beneath the Mill site area, which have been mobilized by natural and/or artificial recharge. The parties agreed that this New Theory warranted additional investigation, along with certain of the other additional studies suggested in the October 5, 2010, DRC Notice. DUSA submitted via email on November 15, 2010, a letter setting out the additional studies to be considered that have been identified to date, including the additional studies suggested in the October 5, 2010, DRC Notice, and proposed additional studies relating to the New Theory, and other additional studies that DUSA believes may be relevant. At a November 30, 2010, meeting between DRC Staff and DUSA technical and regulatory staff, DUSA presented a number of additional studies (herein "Additional Studies") to be performed by DUSA in order to complete the CIR. The Co-Executive Secretary and DUSA further agreed that DUSA would prepare a detailed plan and schedule (the "Plan and Schedule") for performing such studies and for submittal of a revised CIR that meets the requirements of all applicable regulations on or before February 15, 2011. During the November 30, 2010, meeting, it was agreed that both the Plan and Schedule and the revised CIR will be subject to Co-Executive Secretary approval. DUSA's commitment to prepare and submit the Plan and Schedule is set out in a Tolling Agreement (the "Tolling Agreement") dated December 15, 2010, between DUSA and the Co-Executive Secretary.

DUSA submitted a draft Work Plan on February 14, 2011. During subsequent discussions with DRC staff, the Co-Executive Secretary and DUSA agreed that the additional studies could require as many as five phases, and the schedule should include points of consultation between phases at which the Co-Executive Secretary and DUSA could evaluate and agree on the redirection, addition, or elimination of subsequent phases.

The Tolling Agreement was revised on April 28, 2011, to allow time for:

- DUSA to prepare and submit a Revised Work Plan for Phase 1 (the final was submitted May 13, 2011).
- DUSA to prepare and submit a revised Work Plan for Revised Phases 2 through 5 (by June 3, 2011), including a Conceptual Site Model (“CSM”) of potential nitrate sources.
- The Co-Executive Secretary to review and approve the revised Work Plans, including modifications.
- The Co-executive Secretary and DUSA to agree on a revised or replacement Consent Agreement that incorporates the deliverables and timelines in the approved Phase 2 through 5 Work Plan.

This document is the revised Work Plan for Phases 2 through 5, which is being submitted in accordance with the Revised Tolling Agreement and which contains information for the execution of Phases 2 through 5 as described in the Revised Tolling Agreement. The Phase 2 through 5 Work Plan requirements specified in the Revised Tolling Agreement Section 4 are shown below.

*4. Revised Phase 2 through 5 – on or before June 3, 2011, DUSA shall complete and submit for Co-Executive secretary review and approval a Revised Phase 2 through 5 Work Plan and Schedule, which will include, but is not limited to:*

*a) Detailed description of the activities, equipment, procedures, performance objectives, and decision criteria involved in each Phase.*

As discussed during the April 20, 2011 meeting, and as described on page 4 of the Revised Tolling Agreement, detailed Quality Assurance Plans (“QAPs”) for the groundwater quality sampling, and for the stable isotope sampling of groundwater and soil will be submitted separately prior to those field efforts, if those field efforts are required.

*b) An initial CSM of the facility (Revision 0), that DUSA will use as a guide to plan/conduct the Nitrate Investigation.*

This is addressed as Section 2.0 of this document.

- c) *A logic diagram for each Phase to identify all studies and decision processes that may be required to meet all applicable regulatory requirements including the performance objectives of the Consent Agreement, Item 6(A)(iv).*

Logic diagrams are attached as figures to this plan.

- d) *Deadlines for commencement and completion of all field and laboratory work for each Phase, and the final CIR report preparation.*

Deadlines are provided on the schedule included as Table 1 to this document.

- e) *Deadline for submittal of a final revised CIR for Co-Executive Secretary review and approval.*

Deadlines are provided on the schedule included as Table 1 to this document.

## **1.1 Problem Definition**

### **1.1.1 Purpose of the Investigation**

Based on discussions culminating in the Revised Tolling Agreement, DRC and DUSA have agreed to conduct the nitrate investigation in phases. The multi-phased program is designed to evaluate a number of potential sources of nitrate and chloride that may have contributed to the identified plume, both Mill-related sources, non-Mill sources, and sources resulting from historical use. The phased approach will include development of a CSM that will be refined as the investigation progresses and will be used by DRC and DUSA at several decision junctures to:

1. Determine which sources should be removed from further consideration.
2. Assist in quantifying the relative contribution of the remaining sources.
3. Determine whether or not to proceed with future phases of the investigation.

The Phase 1 investigation is described in detail in the *Nitrate Investigation Revised Phase 1 Work Plan, White Mesa Mill Site*, dated May 13, 2011. This Work Plan describes the remaining phases of the investigation per the Revised Tolling Agreement. Each of the phases contemplated by the Revised Tolling Agreement are described briefly below. The purpose of Phases 2 through 5 is to collect data to fill the data gaps, test hypotheses, and update the CSM as described above. Additional plans, as delineated below, will be submitted to address the specific details, activities,



equipment, procedures, objectives, and decision criteria for each of the phases specified in the Revised Tolling Agreement.

#### **1.1.1.1 Phase 2 – Groundwater Quality Sampling and Analysis**

This phase of the investigation will collect groundwater samples from existing on-site wells. Groundwater will be analyzed for specific compounds associated with military activities at the Site and with agricultural use at the Site. A separate QAP Addendum for conventional groundwater sampling and analysis will be submitted which specifies the specific details, activities, equipment, procedures, objectives, and decision criteria for this phase of the investigation. The QAP Addendum will be based upon the existing DRC-approved QAP for groundwater sampling at the White Mesa Mill. The Addendum will follow the same outline as the approved QAP and will supplement the approved QAP to address those activities which are specific to Phase 2 of the Nitrate Investigation. The QAP Addendum will be submitted to DRC on or before July 22, 2011. The schedule assumes DRC will complete review by August 5, 2011 and DUSA will submit a Final QAP by August 12, 2011. Sampling will occur in either Q3 or Q4 2011.

#### **1.1.1.2 Phase 3 – Deep Bedrock Core Sampling and Analysis**

This phase of the investigation will look at bedrock as a pathway for contaminant migration. Based on the results of Phase 1, locations will be selected for further analysis to trace nitrate and chloride from the base of the alluvium into bedrock. The activities associated with Phase 3 of the nitrate investigation are described herein. Specific location information will be provided at a later date after the receipt of the analytical data from Phase 1. The schedule assumes DRC will complete review of this plan by June 24, 2011 and DUSA will submit a Final plan by July 15, 2011. Sampling will be completed in August 2011.

#### **1.1.1.3 Phase 4 – Stable Isotopic Sampling and Analysis**

Stable isotopes of nitrogen, sulfate, and ammonia will be used to identify and “fingerprint” the contamination in groundwater and compare it to the fingerprint of nitrate and chloride coming from potential sources. A separate QAP Addendum for isotopic groundwater sampling and analysis will be submitted which specifies the specific details, activities, equipment, procedures, objectives, and decision criteria for this phase of the investigation. The QAP Addendum will be based upon and utilize the existing DRC-approved QAP for groundwater sampling at the White Mesa Mill. The Addendum will follow the same outline as the approved QAP and will supplement the approved QAP to address those activities which are specific to Phase 4 of the nitrate investigation. The QAP Addendum will be submitted to DRC on or before September 16,



2011. The schedule assumes DRC will complete review by October 7, 2011 and DUSA will submit a Final QAP by October 28, 2011. Sampling will be completed by January 31, 2012.

#### **1.1.1.4 Phase 5 – Isotopic Soil Sampling and Analysis**

A determination regarding the necessity to complete Phase 5 will be completed after review of the data resulting from the previous phases of the nitrate investigation. If completed, Phase 5 will provide an isotopic “fingerprint” of potential sources of nitrate and chloride in soil or deep cores. If this phase is required, a separate Work Plan/QAP will be submitted which specifies the specific details, activities, equipment, procedures, objectives, and decision criteria for this phase of the investigation. A submittal date for the draft QAP for this phase will be established after consultation with DRC determines this phase is needed.

#### **1.1.2 Site Description and Background**

The Site is a uranium mill with a vanadium co-product recovery circuit located within the Colorado Plateau physiographic province approximately 5 miles south of the city of Blanding, Utah. Mill construction began in 1979, and conventionally mined uranium ore was first processed in May 1980. Over its 25-year operating history, the Mill has processed over 4 million tons of conventionally mined and alternate feed uranium ores for the recovery of 25 million pounds of  $U_3O_8$  and 34 million pounds of vanadium to date.

Potential on Site sources of nitrate and chloride addressed in the Nitrate CIR (INTERA, 2009) include:

- The septic leach fields at the Site.
- The municipal sewage plant discharge water used historically as Mill water makeup.
- Livestock activities at the wildlife ponds.
- Livestock activities at the Historic Pond.
- Agricultural activities.
- The former Fly Ash Pond.
- Potential historic spills of ammonia-bearing and/or chloride-bearing process chemicals.
- A potential breach in the Mill circuit floor drains or tailings transfer lines.
- A potential leak in the Mill’s tailings cells.





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#### **1.1.2.1 Site Status**

The Mill was in standby status from November 1999 to April 2002. During the standby period, the Mill received and stockpiled alternate feed materials from the Ashland 1 and Linde formally utilized sites remedial action program sites, as well as from other sources of alternate feed materials.

During the period from April 2002 to May 2003, the Mill processed 266,690 tons of alternate feed materials. Subsequently, the Mill entered standby mode but continued to stockpile alternate feed materials.

Uranium mills are licensed to operate either by the U.S. Nuclear Regulatory Commission ("NRC") or by state agencies that are authorized to implement the NRC's licensing program under the Atomic Energy Act ("Agreement States"). The Mill received its initial source material license from the NRC in 1980. The State of Utah became an Agreement State in 2005, at which time regulatory authority for the Mill passed to the Utah DRC. The Mill is regulated under Utah Radioactive Materials License UT 1900479. Groundwater quality is regulated by the Mill's Utah Groundwater Discharge Permit ("GWDP") UGW370004.

The Mill is currently operating, having commenced operations in March 2005 with the processing of Cameco alternate feed materials. The Mill has since processed natural ores and alternate feeds. Alternate feeds have been processed both in the main mill circuit and the alternate feed circuit, which was constructed in 2009.

#### **1.1.2.2 Physical Setting**

The Mill is located near the western edge of the Blanding Basin within the Canyonlands section of the Colorado Plateau physiographic province. Broad, generally horizontal uplift and subsequent erosion have produced topography consisting of high plateaus, mesas, buttes, monuments, and deep canyons incised into the relatively flat-lying Mesozoic and Paleozoic sedimentary rocks.

Northeast of the Mill site, igneous intrusions forming the core of the Abajo Mountains have disturbed the classic flat-lying Colorado Plateau stratigraphy, resulting in uncharacteristic local folding and faulting of sedimentary rocks. The Abajo's rise to more than 11,000 feet above mean sea level ("msl"), and have likely provided a source of sediments to the Mill site (5,600 feet above msl) during intrusion and disturbance of older rocks.

Quaternary deposits overlie the sequence of Mesozoic rocks present in the region. The Cretaceous Mancos Shale and Dakota Sandstone represent the local top of the Mesozoic section

in the region and are underlain by the Lower Cretaceous Burro Canyon Formation. This unit is underlain in turn by the Jurassic Morrison Formation (which includes the Brushy Basin, Westwater Canyon, Recapture, and Salt Wash Members), the Summerville Formation, the Entrada Sandstone, and the Navajo Sandstone. The Navajo is underlain by the Jurassic Kayenta Formation, which in turn is underlain by the Triassic Chinle and Moenkopi Formations. Paleozoic sedimentary rocks underlie these Mesozoic units.

Cretaceous geologic units that stratigraphically overlie the Burro Canyon Formation regionally (Mancos Shale and Dakota Sandstone) have been removed by erosion in the vicinity of the Mill. Thus, the lower Cretaceous Burro Canyon Formation (already present during the Mid-Tertiary Abajo igneous intrusive event) is directly overlain by Quaternary deposits at the Mill site. The Quaternary colluvial/alluvial sediments are typically coarse-grained deposits that contain little water. The Burro Canyon Formation is described as interbedded conglomerate and grayish-green shale with light-brown sandstone lenses deposited in a fluvial environment (Aubrey, 1989). The average thickness of the unit is approximately 75 feet (U.S. Department of Energy [“DOE”], 2004).

The Burro Canyon Formation hosts the uppermost occurrence of groundwater at the Mill site. Groundwater in this unit is perched (i.e., isolated from groundwater that occurs in geologic units that underlie the Burro Canyon Formation). Perched water is supported by the relatively impermeable, underlying, fine-grained Brushy Basin Member of the Morrison Formation. The permeability of the Burro Canyon Formation is generally low. Some conglomeratic zones may exist east to northeast of the tailings cells, potentially explaining a relatively continuous zone of higher permeability. The saturated thickness of the perched groundwater zone ranges from approximately 82 feet in the northeast portion of the Mill site to less than 5 feet in the southwest portion of the site (DOE, 2004). Groundwater isopleths, based on water level data collected in 2010, indicate that flow in the perched zone is generally from northeast to southwest, although in the eastern portion of the Mill site the gradient has a more southerly component.

Groundwater in the regional Entrada/Navajo aquifer is under artesian pressure (upward flow gradient), providing a hydrologic barrier to any potential seepage from overlying geologic units. Perched groundwater within the Burro Canyon Formation is characterized by low yields and is generally of poor quality, containing moderate to high concentrations of chloride, sulfate, and total dissolved solids (Hunt, 1996).

### **1.1.3 Summary of Previous Investigations**

Previous investigations with respect to the presence of nitrate in groundwater under the Mill include a Nitrate and Chloride Source Review Memo (Tischler, 2009), a Nitrate CIR (INTERA,



2009), an Initial Nitrate Monitoring Report (DUSA, 2009), and quarterly nitrate and chloride reporting to the DRC (DUSA, 2010-2011), and ongoing investigations into historic land uses, which have not yet been published.

The Nitrate and Chloride Source Review Memo (Tischler, 2009) identifies and discusses potential nitrate sources at the Mill site, including septic leach fields, municipal sewage plant discharge water used historically as Mill water makeup, livestock activities at the wildlife ponds and the Historic Pond, the former Fly Ash Pond, potential historic spills of ammonia-bearing process chemicals, a potential breach in the Mill circuit floor drains or tailings transfer lines, Mill laboratories, and a potential leak in the Mill's tailing cells. The Memo also discusses potential historical sources and offsite sources. The Memo concludes that the most likely source for nitrate and chloride comes from upgradient of the current plume in the municipal sewage plant discharge water used historically as Mill water makeup, from possible livestock activity near the Historic Pond, and possible influences from septic leach fields at the Site, in particular, the Semi Autogenous Grinding ("SAG") leach field and the Main Leach Field. Since the publication of the Nitrate and Chloride Source Review Memo, DUSA's understanding of historic land uses has continued to be updated through literature, Internet, and other land use studies, discussed below.

Land uses proximal to the Mill include farming, ranching, cattle grazing, and feed and grain silos. A further evaluation of historical land use in the vicinity of the Site will be performed to supplement the source evaluation (Source Review Report) (Tischler, 2009) that was included in the Nitrate CIR. This further evaluation is currently under way and will (a) identify areas that have been subject to agricultural activities, and (b) evaluate land-use practices that may have led to elevated levels of nitrate and other contaminants in groundwater. Objective (a) is also required to identify areas for sampling of buildup of atmospheric nitrogen, since the goal is to sample areas that have not been subject to human activities. This analysis includes evaluation of historical aerial photography, historical Landsat satellite imagery, and an Internet-based search of historic military activities in the region.

The Nitrate CIR (INTERA, 2009) also discusses the potential sources identified in the Source Review Memo (Tischler, 2009) and describes the sampling design and installation of 19 new wells used to characterize the nitrate and chloride plumes. The CIR characterizes the nitrate and chloride plumes with the data collected from existing and new monitoring wells at the Mill. The investigation concludes that the nitrate and chloride appear to originate from the same source, which is upgradient of the Mill property more than 1.2 miles from the Mill facilities and was not caused by or contributed to in any manner by Mill activities. "In the October 5, 2010 DRC NOTICE of Additional required Action ("NOTICE"), DRC determined that the 2009 CIR is incomplete, and considered the conclusion regarding the sole source of the nitrogen

contamination to be unsubstantiated with direct and reliable evidence. Furthermore, the NOTICE stated that DUSA has additionally identified several onsite sources which have a likelihood of being contributors to the contamination and have yet to be fully examined.”

Beginning with the third quarter of 2009, DUSA performed quarterly sampling and analysis of the new nitrate wells.

## **1.2 Project Description**

### **1.2.1 Project Objectives**

The purpose of this nitrate investigation is to quantify nitrate and chloride in the alluvial soil column in selected locations at the Site with the following goals:

1. To establish background concentrations of nitrate and chloride in the alluvial soil in the vicinity of the Mill.
2. To use the data generated by this investigation to test the “new theory” hypothesis that the nitrate contamination source is or could be caused by naturally occurring nitrate and chloride salt deposits located in the vadose zone near or beneath the Mill site, which have been mobilized by natural and/or artificial recharge (Walvoord, et al., 2003; Scanlon, et al., 2005; and others).
3. To use the data to test hypotheses regarding to what extent Mill-related sources contributed, if at all, to the groundwater nitrate plume.
4. To use the data to test hypotheses regarding to what extent present or historic non-Mill-related sources contributed, if at all, to the groundwater nitrate plume.

The nitrate investigation has been divided into five phases which are described in detail in Section 3.0.

### **1.2.2 Project Measurements**

Project measurements will include laboratory analysis of groundwater, soil, and rock chemistry, and Unified Soil Classification System (“USCS”) soil type classification made at the time of collection by visual-manual inspection as described in the *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) ASTM D 2488 – 09a* (ASTM, 2009). Note that the classifications presented in *ASTM D 2488 – 09a* are identical to the classifications presented in the *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) ASTM D 2487 – 10* (ASTM, 2010), but are derived from field observations rather than laboratory analysis. All rock core descriptions will be described using

the guidelines presented in the State of New York Department of Transportation Rock Core Evaluation Manual (NYDOT, 2006). Groundwater, soil, and rock samples will be submitted to the contract analytical laboratory (“Analytical Laboratory”) for analysis of the analytes specified in each of the activity-specific documents. The bedrock core analyses completed in Phase 3 of the investigation will be analyzed for Synthetic Precipitation Leaching Procedure (“SPLP”) using U.S. Environmental Protection agency (“EPA”) Method 1312. Method 1312 will produce a leachate which will be analyzed for nitrate, chloride, sulfate, and ammonia using EPA Method 353.2, EPA Method 300.0, and EPA Method 350.1 respectively.

### **1.3 Quality Objectives**

Specific quality objectives have been established for each of the data assessment parameters identified. These objectives are expressed as quantitative and qualitative statements concerning the type of data needed to support a decision, based on a specified level of uncertainty. The criteria (predetermined acceptance limits) are expressed as numerical values for laboratory analyses and field tests identified. Further discussion for the deep bedrock core sampling for each parameter and the rationale for its use is presented below.

#### **1.3.1 Precision**

Precision is defined as the measure of variability that exists between individual sample measurements of the same property under identical conditions. Precision is measured through the analysis of samples containing identical concentrations of the parameters of concern. For duplicate measurements, precision is expressed as the relative percent difference (“RPD”) of a data pair and will be calculated by the following equation:

$$RPD = [(A-B)/\{(A+B)/2\}] \times 100$$

Where A (original) and B (duplicate) are the reported concentration for field duplicate samples analyses (or, in the case of analyses performed by the Analytical Laboratory, the percent recoveries for matrix spike and matrix spike duplicate samples) (EPA, 1994a, SW-846, Chapter 1, Section 5.0, page 28).

#### **1.3.2 Accuracy**

Accuracy is defined as a measure of bias in a system or as the degree of agreement between a measured value and a known value. The accuracy of laboratory analyses is evaluated based on analyzing standards of known concentration both before and during analysis. Accuracy will be evaluated by the following equation (EPA, 1994a, SW-846, Chapter 1, Section 5.0, page 24):

$$\% \text{ Recovery} = (|A-B|/C) \times 100$$

Where:

A = the concentration of analyte in a sample

B = the concentration of analyte in an unspiked sample

C = the concentration of spike added

### **1.3.3 Representativeness**

Representativeness is defined as the degree to which a set of data accurately represents the characteristics of a population, parameter, conditions at a sampling point, or an environmental condition. Representativeness is controlled by performing all sampling in compliance with this Plan.

### **1.3.4 Completeness**

Completeness refers to the amount of valid data obtained from a measurement system in reference to the amount that could be obtained under ideal conditions. Laboratory completeness is a measure of the number of samples submitted for analysis compared to the number of analyses found acceptable after review of the analytical data. Completeness will be calculated by the following equation:

$$\text{Completeness} = (\text{Number of valid data points} / \text{total number of measurements}) \times 100$$

Where the number of valid data points is the total number of valid analytical measurements based on the precision, accuracy, and holding time evaluation.

Completeness is determined at the conclusion of the data validation.

### **1.3.5 Comparability**

Comparability expresses the confidence with which one data set can be compared with another. Comparability of data will be achieved by consistently following standard field and laboratory procedures and by using standard measurement units to report analytical data.

### **1.3.6 Detection and Quantitation Limits**

The method detection limit (“MDL”) is the minimum concentration of an analyte that can be reliably distinguished from background for a specific analytical method. The quantitation limit represents the lowest concentration of an analyte that can be accurately and reproducibly quantified in a sample matrix. Project-required reporting limits are minimum quantitation limits for specific analytical methods and sample matrices that are typically several times the MDL to allow for matrix effects.



## **1.4 Project Organization**

### **1.4.1 Functional Groups**

This Plan specifies roles for a Quality Assurance (“QA”) Manager as well as representatives of three different functional groups: the data requestors/users; the data generators, and the data reviewers/approvers. The roles and responsibilities of these representatives are described below.

### **1.4.2 Overall Responsibility for the QA/QC Program**

The overall responsibility for ensuring that the Quality Assurance/Quality Control (“QA/QC”) measures are properly employed is the responsibility of the QA Manager. The QA Manager is typically not directly involved in the data generation (i.e., sampling or analysis) activities. The QA Manager is a qualified person designated by DUSA corporate management.

### **1.4.3 Data Requestors/Users**

The generation of data that meets the objectives of this Plan is necessary for management to make informed decisions in order to quantify nitrate and chloride in the bedrock in selected locations at the Site. The data generated by this investigation will be used to test hypotheses regarding potential sources of nitrate and chloride contamination, including naturally-occurring sources. Accordingly, the data requestors/users (the “Data Users”) are DUSA’s corporate management and regulatory authorities. The data quality objectives (“DQOs”) required for any sampling event, such as acceptable minimum detection limits, are specified in this Plan.

### **1.4.4 Data Generators**

The individuals who carry out the sampling and analysis activities at the request of the Data Users are the data generators. Sample collection, record keeping, and QA/QC activities are conducted by one or more sampling and QC/data monitors (each a “Sampling and QC Monitor”). The Sampling and QC Monitors perform all field sampling activities, collect all field QC samples, and perform all data recording and chain of custody (“COC”) activities in accordance with this Plan. Data generation at the Analytical Laboratory utilized by the Mill to analyze the environmental samples is performed by or under an employee or agent (the “Analysis Monitor”) of the Analytical Laboratory, in accordance with specific the requirements of the Analytical Laboratory’s own QA/QC program.

The responsibilities of the data generators are outlined below.

#### ***1.4.4.1 Sampling and QC Monitors***

The Sampling and QC Monitors are responsible for field activities. These include:

- a. Ensuring that samples are collected, preserved, and transported as specified in the Plan,
- b. Checking that all sample documentation (labels, field data worksheets, COC records, packing lists) is correct and transmitting that information, along with the samples, to the Analytical Laboratory in accordance with this Plan,
- c. Maintaining records of all samples, tracking those samples through subsequent processing and analysis, and, where applicable, appropriately disposing of those samples at the conclusion of the program'
- d. Preparing QC samples for field sample collection during the sampling event,
- e. Preparing QC and sample data for review by the QA Manager,
- f. Preparing QC and sample data for reporting and entry into a computer data base, where appropriate.

INTERA Incorporated's ("INTERA's") field manager, Rob Sengebush, will serve as Sampling and QC Monitor for Phase 3.

#### **1.4.4.2 Analysis Monitor**

The Analysis Monitor is responsible for QA/QC activities at the Analytical Laboratory. These include:

- a. Training and qualifying personnel in specified Analytical Laboratory QC and analytical procedures prior to receiving samples.
- b. Receiving samples from the field and verifying that incoming samples correspond to the packing list or COC sheet.
- c. Verifying that Analytical Laboratory QC and analytical procedures meet the Analytical Laboratory's QA/QC program, and are in accordance with the requirements for maintaining National Environmental Laboratory Accreditation Program ("NELAP") and/or National Voluntary Laboratory Accreditation Program ("NAVLAP") certification.

#### **1.4.4.3 Data Reviewers/Approvers**

The QA Manager has broad authority to approve or disapprove project plans, specific analyses, and final reports. In general, the QA Manager is responsible for reviewing and advising on all aspects of QA/QC, including:

- a. Ensuring that the data produced by the data generators meet the specifications set out in this Plan.



- b. Making on-site evaluations and submitting audit samples to assist in reviewing QA/QC procedures.
- c. Determining (with the Sampling and QC Monitor and Analysis Monitor) appropriate sampling equipment and sample containers, in accordance with this Plan, to minimize contamination.
- d. Supervising all QA/QC measures to assure proper adherence to this Plan and determining corrective measures to be taken when deviations from this Plan occur.

The QA Manager may delegate certain of these responsibilities to one or more Sampling and QC Monitors or to other qualified personnel.

## **1.5 Special Training and Certification**

All soil and rock core logging will be overseen or conducted by a State of Utah Certified Professional Geologist (“PG”), using the ASTM Standard Practice for Description and Identification of Soils (visual-manual procedure) and the NYDOT Rock Core Evaluation Manual.

Site-specific training for all field personnel will be completed as required by Mill procedures and will be conducted by Mill personnel.

## **1.6 Documents and Records**

### **1.6.1 Field Documentation**

Field documentation will consist of, but not be limited to, detailed field note books, COC forms, and digital photographs. In addition, the locations of borings and other field activities will be recorded using a hand held global positioning system (“GPS”) instrument. Soil and rock core logging and details from the boring such as sampling intervals and sample location will be recorded on a field boring log. Information from the field boring log will be used to create a final boring log. Copies of these forms are included in Appendix B. Completed forms will be included in the report. DRC requested the use of a boring log that matched WMMW-16. The log that will be used is located in Appendix B and contains the same relevant information fields. The boring log form does not include gamma or neutron logging fields or well completion fields, since those elements are not part of this investigation.

### **1.6.2 Reports Generated**

Upon completion of the field work and laboratory analysis, a Report describing the results and results of the QA/QC checks will be generated and submitted to the DRC.



## 2.0 CONCEPTUAL SITE MODEL

This CSM follows the *ASTM E 1698 Standard Guidance for Development of a Conceptual Site Model* (Appendix A).

### 2.1 Site Summary

DUSA's White Mesa property hosts an active uranium mill that is currently processing uranium ore. Concentrations of nitrate as nitrogen have exceeded the State of Utah's water quality standard of 10 mg/L in certain monitoring wells at the Mill site. Typically, samples from wells that have exceeded the nitrate standard also have higher concentrations of chloride than samples from other wells at the Site.

### 2.2 Site Description

The purpose of this section is to identify the constituents of concern, establish background concentrations of those constituents, discuss potential source locations (including decisions and data needs for determining if a source is viable or can and should be eliminated), and discuss timing and duration of events required to account for the constituent mass observed in groundwater.

#### 2.2.1 Identify Contaminants

DUSA received a *Request for Voluntary Plan and Schedule to Investigate and Remediate Nitrate Contamination at the White Mesa Mill site*, near Blanding, Utah. The Request was dated September 30, 2008, and was received from the Co-Executive Secretary of the Utah Water Quality Board, of the UDEQ. In the Request, the Co-Executive Secretary noted that groundwater nitrate levels have exceeded the State water quality standard of 10 mg/L in certain monitoring wells at the Mill Site. Figure 1 is a regional map showing the location of the Mill Site. Subsequently, in a letter dated December 1, 2009, UDEQ noted that elevated chloride concentrations exist, apparently coincident with elevated nitrate concentrations. Therefore, nitrate and chloride are considered to be constituents of concern for this investigation. Table 2 presents the first quarter 2011 chloride and nitrate concentrations in groundwater.

#### 2.2.2 Establishing Background Concentrations of Contaminants

Installation of 19 new monitoring wells has allowed the nitrate and chloride plumes to be fully bounded at the Site (Figures 2 and 3). On Figure 2, nitrate iso-contours start at 5 mg/L because that value appears to separate the plume from background. However, as evident from Figure 2, the 10 mg/L contour that defines the groundwater compliance limit for nitrate at a number of wells at the Site as specified in GWDP No. UGW370004 is completely closed and defined at the

Site. Per discussions with UDEQ, the nitrate plume is considered to have been bounded when the concentrations of nitrate in monitoring wells upgradient, downgradient, and in both crossgradient directions are less than 10 mg/L. There is no groundwater standard for chloride, but the iso-contours start at 100 mg/L because that value appears to separate the plume from background.

A feature of the plume maps is that the nitrate (Figure 2) and chloride plumes (Figure 3) are co-located geographically. Almost all locations that have elevated nitrate concentrations also have elevated chloride concentrations, implying that the nitrate and chloride impacts to groundwater had the same source. However, the nitrate plume shows a lobe extending to the southeast coincident with the chloroform plume (Figure 4), but the chloride plume does not. This indicates that elevated nitrate was present in the chloroform plume but chloride was not. The chloride plume demonstrates that there are two distinct plumes; a nitrate-chloride plume and the chloroform plume with distinctly different sources.

### **2.2.3 Source Locations, Boundaries, and Volumes**

Potential on Site sources of nitrate and chloride addressed in the CIR (INTERA, 2009) include:

- The septic leach fields at the Mill site.
- The municipal sewage plant discharge water used historically as Mill water makeup.
- Livestock activities at the wildlife ponds.
- Livestock activities at the Historic Pond.
- Agricultural activities.
- The former Fly Ash Pond.
- Potential historic spills of ammonia-bearing and/or chloride-bearing process chemicals.
- A potential breach in the Mill circuit floor drains or tailings transfer lines.
- A potential leak in the Mill's tailings cells.<sup>1</sup>

Subsequent to publication of the CIR, other potential sources have been identified. One potential source is a natural nitrate reservoir. Such concentrations or “reservoirs” of nitrate and chloride have been identified in the scientific literature (Walvoord, et al., 2003; Scanlon, et al., 2005; and others). “Unsaturated-zone chloride and nitrate profiles archive changes in recharge related to recent conversion of rangeland to agricultural ecosystems. Increased recharge associated with dryland as well as irrigated agriculture can lead to degradation of groundwater quality because of

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<sup>1</sup> Based on extensive analysis in the background report, age dating of the groundwater reported in the University of Utah Report (Hurst and Solomon 2008), mass balance analysis in the original CIR and the fact that the presence of the nitrate plume is upgradient, the tailings cells are not considered a potential source and will not be studied specifically in Phases 1 through 5.

leaching of salts that have been accumulating in the unsaturated zone for thousands of years prior to cultivation, because of application of fertilizers, and, in irrigated areas, because of evapo-concentration of applied groundwater. In the SHP (southern high plains), median groundwater nitrate-N concentrations increased by 221% beneath irrigated areas and 163% beneath dryland areas, reflecting LU/LC-induced (land use/land cover) contamination of groundwater.” (Scanlon, et al., 2005).

A second potential source that has been identified is military use of the Mill site as part of the Blanding Pershing Missile Launch Complex. Pershing missiles were tested by launching them from the Blanding site to a target at the White Sands, New Mexico, Missile Base. The Blanding operation was described as a “shoot and scoot” operation in which mobile launch vehicles would deploy to Black Mesa, adjacent to the White Mesa Bivouac site, fire their missiles and “scoot” back to the bivouac site. One possible scenario that may have resulted in nitrate and chloride contamination at White Mesa is as follows:

- The missile firing at Black Mesa caused clouds of oxidized constituents from burning of rocket motors to “exhaust” on the launch vehicles.
- Launch vehicles “scooted” back to White Mesa where they needed to be cleaned prior to the next launch.
- The military required a water source with which to clean the launch vehicles and several ponds were available at the White Mesa site (notably the Historic Pond which was highly developed at the time – see 1968 aerial photograph with nitrate plume overlain [Figure 5]).
- Cleaning the launch vehicles involved washing them with pond water and letting that water drain directly to the soil near the pond where it infiltrated to groundwater, or returning it to the pond or other containment where it infiltrated to groundwater.

#### **2.2.4 Time of Initiation, Duration, and Rate of Contaminant Release**

Any potential source of nitrate and chloride must meet three necessary conditions to have caused the mass of nitrate and chloride observed in the groundwater plume beneath the Mill site. First, the potential source must have a means to reach groundwater, such as sufficient water or other fluid to travel through the vadose zone. Second, there must have been sufficient nitrate and chloride in the source to account for the nitrate and chloride mass observed in the groundwater. Third, there must have been sufficient time to travel from the source through the vadose zone and then downgradient in groundwater to account for the current distribution of the nitrate/chloride plume.

Travel times through the vadose zone depend on the amount of head available to drive them but have been calculated to be on the order of 18-20 feet per year (“ft/yr”) for a pond-like source that maintains a constant head (HGC, 2009). Thus, it would take approximately two to three years for nitrate and chloride from a pond-like source to reach groundwater, assuming groundwater is 40-60 feet below ground surface (“bgs”).

Perched zone pore velocities beneath and immediately upgradient of the tailings cells were calculated in HGC, (2005), based on data from wells MW-23, MW-25, MW-27, MW-28, MW-29, MW-30, MW-31, MW-32, TW4-20, TW4-21, and TW4-22. Estimated hydraulic conductivities range from approximately  $2 \times 10^{-7}$  to  $1 \times 10^{-4}$  cubic meters/second (“cm/s”) and yield a geometric average of approximately  $3 \times 10^{-5}$  cm/s or 31 ft/yr. Using hydraulic gradients in the vicinity of each well, the estimated conductivity at each well, and an effective porosity of 0.18, the estimated pore velocities ranged from 49.5 ft/yr at TW4-21, to 0.010 ft/yr at MW-23, and have a geometric average of approximately 4.5 ft/yr. Hydraulic gradients in the vicinity of most of these wells have not changed significantly since 2005, nor have the estimated pore velocities.

The current locus of highest nitrate concentrations in the plume is monitor well TWN-2, approximately 2,850 feet upgradient of monitor well MW-31 where nitrate concentrations have been stable since sampling began at that location in 2005. The average nitrate concentration in samples from MW-31 is 23 mg/L with a standard deviation of 3 mg/L. Using the highest of the estimated range of pore velocities, 49.5 ft/yr, it would have taken a minimum of 57 years for nitrate to travel from TWN-2 to MW-31 in groundwater. If the Historic Pond had maintained a higher gradient in the vicinity of TWN-2 as was likely (see Figure 5 – current nitrate plume and wells overlain on 1968 aerial photograph), travel times may have been somewhat faster. However, the White Mesa Mill has been present at the Mill site for only 31 years and there has been no pond at that location since then.

### **2.3 Migration Pathway Descriptions**

A migration pathway is defined as the course through which contaminants in the environment may move away from the source(s) to potential environmental receptors, creating a potential exposure pathway. An exposure pathway is incomplete if any of the following elements are missing: 1) a mechanism of contaminant release from primary or secondary sources, 2) a transport medium if potential environmental receptors are not located at the source, and 3) a point of potential contact of environmental receptors with the contaminated medium. As discussed in Section 2.4, for the Mill nitrate and chloride, there is no contact with human or ecological receptors.

Thirty one (31) potential sources were identified in Section 2.3.3.1. Due to the large number of potential sources, similar sources will be grouped together for purposes of discussion. The first group consists of potential process-related sources such as on-site leach fields, Mill circuit sources, and chemical storage facilities. The second group contains ponds and pond-like features including disturbances observed on aerial photographs near far upgradient and far downgradient wells that contain elevated nitrate and chloride. This second group of sources also includes the locations of potential impact by military or agricultural uses of the Mill site, described above. The third group of sources consists of the possibility that a natural nitrate reservoir existed in the vadose zone across the Mill site prior to modern land use and that the change in land use mobilized that vadose zone reservoir and transported it to groundwater.

Figure 6 is a map showing the location of structural cross sections across the Mill site. Figures 7 through 9 are structural cross sections with the locations of potential sources plotted on them. Note that the vertical exaggeration of the cross sections ranges from 3:1 to 20:1, which magnifies the apparent slopes of the contacts depicted in the diagrams. Figure 10 is a wire frame diagram of the elevation of the bedrock surface beneath the alluvium, the distribution and thickness of the Mancos Shale at the site, and the location of structural cross sections. The distribution of the Mancos shown in Figure 10 coincides with the area(s) where the Mancos is estimated to be at least 5 feet thick. Figures 11 through 14 are schematic diagrams depicting pathways for each group of sources. There are two schematic diagrams for potential process related sources, one depicting a thick section of Mancos Shale beneath the source and one depicting a thin section, due to the importance of that low permeability unit in the time and or pathway from the surface to groundwater.

Figure 10 shows a paleoridge of Mancos Shale in the vicinity of the Mill site that would likely impact seepage from potential sources in two ways: 1) the thicker the Mancos, the slower the average rate of downward movement due to the relatively low permeability of the Mancos, and the greater the potential for lateral spreading; and 2) the steeper the slope of the alluvium/Mancos contact, the greater the potential for deflection of seepage downslope. Furthermore, should a mound develop beneath a seepage source, lateral flow from the center of the mound could cause seepage to move laterally in all directions including upslope. With regard to the potential for downslope movement at the margins of the Mancos paleoridge, seepage from potential process-related sources such as the scale house leach field, may move in an easterly or southerly direction when it encounters the alluvial-Mancos interface, whereas seepage from potential process-related sources such as the SAG leach field on the other side of the paleoridge may be constrained to move in a westerly direction. Note that the thickness of the Mancos Shale beneath the location of the western half of the Historic Pond is less than 5 feet and is not expected to be a significant barrier.



Once seepage migrates into the Dakota Sandstone/Burro Canyon Formation, the relatively thin, sub-horizontal, discontinuous, interbedded shale and conglomeratic zones depicted in the cross sections are expected to exert an influence on the movement of the seepage. The impact of the interbedded shales is expected to be retardation and lateral spreading of seepage because of the relatively low permeability of the shales. The impact of the interbedded conglomeratic zones is expected to be mainly lateral spreading of the seepage. Hydraulic testing at the Mill site indicates that conglomeratic zones may or may not have higher permeability than surrounding sandstones, and suggests that the degree of cementation is an important control in the permeability of these materials. Overall, the Mancos Shale, where thicker than about 5 feet, is expected to exert more influence on seepage than the sub-horizontal, relatively discontinuous shale and conglomeratic zones present in the Dakota Sandstone and Burro Canyon Formations.

### **2.3.1 Soil and bedrock**

Assuming that the nitrate and chloride sources originated at the ground surface or within the alluvial soil (natural nitrate reservoir), alluvial soils and bedrock at the Mill site would be a potential pathway for contaminant migration. A soil and bedrock investigation is ongoing in Phases 1 and 3 of this investigation and early indications are that there is nitrate and chloride presence connected with this source.

### **2.3.2 Groundwater**

Groundwater flow at the Mill site is generally to the southwest toward discharge points such as Ruin Springs. Groundwater is a potential pathway for contaminant migration. It has been estimated that travel times between the downgradient edge of Tailings Impoundment 3 and Ruin Spring (the nearest location of a potential receptor), a distance of 10,000 feet, would be between 3,300 to 14,000 years.

### **2.3.3 Specific Source Locations and Data Needs**

This section evaluates each potential source location or feature and states the hypothesis that describes the potential pathway to groundwater that might cause observed concentrations of nitrate and chloride in groundwater. The decision that is required to determine whether any hypothesis is correct is stated explicitly. Data needs, data gaps, and data that will be collected for each potential source are also described. For the purpose of developing the logic diagrams (Figures 15-18) and the CSM diagram (Figure 19), potential source locations can be classified by type: potential mill-process-related sources, potential pond-related sources (Fly Ash Pond, Historic Pond, wildlife pond, Lawzy Lake, and other pond-like sources), and the potential natural nitrate/chloride reservoir source. Please refer to the logic diagrams and the CSM for each group of sources.





The following section will discuss each source and the decision criteria. The terms as defined below are used in the discussions in Section 2.3.3.1.

### 1) Hydrogeologic Study

Denison will perform a hydrogeologic evaluation (the “Hydrogeologic Evaluation”) of each potential source to determine if any potential contamination from the potential source could have contributed to the plume. The Hydrogeologic Evaluation will evaluate the vertical permeability of soil and bedrock beneath the surface area from available lithologic logs of soil and bedrock (including logs from Phase 1 and Phase 3 activities). The Hydrogeologic Evaluation will also evaluate the permeabilities within the perched aquifer and rates of groundwater movement in that aquifer between each potential source to the upgradient and downgradient edges of the plume, as appropriate, based on existing permeability information. To the extent data is available, the Hydrogeologic Evaluation will also consider elevations of the alluvial/bedrock interface and other geologic information if appropriate. The Hydrogeologic Evaluation will be submitted to the Executive Secretary for review and comment on or before December 16, 2011.

### 2) Isotopic Analysis

Phase 4 of the investigation contemplates the performance of a stable isotopes analysis of groundwater, with details to be provided later, and Phase 5 contemplates the performance of isotopic soil sampling and analysis, if needed. These Phase 4 and Phase 5 analyses, which may include age dating of water, are referred to in this Plan as the “Isotopic Analysis.” The purpose of the Isotopic Analysis is to determine the isotopic fingerprint (the “Isotopic Fingerprint”) of the plume and of each source, if required. Each Isotopic Fingerprint may be based in part on stable isotope analyses and in part on age dating of water. The details of the Isotopic Analysis and the factors to be considered in developing each Isotopic Fingerprint will be determined, in connection with the review and Executive Secretary approval of more specific plans for each of Phase 4 and Phase 5, which will be submitted at later dates. The terms “statistically comparable” and “uniquely identifiable” will be defined in the QAPs for these phases.

### 3) Weight of Evidence

In those circumstances where a potential source cannot be dismissed as not contributing to the plume or included as contributing to the plume based on definitive criteria specified in Section 2.3.3.1, it will be necessary to make a determination whether or not to dismiss or include the potential source based on the existing weight of evidence (the “Weight of Evidence”). For the purposes of this Plan, a Weight of Evidence analysis means an analysis that weighs the preponderance of all relevant available information to arrive at a decision. It is expected that such an analysis will involve evaluating several different lines of evidence, each of which may not be conclusive by itself in arriving at the decision, but which together can lead to the decision.



#### 4) Potential and Possible Sources

In the discussion in Section 2.3.3.1 below, all sources to be evaluated under this Plan are referred to as “potential sources”. Potential sources that cannot be definitively rejected or included based on the criteria in Section 2.3.3.1, and must undergo a Weight of Evidence analysis, are referred to in Section 2.3.3.1 as “possible sources”.

##### ***2.3.3.1 Potential Nitrate/Chloride Source Locations:***

Potential Nitrate Source Locations:

1. Main leach field (also known as Leach Field east of Scalehouse, 1985 to present)
2. Sewage vault/lift station (currently active)
3. Scale house leach field, (also known as Leach Field south of Scalehouse, 1977-1979)
4. Former office leach field
5. Ammonia tanks
6. SAG leach field (Leach Field north of mill building, 1998 to 2009)
7. Cell 1 leach field (Leach Field east of Cell #1, up to 1985)
8. Fly ash pond
9. Sodium Chlorate Tanks (as a potential chloride source)
10. Ammonium sulfate crystal tanks
11. Lawzy sump
12. Lawzy Lake
13. Former vault/lift station (to Former Office Leach Field) (1992 to 2009)
14. Truck shop leach field (1979-1985)
15. New Counter Current Decant/Solvent Extraction (CCD/SX) leach field (currently active)
16. Historical Pond (two hypotheses, 16-1 and 16-2)
17. Wildlife Pond (two hypotheses, 17-1 and 17-2)
18. CCD (included inadvertently and eliminated as discussed below)
19. YC Precip Mini Lab
20. V2O5 Mini Lab & V2O5 Precip (two hypotheses, 20-1 and 20-2)

21. SX Mini Lab
22. Chem Lab
23. Met Lab
24. V2O5 Oxidation Tanks (two hypotheses, 24-1 and 24-2)
25. Natural Nitrate Reservoir
  
- 26 – 32 Other Ponds or Pond-like Sources

**1. Main leach field (also known as Leach Field east of Scalehouse, 1985 to present)**

Hypothesis 1: Nitrates and chlorides associated with sewage may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service (1985) for detectable levels of constituents from this potential source to reach groundwater and if so to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct

coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of these constituents are present above background in alluvium and bedrock down to groundwater, this can be eliminated as a potential source. If any of those constituents are present above background, conduct mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## **2. Sewage vault/lift station (currently active)**

Hypothesis 2: Nitrates and chlorides associated with sewage may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach groundwater and if so to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of these constituents are present above background in alluvium and bedrock down to groundwater, this can be eliminated as a potential source. If any of those constituents are present above background, conduct mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct Isotopic Analysis on samples of bedrock core samples and of



groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

### **3. Scale house leach field, (also known as Leach Field south of Scalehouse, 1977-1979)**

Hypothesis 3: Nitrates and chlorides associated with sewage may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service (1977) for detectable levels of constituents from this potential source to reach groundwater and if so to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of these constituents are present above background in alluvium and bedrock down to groundwater, this can be eliminated as a potential source. If any of those constituents are present above background, conduct mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct Isotopic Analysis on samples of bedrock core samples and of



groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.



#### **4. Former office leach field**

Hypothesis 4: Nitrates and chlorides associated with sewage and or laboratory wastes (prior to 1981) may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service (1979) for detectable levels of constituents from this potential source to reach groundwater and if so to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of these constituents are present above background in alluvium and bedrock down to groundwater, this can be eliminated as a potential source. If any of those constituents are present above background, conduct mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed

in the plume, conduct Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## 5. Ammonia tanks

Hypothesis 5: Ammonium may have leaked from the tanks through the alluvial soil and bedrock to groundwater to the plume and was oxidized from ammonia to nitrate. Nitrogen in the ammonia tanks is solely in the ammonium ( $\text{NH}_4^+$ ) form. Ammonium cations are typically strongly retarded in a soil water system and likely would not travel through the alluvium and bedrock in the ammonia form. It would have to be converted to the nitrate in a process above the alluvium or in the near subsurface. That is, there would have to be a source of oxygenated water or other oxidizing fluid (such as a pond) immediately below or adjacent to the ammonium tanks, and it would have to create sufficient head to drive nitrated water all the way to groundwater. If this were the case, nitrogen would be detected as the nitrate (not ammonia) form continuously through the alluvium and the bedrock. The ammonia tanks are not a source of chloride.

Necessary Conditions: a) Is there evidence of nitrate concentration in the vadose zone beneath this feature? b) Is nitrate present in the alluvium and bedrock cores below this feature? c) Is there an oxidation source adjacent to or beneath the tanks sufficient to convert ammonia to nitrate? d) Was there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? e) Did this potential source have sufficient mass to have contributed measurably to nitrate observed in the plume? f) Has there been sufficient time since this potential source was put into service (circa 1980) for detectable levels of constituents from this potential source to reach the plume? Note that there would need to be sufficient time for any ammonium to be oxidized to nitrate, for nitrate to be transported to groundwater, and then be transported to the downgradient edge of the plume. and g) Since this potential source is not associated with any chloride, is there a plausible alternate source for chloride? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater beneath this feature. Possible need for Isotopic Analysis Data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Need ammonium and dissolved oxygen from adjacent monitor wells. Possible need for Isotopic Analysis Data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If nitrate is not present above background in the alluvium and bedrock down to groundwater, this can be eliminated as a potential source. If nitrate is present above background, conduct mass balance calculation to determine if the concentrations in alluvium and bedrock are sufficient to have contributed to nitrate observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate observed in groundwater, conduct an Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source of nitrate has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source of nitrate has been identified. If a possible source of nitrate has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed nitrate to the plume. If the possible source has been determined to have contributed nitrate to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed nitrate to the plume.

## **6. SAG leach field (Leach Field north of mill building, 1998 to 2009)**

Hypothesis 6: Nitrates and chlorides associated with sewage may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service (1998) for detectable levels of constituents from this potential source to reach groundwater and if so to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of these constituents are present above background in alluvium and bedrock down to groundwater, this can be eliminated as a potential source. If any of those constituents are present above background, conduct mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct Isotopic Analysis on samples of bedrock core samples and of

groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## **7. Cell 1 leach field (Leach Field east of Cell #1, 1979 to 1985)**

Hypothesis 7: Nitrates and chlorides associated with sewage may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service (1979) for detectable levels of constituents from this potential source to reach groundwater and if so to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of these constituents are present above background in alluvium and bedrock down to groundwater, this can be eliminated as a potential source. If any of those constituents are present above background, conduct mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct Isotopic Analysis on samples of bedrock core samples and of



groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.



## 8. Fly ash pond

Hypothesis 8: Nitrates and chlorides associated with coal and coal ash, and potential runoff from site processes could have ponded and may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. The pond received coal flyash, containing oxidized nitrogen (the nitrate not ammonium form) sporadically from 1980 to 1989. The pond could potentially have received some washwaters containing ammonium nitrogen from the vanadium circuit from 1980 through the present.

Necessary Conditions: a) Is there evidence of nitrate, and/or ammonium, and chloride concentrations in the vadose zone beneath this feature? c) If ammonium is present, is there an oxidation source adjacent to or beneath the tanks sufficient to convert ammonium to nitrate? d) Was there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? e) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? and d) Has there been sufficient time since this potential source was put into service (circa 1981) for detectable levels of constituents from this potential source to reach groundwater and if so to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). If only ammonium nitrogen is present above background, identify whether there is a sufficient oxidation source to convert

ammonia to nitrate. Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of those constituents are present above background, then this can be eliminated as a potential source. If any of those constituents are present above background, conduct mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in groundwater. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in groundwater, conduct isotopic analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the isotopic fingerprint of the core sample is statistically comparable to the isotopic fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## 9. Sodium chlorate tanks

Hypothesis 9: Chlorides associated with sodium chlorate storage may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. If this were an appreciable source, it would also be associated with measurably elevated sodium in soil and/or groundwater adjacent to and beneath the tank area. Sodium chlorate is a not a source of nitrogen atoms and has been retained for evaluation as a chloride source.

Necessary Conditions: a) Is there evidence of chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service (1979) for detectable levels of constituents from this potential source to reach groundwater? Since this source is not associated with any nitrate, is there a plausible alternate source for nitrate? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of chloride in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need chloride concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for chloride concentration data. If chloride is present above background, conduct a mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to chloride observed in the plume. If chloride is not present above background or the quantities are not sufficient, this can be eliminated as a potential source. If the concentrations in bedrock are sufficient to have contributed to chloride observed in the

plume, conduct Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the chloride source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed chloride to the plume. If the possible source has been determined to have contributed chloride to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed chloride to the plume.

## 10. Ammonium sulfate crystal tanks

Hypothesis 10: Ammonium sulfate crystals may have spilled around the ammonium sulfate crystal tanks. Over time and with rain the ammonium converts to nitrate and may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. Nitrogen in the ammonium sulfate tanks is solely in the ammonium ( $\text{NH}_4^+$ ) form. Ammonium cations are typically strongly retarded in a soil water system and likely would not travel through the alluvium and bedrock in the ammonia form. It would have to be converted to the nitrate from a process above the alluvium or in the near subsurface. That is, there would have to be a source of oxygenated water or other oxidizing fluid (such as a pond) immediately below or adjacent to the ammonium sulfate tanks, and it would have to create sufficient head to drive nitrated water all the way to groundwater. If this were the case, nitrogen would be detected as the nitrate (not ammonium) form continuously through the alluvium and the bedrock. The ammonium sulfate tanks are not a source of chloride. A combination of elevated nitrate and sulfate in the soil adjacent to or beneath the tanks or in the groundwater near the tanks would support this as a possible source.

Necessary Conditions: a) Is there evidence of nitrate concentration in the vadose zone beneath this feature? b) Are nitrate and sulfate both elevated in the alluvium and bedrock cores below this feature? c) Is there an oxidation source adjacent to or beneath the tanks sufficient to convert ammonia to nitrogen? d) was there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? e) Did this source have sufficient mass to have contributed measurably to nitrate observed in the plume? f) Has there been sufficient time since this source was put into service (circa 1980) for detectable levels of constituents from this potential source to reach groundwater? Note that there would need to be sufficient time for any ammonium to be oxidized to nitrate, for nitrate to be transported to groundwater, and then be transported to the downgradient edge of the plume. and g) Since this potential source is not associated with any chloride, is there a plausible alternate source for chloride? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction

potential in the groundwater beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Need ammonium and dissolved oxygen from adjacent monitor wells. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, sulfate, and ammonium concentration data. If nitrate is not present above background in alluvium and bedrock down to groundwater, this can be eliminated as a potential source. If nitrate is present above background, conduct mass balance calculation to determine if the concentrations in alluvium and bedrock are sufficient to have contributed to nitrate observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate observed in plume, conduct Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic fingerprint is uniquely identifiable to the potential source, then the source of nitrate has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the isotopic fingerprint of groundwater from the plume, a possible source of nitrate has been identified. If a possible source of nitrate has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed nitrate to the plume. If the possible source has been determined to have contributed nitrate to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed nitrate to the plume.

## 11. Lawzy sump

Hypothesis 11: This unlined sump was used to pump water from Lawzy Lake (which was filled from the frog pond that may have contained water from the municipal water treatment plant located north of the Mill) to mill processes. Nitrate and chloride laden water from the sump may have leached through alluvial soil and bedrock to groundwater and contributed to the plume. While not always present in soils and groundwater associated with cattle wastes and byproducts, cryptosporidium is frequently present in livestock and animal sources, not human or industrial (chemical) sources. If detected along with elevated nitrate, the presence of cryptosporidium would help to earmark the source of nitrate as being of livestock/animal origin.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in groundwater? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, ammonium and cryptosporidium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct a coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of those constituents are

present above background then this can be eliminated as a potential source. If any of those constituents are present above background, conduct a mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct an Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the isotopic fingerprint of groundwater from the plume, a possible source has been identified. Further, if cryptosporidium is present along with elevated nitrate in water or alluvium, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.



## 12. Lawzy Lake

Hypothesis 12: Nitrate and chloride laden water from Lawzy Lake (which was filled from the frog pond, which may have contained water from the municipal water treatment plant located north of the Mill) may have leached through alluvial soil and bedrock to groundwater and contributed to the plume. While not always present in soils and groundwater associated with cattle wastes and byproducts, cryptosporidium is frequently present in livestock and animal sources, not human or industrial (chemical) sources. If detected along with elevated nitrate, the presence of cryptosporidium would help to earmark the source of nitrate as being of livestock/animal origin.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct a coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of those constituents are observed above background, then this is eliminated as a potential source. If any of those

constituents are present above background, conduct a mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct an Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. Further, if cryptosporidium is present along with elevated nitrate in water or alluvium, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

### **13. Former vault/lift station (to Former Office Leach Field) (1992 to 2009)**

Hypothesis 13: Nitrates and chlorides associated with sewage may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service (1992) for detectable levels of constituents from this potential source to reach groundwater and if so to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of these constituents are present above background in alluvium and bedrock down to groundwater, this can be eliminated as a potential source. If any of those constituents are present above background, conduct mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct Isotopic Analysis on samples of bedrock core samples and of



groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

#### **14. Truck shop leach field (1979-1985)**

Hypothesis 14: Nitrates and chlorides associated with sewage may have leached through alluvial soil and bedrock to groundwater and contributed to the plume.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service (1979) for detectable levels of constituents from this potential source to reach groundwater and if so to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of these constituents are present above background in alluvium and bedrock down to groundwater, this can be eliminated as a potential source. If any of those constituents are present above background, conduct mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct Isotopic Analysis on samples of bedrock core samples and of

groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## **15. New Counter Current Decant/Solvent Extraction (CCD/SX) leach field (currently active)**

Hypothesis 15: Nitrates and chlorides associated with sewage may have leached through alluvial soil and bedrock to groundwater and contributed to the plume. Note: This leach field did not yet exist when the nitrate plume was identified.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service (2009) for detectable levels of constituents from this potential source to reach groundwater and if so to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of these constituents are present above background in alluvium and bedrock down to groundwater, this can be eliminated as a potential source. If any of those constituents are present above background, conduct mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the

concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.



## 16. Historic Pond

Hypothesis 16-1: The historic pond was associated with agriculture and may have been used as a stock pond, a fertilizer mixing pond, or collected fertilizer from runoff of nearby agricultural land. Nitrate and chloride laden water from the historic pond may have leached through the alluvial soil and bedrock to groundwater. While not always present in soils and groundwater associated with cattle wastes and byproducts, cryptosporidium is frequently present in livestock and animal sources, not human or industrial (chemical) sources. If detected along with elevated nitrate, the presence of cryptosporidium would help to earmark the source of nitrate as being of livestock/animal origin. Based on anecdotal information (interviews with landowners), the pond area was one of several areas that may have been used for dumping truckloads of salt for cattle salt licks. If this is correct, elevated levels of sodium chloride may be present in soil and or groundwater in the areas of the historic pond. Historical sheep dipping activities may also have impacted the pond.

Necessary Conditions: a) Is there evidence of nitrate, sodium, or chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in groundwater? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach groundwater? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Sufficient (but not necessary) condition: Is cryptosporidium present in the same media (soil or groundwater) with elevated levels of nitrate?

Data needs for decision: Data on the concentration of nitrate and/or ammonium, sodium, chloride, and cryptosporidium, in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on concentrations of the same constituents in groundwater. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, ammonium, sodium, and cryptosporidium concentration data from the bedrock portion of the vadose zone. Data on the same constituents in

groundwater. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. Collect data on concentrations of chemical constituents in groundwater that might be associated with agricultural uses of this feature along with cryptosporidium (Phase 2). If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, sodium, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, sodium, chloride, and ammonium concentration data. If none of those constituents are present above background, this can be eliminated as a potential source. If any of those constituents are present above background, conduct mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct an Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the isotopic fingerprint of groundwater from the plume, a possible source has been identified. Further, if cryptosporidium is present along with elevated nitrate in water or alluvium, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

Hypothesis 16-2: Historical pond was filled with water from one or more ponds north of the Mill site and used by the military during the Pershing Missile Operation at Blanding Launch Site (1963-1970) as wash water for equipment used to launch missiles. Launch equipment may have become coated with nitrate and chloride as oxidized material from “blow down” rained down on the launch vehicle during missile launch. Aerial photography of the site shows that the pond was full of water during the period of military use, and was dry in a 1973 photo, after the military left the site. Nitrate and chloride-laden water from the historical pond may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume.

Per the current owner of Morton-Thiokol, ATK, the Thiokol Pershing Missile rocket motors (models Thiokol TX-174 and TX-175) used aluminum fuel with ammonium perchlorate as an oxygen source. Since ammonium would have been oxidized during the launch combustion process, if ammonium residuals from Pershing equipment decontamination reached the pond, the residuals would already have been oxidized to the nitrate form. Therefore, for this activity to be a nitrate source, an oxidizing environment in groundwater or the alluvium is not required.

Necessary Conditions: a) Is there evidence of nitrate or ammonium, perchlorate, and/or aluminum concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was possibly used by the Pershing Missile Operation (1963 to 1970) for detectable levels of constituents from this activity to reach the plume or for existing constituents in the pond to reach groundwater by hydraulic head generated during this period? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data gaps: Need nitrate, chloride, aluminum, perchlorate, and ammonium concentration data from the bedrock portion of the vadose zone. Data on concentrations of the same constituents in groundwater. Need background concentrations of aluminum in alluvial soils. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 or subsequent sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, ammonium, aluminum, or perchlorate) are present above background, conduct a coring study of bedrock to groundwater (Phase 3). If aluminum or perchlorate are elevated in alluvium and/or bedrock, military use is confirmed. Analyze bedrock core samples for concentration data of those constituents. If none of those constituents are present above background, this can be eliminated as a potential source. If any of those constituents are present above background, conduct a mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in

bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct an Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## 17. Wildlife Pond

Hypothesis 17-1: The wildlife pond was historically filled with water from the frog pond, which may have contained water from the municipal wastewater treatment facility located north of the Mill. Nitrate and chloride laden water from the wildlife pond may have leached through the alluvial soil and bedrock to groundwater.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach groundwater? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium, and in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. Data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature (Phase 2). If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of those constituents are present above background,

this can be eliminated as a potential source. If any of those constituents are present above background, conduct a mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct an Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

Hypothesis 17-2: The wildlife pond was historically associated with agriculture and may have been used as a stock pond, a fertilizer mixing pond, or collected fertilizer from runoff of nearby agricultural land, or may have been utilized in connection with historic sheep dipping activities. Nitrate and chloride laden water from the wildlife pond may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. It is also possible that military activity could have been associated with the wildlife pond.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, ammonium, and cryptosporidium in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. Data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature (Phase 2). If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of those constituents are present above background, this can be eliminated as a potential source. If any of those constituents are present above

background, conduct a mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct an Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. Further, if cryptosporidium is present along with elevated nitrate in water or alluvium, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.





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## **18. CCD Circuit**

This area was inadvertently added to the Phase 1 Plan. The CCD circuit uses no chlorinated, ammoniated or nitrated compounds. The CCD area contains no chlorinated, ammoniated, or nitrated process solutions. The former sewage vault and current leach field near the CCD area are addressed as individual sources elsewhere in this section. This area will not be considered further.

## 19. YC Precip Mini Lab

Hypothesis 19: Ammonium or nitrate-bearing chemicals from the mini-lab may have spilled or leaked. Ammonium-, nitrate- or chloride-laden water from the lab may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. The minilab areas use very small quantities of reagents and process solutions which drain either to an above-the floor bucket, or in-floor drain sump, which is pumped back to the process. If this were a source of contamination, there would need to be evidence of a breach or failure of the building floor or the sump. This potential source is inaccessible to geoprobe and core drilling equipment and is a low priority due to generally small amounts of nitrate or chloride that it could possibly have contributed to the plume. Therefore, no sampling will be conducted at this location.

Necessary Conditions: a) Were nitrate-bearing chemicals, ammonia-bearing chemicals or chloride-bearing chemicals used in this lab and at what time periods? b) Is there evidence of a failure of the floor sump and/or floor drains? c) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) If only ammonia-bearing compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonia to nitrogen? d) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? and e) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach groundwater? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the use of ammonium-bearing, nitrate-bearing, and chloride-bearing compounds in this lab. Information on the condition and history of the floor, drains, and sumps in the building. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater adjacent to this building. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need information on the structure and history of the floors and drains. Need information on chemicals and use rates in the mini-lab. Need nitrate, ammonium and dissolved oxygen from adjacent monitor wells. Data on concentrations of nitrate, chloride,

and ammonium is already available from the groundwater and nitrate monitoring programs. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Determine if there has been a failure or breach of the sink, sump, or collection bucket. If not, this potential source has been eliminated. If not eliminated, perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If no nitrate-bearing, ammonia-bearing or chloride-bearing compounds were used in this lab, this potential source can be eliminated. Is there any evidence of a failure of the building floor or sumps? If any of these compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonia to nitrogen, and is there a hydraulic head sufficient to drive nitrate or chloride from the vadose zone to groundwater? If the answer to any of these is no, this potential source can be eliminated. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## 20. V<sub>2</sub>O<sub>5</sub> Mini Lab & V<sub>2</sub>O<sub>5</sub> Precip

Hypothesis 20-1: Ammonium or nitrate-bearing chemicals from the mini-lab may have spilled or leaked. Ammonium-, nitrate- or chloride-laden water from the lab may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. The mini-lab areas use very small quantities of reagents and process solutions which drain either to an above-the floor bucket, or in-floor drain sump, which is pumped back to the process. If this were a source of contamination, there would need to be evidence of a breach or failure of the building floor or the sump.

Necessary Conditions: a) Were nitrate-bearing chemicals, ammonia-bearing chemicals or chloride-bearing chemicals used in this lab and at what time periods? a) Is there evidence of a failure of the floor sump and/or floor drains? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) If only ammonia-bearing compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonia to nitrogen? d) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? and e) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the use of ammonium-bearing, nitrate-bearing, and chloride-bearing compounds in this lab. Information on the condition and history of the floor, drains, and sumps in the building. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater adjacent to this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need information on the structure and history of the floors and drains. Need information on chemicals and use rates in the mini-lab. Need nitrate, ammonium and dissolved oxygen from adjacent monitor wells. Data on concentrations of nitrate, chloride, and ammonium is already available from the groundwater and nitrate monitoring programs. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Determine if there has been a failure or breach of the sink, sump, or collection bucket. If not, this potential source has been eliminated. If not eliminated, perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If no nitrate-bearing, ammonia-bearing or chloride-bearing compounds were used in this lab, this potential source can be eliminated. If any of these compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonia to nitrogen, and is there a hydraulic head sufficient to drive nitrate or chloride from the vadose zone to groundwater? If the answer to any of these is no, this potential source can be eliminated. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

Hypothesis 20-2: Ammonium sulfate from the mix tanks on the first floor or the precip tanks on the upper floor may have spilled and leached through the alluvial soil and bedrock to groundwater. Nitrogen in the ammonium sulfate mix and precip tanks is solely in the ammonium ( $\text{NH}_4^+$ ) form. Ammonium cations are typically strongly retarded in a soil water system and likely would not travel through the alluvium and bedrock in the ammonia form. It would have to be converted to the nitrate from a process above the alluvium or in the near subsurface. That is, there would have to be a source of oxygenated water or other oxidizing fluid (such as a pond) immediately below or adjacent to the ammonium tanks, and it would have to create sufficient head to drive nitrated water all the way to groundwater. If this were the case, nitrogen would be detected as the nitrate (not ammonia) form continuously through the alluvium and the bedrock. The ammonium sulfate mix and precip. tanks are not a source of chloride.

Necessary Conditions: a) Is there evidence of nitrate concentration in the vadose zone beneath this feature? b) Is nitrate present in the alluvium and bedrock cores below this feature? c) Is there an oxidation source adjacent to or beneath the tanks sufficient to convert ammonium to nitrate? d) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? e) Did this potential source have sufficient mass to have contributed measurably to nitrate observed in the plume? f) Has there been sufficient time since this potential source was put into service (circa 1980) for detectable levels of constituents from this potential source to reach groundwater? Note that there would need to be sufficient time for any ammonium to be oxidized to nitrate, for nitrate to be transported to groundwater, and then be transported to the downgradient edge of the plume. and g) Since this potential source is not associated with any chloride, is there a plausible alternate source for chloride? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Need ammonium and dissolved oxygen from adjacent monitor

wells. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Determine if there has been a failure or breach of the floor or floor drain sump. If not, this potential source has been eliminated. If not eliminated, perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct a coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If nitrate is not present above background in alluvium and bedrock down to groundwater, this can be eliminated as a source. If nitrate is present above background, conduct a mass balance calculation to determine if the concentrations in alluvium and bedrock are sufficient to have contributed to nitrate observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate observed in the plume, conduct an Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## 21. SX Mini Lab

Hypothesis 21: Ammonium-, nitrate- or chloride-bearing chemicals from the mini-lab may have spilled or leaked. Ammonium-, nitrate- or chloride-laden water from the lab may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. This potential source is inaccessible to geoprobe and core drilling equipment and is a low priority due to generally small amounts of nitrate that it could possibly have contributed to the plume. Therefore, no sampling will be conducted at this location. The minilab areas use very small quantities of reagents and process solutions which drain either to an above-the floor bucket, or in-floor drain sump, which is pumped back to the process. If this were a source of contamination, there would need to be evidence of a breach or failure of the building floor or the sump.

Necessary Conditions: a) Were nitrate-bearing chemicals, ammonia-bearing chemicals or chloride-bearing chemicals used in this lab and at what time periods? b) Is there evidence of a failure of the floor sump and/or floor drains? c) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? d) If only ammonia-bearing compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonia to nitrogen? e) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? and f) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the use of ammonium-bearing, nitrate-bearing, and chloride-bearing compounds in this lab. Information on the condition and history of the floor, drains, and sumps in the building. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater adjacent to this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need information on the structure and history of the floors and drains. Need information on chemicals and use rates in the mini-lab. Need nitrate, ammonium and dissolved oxygen from adjacent monitor wells. Data on concentrations of nitrate, chloride, and ammonium is already available from the groundwater and nitrate monitoring programs.



Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Determine if there has been a failure or breach of the sink, sump, or collection bucket. If not, this potential source has been eliminated. If not eliminated, perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If no nitrate-bearing, ammonia-bearing or chloride-bearing compounds were used in this lab, this source can be eliminated. Is there any evidence of a failure of the building floor or sumps? If any of these compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonia to nitrogen? Is there a hydraulic head sufficient to drive nitrate or chloride from the vadose zone to groundwater? If the answer to any of these is no, this potential source can be eliminated. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## 22. Chem Lab

Hypothesis 22: Ammonium-, nitrate- or chloride-bearing chemicals from the mini-lab may have spilled or leaked, or lab sink drain water may have leaked from the underground piping that conveys lab drain wastes to the tailings cells. Ammonium-, nitrate- or chloride-laden water from the lab may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. This potential source is inaccessible to geoprobe and core drilling equipment and is low priority due to generally small amounts of nitrate that it could possibly have contributed to groundwater. Therefore, no sampling will be conducted at this location.

Necessary Conditions: a) Were nitrate-bearing chemicals, ammonia-bearing chemicals or chloride-bearing chemicals used in this lab and at what time periods? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) If only ammonia-bearing compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonia to nitrogen? d) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? and e) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the use of ammonium-bearing, nitrate-bearing, and chloride-bearing compounds in this lab. Data on concentrations of the same chemical constituents in groundwater. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need data on the types and amounts of chemicals used at this facility. Data on concentrations of nitrate, chloride, and ammonium is already available from the groundwater and nitrate monitoring programs. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If no nitrate-bearing, ammonia-bearing or chloride-bearing compounds were used

in this lab, this potential source can be eliminated. If any of these compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonia to nitrogen, and is there a hydraulic head sufficient to drive nitrate or chloride from the vadose zone to groundwater? If not, this potential source can be eliminated. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

### 23. Met Lab

Hypothesis 23: Ammonium-, nitrate- or chloride-bearing chemicals from the Met lab may have spilled or leaked, or lab sink drain water may have leaked from the underground piping used to convey lab drain wastes to the tailings cells. Ammonium-, nitrate- or chloride-laden water from the lab may have leached through the alluvial soil and bedrock to groundwater and contributed to the plume. This potential source is inaccessible to geoprobe and core drilling equipment and is a low priority due to generally small amounts of nitrate that it could possibly have contributed to groundwater. Therefore no sampling will be conducted at this location.

Necessary Conditions: a) Were nitrate-bearing chemicals, ammonia-bearing chemicals or chloride-bearing chemicals used in this lab and at what time periods? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) If only ammonia-bearing compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonia to nitrogen? d) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? and e) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the use of ammonium-bearing, nitrate-bearing, and chloride-bearing compounds in this lab. Data on concentrations of the same chemical constituents in groundwater. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need data on the types and amounts of chemicals used at this facility. Data on concentrations of nitrate, chloride, and ammonium is already available from the groundwater and nitrate monitoring programs. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If no nitrate-bearing, ammonia-bearing or chloride-bearing compounds were used



in this lab, this potential source can be eliminated. If any of these compounds were used, is there an oxidation source adjacent to or beneath the lab sufficient to convert ammonia to nitrogen, and is there a hydraulic head sufficient to drive nitrate or chloride from the vadose zone to groundwater? If not, this potential source can be eliminated. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## 24. V<sub>2</sub>O<sub>5</sub> Oxidation Tanks

Hypothesis 24-1: Ammoniated solutions from the V<sub>2</sub>O<sub>5</sub> oxidation area could have spilled or overflowed, entered the floor drains and/or drain sumps and leaked out of the drains, through the alluvial soil and bedrock into groundwater, before entering the tailings system, and have contributed to the plume. Anhydrous ammonia is added to raffinate solution from the uranium solvent extraction area in this part of the plant. Nitrogen in this area is solely in the ammonium (NH<sub>4</sub><sup>+</sup>) form. Anything spilled or washed down to floors or sumps is pumped back from the sumps into the process and remains within the building. If this were a source of contamination, there would need to be evidence of a breach or failure of the building floor or the sump. Ammonium cations are typically strongly retarded in a soil water system and likely would not travel through the alluvium and bedrock in the ammonia form. It would have to be converted to nitrate from a process above the alluvium or in the near subsurface. That is, there would have to be a source of oxygenated water or other oxidizing fluid (such as a pond) immediately below or adjacent to the ammonium tanks, and it would have to create sufficient head to drive nitrated water all the way to groundwater.

Necessary Conditions: a) Is there evidence of a failure of the floor sump and/or floor drains? c) Is there an oxidation source adjacent to or beneath the tanks sufficient to convert ammonium to nitrate? d) Is there a hydraulic head sufficient to drive nitrate from the vadose zone to groundwater? e) Did this potential source have sufficient mass to have contributed measurably to nitrate observed in the plume? f) Has there been sufficient time since this potential source was put into service (circa 1980) for detectable levels of constituents from this potential source to reach the plume? Note that there would need to be sufficient time for any ammonium to be oxidized to nitrate, for nitrate to be transported to groundwater, and then be transported to the downgradient edge of the plume, and g) Since this potential source is not associated with any chloride, is there a plausible alternate source for chloride? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Information on the condition and history of the floor, drains, and sumps in the building. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater adjacent to this feature.

Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need information on the structure and history of the floors and drains. Need nitrate, ammonium and dissolved oxygen from adjacent monitor wells. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Determine if there has been a failure or breach of the floor or floor drain sump. If not, this potential source has been eliminated. If not eliminated, perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct a coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If nitrate is not present above background in alluvium and bedrock down to groundwater, this can be eliminated as a potential source. If nitrate is present above background, conduct a mass balance calculation to determine if the concentrations in alluvium and bedrock are sufficient to have contributed to nitrate observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate observed in the plume, conduct an Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

Hypothesis 24-2: Sodium chlorate or chlorinated solutions from the  $V_2O_5$  oxidation area could have spilled or overflowed, entered the floor drains and/or drain sumps and leaked out of the drains, through the alluvial soil and bedrock into groundwater, before entering the tailings system, and have contributed to the plume. Anything spilled or washed down to floors or sumps is pumped back from the sumps into the process and remains within the building. If this were a source of contamination, there would need to be evidence of a breach or failure of the building floor or the sump. If this were an appreciable source, it would also be associated with measurably elevated sodium in soil and/or groundwater adjacent to and beneath the tank area. Sodium chlorate is not a source of nitrogen atoms, and this hypothesis has been retained for evaluation only as a chloride source.

Necessary Conditions: a) Is there evidence of chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service (1979) for detectable levels of constituents from this potential source to reach groundwater? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Information on the condition and history of the floor, drains, and sumps in the building. Data on the concentration of nitrate, chloride, ammonium, dissolved oxygen, and oxidation reduction potential in the groundwater adjacent to this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need information on the structure and history of the floors and drains. Need nitrate, ammonium and dissolved oxygen from adjacent monitor wells. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct a coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for chloride concentration data. If chloride is present above background, conduct a mass





balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to chloride observed in the plume. If chloride is not present above background or the quantities are not sufficient, this can be eliminated as a potential source. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## **25. Natural Nitrate Reservoir**

Hypothesis 25: Increased recharge or irrigation of dry land could have led to leaching of salts that have been accumulating in the unsaturated zone for thousands of years, forming a nitrate reservoir in the subsurface alluvium which is driven through the alluvial soil and bedrock to groundwater by surface water (wildlife or other ponds) percolation.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time for detectable levels of constituents from this potential source to reach the plume? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, and ammonium in the alluvial and bedrock portion of the vadose zone beneath this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct a coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of those constituents are present above background, this may be eliminated as a potential source. If any of those constituents are present above background, conduct a mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in groundwater, conduct an Isotopic Analysis

on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic Fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## **26. Other ponds or pond like sources (26-32)**

Hypothesis 26: These areas were used historically as agriculture-related stock ponds and fertilizer mixing ponds. Anecdotal evidence suggests ponds may have been used for sheep dipping, that occasionally cattle broke through the ice and drowned, and that truckloads of salt crystals were deposited in the vicinity for the cattle. Nitrates and chlorides associated with these agricultural-related activities may have leached through the alluvial soil and bedrock to groundwater. While not always present in soils and groundwater associated with cattle wastes and byproducts, cryptosporidium is frequently present in livestock and animal sources, not human or industrial (chemical) sources. If detected along with elevated nitrate, the presence of cryptosporidium would help to earmark the source of nitrate as being of livestock/animal origin. There is also the potential for military activity in connection with any of the historic ponds near the site.

Necessary Conditions: a) Is there evidence of nitrate and chloride concentrations in the vadose zone beneath this feature? b) Did this potential source have sufficient mass to have contributed measurably to nitrate and/or chloride observed in the plume? c) Does the hydrogeology support and explain transport to groundwater? and d) Has there been sufficient time since this potential source was put into service for detectable levels of constituents from this potential source to reach groundwater? If this potential source could have contributed to the plume, is the Isotopic Fingerprint statistically comparable to the Isotopic Fingerprint of the plume? If the Isotopic Fingerprint of the potential source is statistically comparable to the Isotopic Fingerprint of the plume, is it uniquely comparable or does the Weight of Evidence indicate that it contributed to the plume?

Data needs for decision: Data on the concentration of nitrate, chloride, ammonium, and cryptosporidium in the alluvial and bedrock portion of the vadose zone beneath this feature. Data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Data gaps: Need nitrate, chloride, and ammonium concentration data from the bedrock portion of the vadose zone. Data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature. Possible need for Isotopic Analysis data. Possible need for Non-Isotopic Groundwater Data (for Weight of Evidence analysis).

Decision Process: Perform a hydrogeologic evaluation to determine if any potential contamination from this potential source could have contributed to the plume. If not, this

potential source is ruled out. If the hydrogeologic analysis is not conclusive, proceed as follows. Review data on concentrations of chemical constituents in groundwater that might be associated with agricultural or military uses of this feature (Phase 2). If the results of Phase 1 sampling of the alluvium provide evidence that any of the constituents (nitrate, chloride, or ammonium) are present above background, conduct coring study of bedrock to groundwater (Phase 3). Analyze bedrock core samples for nitrate, chloride, and ammonium concentration data. If none of those constituents are present above background, then this may be eliminated as a potential source. If any of those constituents are present above background, conduct a mass balance calculation to determine if the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume. If the concentrations in bedrock are sufficient to have contributed to nitrate and chloride observed in the plume, conduct an Isotopic Analysis on samples of bedrock core samples and of groundwater from the plume (Phase 5). If the Isotopic 'fingerprint is uniquely identifiable to the potential source, then the source has been identified. If the Isotopic Fingerprint of the core sample is not uniquely identifiable to the potential source but is statistically comparable to the Isotopic Fingerprint of groundwater from the plume, a possible source has been identified. Further, if cryptosporidium is present along with elevated nitrate in water or alluvium, a possible source has been identified. If a possible source has been identified, perform a Weight of Evidence analysis to determine if the possible source has contributed to the plume. If the possible source has been determined to have contributed to the plume, perform a hydrogeologic and mass balance analysis to determine to what extent the source has contributed to the plume.

## **2.4 Environmental Receptor Identification**

An environmental receptor can be humans or other living organisms potentially exposed to and adversely affected by contaminants because they are present at the source(s) or along the contaminant migration pathway.

### **2.4.1 Humans**

Humans are a potential receptor because they may be present at the source; however nitrate and chloride in soil pose no risk to humans. Humans do not come in contact with groundwater at the Site; therefore, the human risk pathway is incomplete.

### **2.4.2 Ecological**

Potential ecological receptors are not at risk from nitrates and chlorides in soil. Potential ecological receptors do not come into contact with groundwater at the Mill site; therefore, the ecological risk pathway is incomplete.

### **3.0 DATA GENERATION AND ACQUISITION**

#### **3.1 Phase 1 Geoprobe Investigation of Background, Natural Nitrate Reservoir, and Potential Site Sources**

The purpose of the Phase 1 investigation was to determine background concentrations of nitrate and chloride in the alluvial soil column in undisturbed areas in the vicinity of the Mill, to locate a natural nitrate and chloride reservoir exists in the alluvial soil, and to compare nitrate and chloride concentrations found in soil near potential Mill sources to background concentrations. The Phase 1 investigation is described in more detail in DUSA's May 13, 2011, submittal to the DRC titled Nitrate Investigation Phase 1 Work Plan.

#### **3.2 Phase 2 Groundwater Quality Sampling and Analysis**

A separate QAP Addendum will be submitted which specifies the specific details, activities, equipment, procedures, objectives, and decision criteria for this phase of the investigation. The QAP Addendum will be based upon and utilize the existing DRC-approved QAP for groundwater sampling at the White Mesa Mill. The Addendum will follow the same outline as the approved QAP and will: a) supplement the approved QAP to address additional activities which are specific to Phase 2 of the nitrate investigation and are not currently addressed in the QAP and b) adjust existing procedures in the approved QAP which need to be modified or omitted to be suitable for the Nitrate Investigation.

#### **3.3 Phase 3 Deep Bedrock Core Sampling and Analysis**

The objective of deep bedrock core sampling and analysis is to trace nitrate and chloride from the base of the alluvium and into the bedrock column (Dakota Formation and upper Burro Canyon Formation) to the water table. The coring will take place in two separate sub-phases: Phase 3A Deep Bedrock Coring in Undisturbed Locations, and Phase 3B Deep Bedrock Coring of Potential Nitrate Source Locations.

##### **3.3.1 Sampling Design**

Phase 3A: At this time it is anticipated that at least four coring locations associated with locating the natural nitrate reservoir will be chosen based on field test kit and analytical results from the 20 background soil borings advanced during Phase 1A of this investigation. At the time of this Phases 2-5 work plan, analytical results have not been received; therefore, exact locations of bedrock cores cannot be listed here. Figure 20 presents the potential locations for coring. Preliminary results from Phase 1A indicate the presence of a nitrate and chloride spike at one of the deeper, undisturbed alluvial locations with nitrate and chloride concentrations rising

gradually with depth to a peak and then falling with depth below the peak. This observation is consistent with the findings reported by Walvoord, et al (2003), where they described a natural nitrate reservoir beneath desert soils. Some alluvial borings at undisturbed locations saw the highest concentrations of nitrate and chloride at the base of the alluvial material. Still other borings yielded samples in which there was no detected nitrate or chloride in alluvial materials. The alluvium is generally thin at the Mill property, and the presence of a nitrate and chloride spike in the deepest of the alluvial borings suggests that evidence of a natural nitrate reservoir may be found in the upper part of the bedrock at the undisturbed sites. Therefore, the bedrock cores to test the natural nitrate reservoir hypothesis will be advanced through the alluvial soil to approximately 20 feet below the surface of the bedrock, and samples will be taken at 4 foot intervals for shipment to the Analytical Laboratory. Remaining core will be archived. If any nitrate and/or chloride is detected above background in samples sent to the Analytical Laboratory, additional samples from adjacent intervals will be selected from the archived core and sent for Analytical Laboratory analysis. All samples will undergo an SPLP leaching procedure and the leachate will be analyzed for nitrate, chloride, sulfate, and ammonia.

Phase 3B: One coring location associated with each pond or pond-like source and each potential process-related source where nitrate and chloride are detected in alluvial material will be selected based on analytical results from the source borings conducted in Phase 1B of this investigation. At the time of this Phase 2-5 work plan, analytical results have not been received; therefore, exact locations of bedrock cores cannot be listed here. The bedrock core will be advanced through the alluvium and bedrock to groundwater. Water levels in the perched aquifer have been relatively stable for the last 20 years. Therefore, the presence of nitrate and chloride above background in the 10-foot interval above the water table would provide strong evidence that a source had indeed contributed those constituents to groundwater. Three (3) samples will be collected from each bedrock core location. Bedrock core samples will be collected randomly from the first 1/3, second 1/3, and third 1/3 interval of the total penetrated depth at each location, but during evaluation of results special emphasis will be placed on the sample from the interval above the groundwater table. All samples will undergo an SPLP leaching procedure and the leachate will be analyzed for nitrate, chloride, sulfate, and ammonia. The remaining core will be archived. If any nitrate and/or chloride is detected above background in samples sent to the Analytical Laboratory, additional samples from adjacent intervals will be selected from the archived core and sent for Analytical Laboratory analysis.





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### **3.3.2 Field Activities and Sampling Methods**

The coring will be conducted with a conventional truck-mounted drill rig using a combination of hollow-stem auger and air-rotary methods, without introducing water or other drilling fluids into the borehole.

Cores will be logged by a Utah-Licensed Professional Geologist. Photographs of cores will be collected and GPS coordinates will be recorded.

No field testing will be conducted on these rock cores. The core intervals for Analytical Laboratory analysis will be packaged and shipped to a State of Utah-certified Analytical Laboratory for analysis for the presence of nitrate, chloride, sulfate, and ammonia in the rock cores following the SPLP leaching method. The Analytical Laboratory will need to crush, pulverize, and blend the rock core material before conducting the analysis. Results will be reported in mg/Kg.

The core-hole borings will be backfilled with hydrated bentonite after drilling. The as-built boring locations will be recorded with a hand-held GPS instrument for plotting on the Mill site map and for future reference in the field.

Equipment decontamination will be implemented for all non-disposable equipment that comes in contact with bedrock before moving equipment to a new location or collecting a new sample. Commercial third-party deionized water will be used for rinsate blank collection.

#### **3.3.2.1 Sample Identification**

Each sample collected at the Site during the nitrate investigation will be identified using a unique sample ID. The description of the sample type and the point name will be recorded on the COC forms, as well as in the field notes.

Field log books will be used to document field sampling information. Sample IDs will be listed on the sample labels and the COC forms submitted to the Analytical Laboratory, and will be cross-referenced to the name in permanently bound field log books, on sample data sheets, and on COC forms.

Coring samples will be named according to the coring location and top and bottom of the depth interval at which they were collected, following the convention C-††X-tt-dd, where †† X is the core location which will be previously determined based on the soil boring locations given in Phase 1, tt is the top of the depth interval, and dd is the bottom of the depth interval expressed in

feet bgs. For example, the sample collected at C-01A in the depth interval between 25 and 26 feet bgs would be named C-01A-25-26.

QC samples will be named as follows:

- Duplicate samples will have the same name as the parent sample with a D added at the end of the sample name.
- Equipment blanks will have the same name as the boring location with a terminal RB added at the end.

### **3.3.3 Sample Containers and Holding Times**

The type of sample containers to be used for each analysis, the sample volumes required, the preservation requirements, and the holding times for samples prior to extraction and analysis are presented in Tables 3 and 4.

### **3.3.4 Analytical Methods**

All rock samples will be submitted to the Analytical Laboratory for SPLP using EPA Method 1312 using Extraction Fluid #3. Method 1312 will produce a leachate of all rock samples which will be analyzed for nitrate, chloride, sulfate, and nitrogen as ammonia using EPA Method 353.2, EPA Method 300.0, and EPA Method 350.1 respectively.

## **3.4 Phase 4 Stable Isotopic Sampling and Analysis of Groundwater in Existing Wells**

A separate QAP Addendum will be submitted which specifies the specific details, activities, equipment, procedures, objectives, and decision criteria for this phase of the investigation. The QAP Addendum will be based upon and utilize the existing DRC-approved QAP for groundwater sampling at the White Mesa Mill. The Addendum will follow the same outline as the approved QAP and will supplement the approved QAP to address those activities which are specific to Phase 4 of the nitrate investigation.

## **3.5 Phase 5 Isotopic Soil Sampling and Analysis**

A determination regarding the necessity to complete Phase 5 will be completed after review of the data resulting from the previous phases of the nitrate investigation. If completed, Phase 5 will provide an isotopic “fingerprint” of potential sources of nitrate and chloride in soil or deep cores. If Phase 5 is required, a separate Work Plan/QAP will be submitted which specifies the specific details, activities, equipment, procedures, objectives, and decision criteria for this phase of the investigation.

### **3.6 Sample Handling and Custody**

#### **3.6.1 Sample Labeling**

Deep bedrock core samples will be collected in resealable plastic bags due to the inflexible nature of the samples and the inability to “fit” rock cores into a traditional sample jar.

Resealable plastic bags which are archived will be labeled with an indelible marker with the following information:

- Sample identification
- Date

Deep bedrock cores provided to the Analytical Laboratory for analysis will be labeled with an adhesive label showing the following information:

- Sample identification
- Date
- Time of collection
- Project name
- Sampler’s initials
- Analysis required

Resealable bags will be sealed and placed on ice in a cooler.

#### **3.6.2 Sample Documentation**

Documentation during sampling is essential to proper sample identification. All personnel will adhere to the following general guidelines for maintaining field documentation:

- Documentation will be completed in permanent black or blue ink.
- All entries will be legible.
- Errors will be corrected by crossing out the entry with a single line and then dating and initialing the lineout.
- Any serialized documents will be maintained by INTERA and referenced in the field log book.
- Unused portions of pages will be crossed out, and each page will be signed and dated.

The field team leader and sampling personnel are responsible for proper documentation of activities.

### **3.6.3 Chain of Custody**

Standard sample custody procedures will be used to maintain and document sample integrity during collection, transportation, storage, and analysis. A sample will be considered to be in custody if one of the following statements applies:

- It is in a person's physical possession or view.
- It is in a secure area with restricted access.
- It is placed in a container and secured with an official seal in such a way that the sample cannot be reached without breaking the seal.

COC procedures provide an accurate written record that traces the possession of individual samples from the time of collection in the field to the time of acceptance at the Analytical Laboratory. The COC form will also be used to document all samples collected and the analyses requested. Information that the field personnel will record on the COC form includes the following:

- Project name and number
- Sampling location
- Name and signature of sampler
- Destination of sample (Analytical Laboratory name)
- Sample ID
- Date and time of collection
- Number and type of containers filled
- Analyses requested
- Preservatives used (if applicable)
- Filtering (if applicable)
- Signatures of individuals involved in custody transfer, including the date and time of transfer
- Air bill number (if applicable) or courier information
- Project contact and phone number

Unused lines on the COC form will be crossed out. Field personnel will sign COC forms. The COC form will be placed in a waterproof plastic bag and taped to the inside of the shipping container used to transport the samples. Signed air bills will serve as evidence of custody transfer between field personnel and the courier, and between the courier and the Analytical Laboratory.



Copies of the COC form and the air bill will be retained and filed by field personnel before the containers are shipped.

The Analytical Laboratory sample custodian will receive all incoming samples, sign the accompanying COC forms, and retain copies of the forms as permanent records. The Analytical Laboratory sample custodian will record all pertinent information concerning the samples, including the persons delivering the samples, the date and time received, sample condition at the time of receipt (e.g., sealed, unsealed, or broken container; temperature; or other relevant remarks), the sample IDs, and any unique Analytical Laboratory IDs for the samples. When the sample transfer process is complete, the custodian is responsible for maintaining internal log books, tracking reports, and other records necessary to maintain custody throughout sample preparation and analysis.

The Analytical Laboratory will provide a secure storage area for all samples. Access to this area will be restricted to authorized personnel. The custodian will ensure that samples requiring special handling, including samples that are heat- or light-sensitive, radioactive, or have other unusual physical characteristics, are properly stored and maintained pending analysis.

#### **3.6.4 Sample Shipment**

The following procedures will be implemented when samples collected during the remediation activities are shipped:

- The cooler will be filled with bubble wrap, sample containers, and packing material. Sufficient packing material will be used to minimize sample container breakage during shipment.
- The COC forms will be placed inside a plastic bag. The bag will be sealed and taped to the inside of the cooler lid. The air bill, if required, will be filled out before the samples are handed over to the carrier. The Analytical Laboratory will be notified if the sampler suspects that the sample contains any substance that would require Analytical Laboratory personnel to take safety precautions.
- The cooler will be closed and taped shut with packing tape around both ends. If the cooler has a drain, it will be taped shut both inside and outside of the cooler.
- Signed and dated custody seals will be placed on the front and side of each cooler. Wide clear tape will be placed over the seals.
- The COC form will be transported within the taped, sealed cooler. When the cooler is received at the Analytical Laboratory, Analytical Laboratory personnel will open the cooler and sign the COC form to document transfer of samples.

- Multiple coolers may be sent in one shipment to the Analytical Laboratory. The outsides of the coolers will be marked to indicate the number of coolers in the shipment.

### **3.7 Quality Control**

#### **3.7.1 Field Quality Control Methods**

Field quality control measures include complete documentation of all field activities on the appropriate forms. Field QC samples include the collection of field duplicates for analysis by the Analytical Laboratory. Field duplicates will be collected at a frequency of 1 duplicate per 10 field samples. Duplicates will be collected by mixing the field sample and splitting the sample into 2 containers. The samples will be labeled as separate samples and submitted blind to the Analytical Laboratory. Duplicate assessment will be completed as described in Section 3.7.3.4, below.

#### **3.7.2 Analytical Laboratory Quality Control Methods**

Analytical QA/QC will be governed by the QA/QC program of the Analytical Laboratory. Every effort will be made to use Analytical Laboratories that are certified by the State of Utah and by NELAP and/or NAVLAP, and are capable of performing the analytical procedures specified in Table 4, and have a QA/QC program that includes the spikes, blanks, and duplicates described below.

##### **3.7.2.1 Spikes, Blanks and Check Samples**

Analytical Laboratory QC samples will assess the accuracy and precision of the analyses. Following are descriptions of the types of QC samples that may be used by the Analytical Laboratory to assess the quality of the data. Analytical QC will be completed as required by the specific method used for analysis. Assessment of Analytical Laboratory QC samples will be as specified in the method.

##### **a. Matrix Spike/Matrix Spike Duplicate**

A spiked field sample analyzed in duplicate may be analyzed with every analytical batch. Analytes stipulated by the analytical method, by applicable regulations, or by other specific requirements may be spiked into the samples. Selection of the sample to be spiked depends on the information required and the variety of conditions within a typical matrix. The matrix spike sample serves as a check evaluating the effect of the sample matrix on the accuracy of analysis. The matrix spike duplicate serves as a check of the analytical precision. Assessment of the matrix spike/matrix spike duplicate will be completed using the method- and Analytical Laboratory-established limits.

b. Method Blanks

Each analytical batch shall be accompanied by a method blank. The method blank shall be carried through the entire analytical procedure. Contamination detected in analysis of method blanks will be used to evaluate any Analytical Laboratory contamination of environmental samples which may have occurred. Method blank detections will be assessed to determine if there is any effect on the sample data usability. Method blank effects will be discussed and a determination made on a case-by-case basis.

c. Check Samples

Each analytical batch shall contain a number of check samples. For each method, the Analytical Laboratory will analyze the check samples or their equivalents specified in the analytical method. Check samples may include a laboratory control sample (“LCS”), calibration checks, laboratory fortified blanks, or sample duplicates. Check samples will be reviewed for compliance with the Analytical Laboratory and method-specified acceptance limits.

### **3.7.3 Internal Quality Control Checks**

#### ***3.7.3.1 Field Quality Control Check Procedures***

The QA Manager will perform the QA/QC analysis of field procedures as described below.

#### ***3.7.3.2 Review of Compliance with Procedures in this Plan***

Observation of technician performance is monitored by the QA Manager on a periodic basis to ensure compliance with this Plan.

#### ***3.7.3.3 Completeness Review***

The QA Manager will review all analytical results to confirm that the analytical results are complete (i.e., there is an analytical result for each required constituent). The completeness goal for this project is 95%.

#### ***3.7.3.4 Duplicates***

The following analyses will be performed on duplicate field samples:

- Relative percent difference.

RPDs will be calculated in comparisons of duplicate and original field sample results. Non-conformance will exist when the RPD is greater than 35, unless the measured concentrations are less than 5 times the required detection limit (EPA, 1994b).

#### **3.7.3.5 Use of QC Samples to Assess Conformance with this Plan**

QC samples generated during field activities and in the Analytical Laboratory will be used to assess the usability of the data for meeting project objectives. QC data which do not meet the requirements specified herein may require that the associated sample data be flagged for limited use or be removed from the overall data pool. Data flagging will follow standard EPA guidelines specified in Functional Guidelines as applicable to the analytical method. QC samples will be used to determine if the data meet the project objectives.

#### **3.7.4 Instrument Equipment Testing, Inspection, and Maintenance**

The Analytical Laboratory is responsible for the maintenance of its instruments in accordance with Analytical Laboratory procedures and as required in order to maintain its NELAP and/or NAVLAP certifications. Preventive maintenance will be performed on a scheduled basis to minimize downtime and the potential interruption of analytical work.

Sampling and field equipment shall be tested, inspected, and maintained in accordance with manufacturers' recommendations.

#### **3.7.5 Instrument Calibration**

A fundamental requirement for collection of valid data is the proper calibration of all sample collection and analytical instruments. Analytical Laboratory equipment shall be calibrated in accordance with Analytical Laboratory procedures and as described in the analytical methods.



## 4.0 DATA EVALUATION

What data will be collected, and decisions based on data collected, etc.

(Discuss Logic Diagrams here?)

Data evaluation will be completed as described throughout this plan. Analytical data will be evaluated as described using Analytical Laboratory generated QC samples as specified in the analytical methods. Field data will be evaluated against the specific QC samples generated in the field and documentation will be reviewed for completeness and accuracy.

For the SPLP, Extraction Fluid #3 will be used. Standard extraction requires the addition of nitric acid and sulfuric acid during the leaching process. Since the leachates will be analyzed for nitrate+nitrite and sulfate, the deionized leaching process contemplated by the method (for cyanide-containing samples) will be used in lieu of the standard leaching procedure.

As previously described, the soil samples are being leached and analyzed using water methodologies, which will yield concentrations in liquid units (such as mg/L). During the data interpretation and preparation of a revised CSM, the calculations and/or the relationship for converting the results to soil mass units will be provided.

Data usability will be assessed based on compliance with the QC standards specified in the analytical method.

## **5.0 AUDITS**

DUSA may perform system and performance audits in order to ensure that data of known and defensible quality are produced during a sampling program. The frequency and timing of system and performance audits shall be as determined by DUSA.

### **5.1 System Audits**

System audits are qualitative evaluations of all components of field and Analytical Laboratory QC measurement systems. They determine if the measurement systems are being used appropriately. System audits will review field and Analytical Laboratory operations, including sampling equipment, Analytical Laboratory equipment, sampling procedures, and equipment calibrations, to evaluate the effectiveness of the QA program and to identify any weakness that may exist. The audits may be carried out before all systems are operational, during the program, or after the completion of the program. Such audits typically involve a comparison of the activities required under this Plan with those actually scheduled or performed. A special type of systems audit is the data management audit. This audit addresses only data collection and management activities.

### **5.2 Performance Audits**

The performance audit is a quantitative evaluation of the measurement systems of a program. It requires testing the measurement systems with samples of known composition or behavior to evaluate precision and accuracy. With respect to performance audits of the analytical process, either blind performance evaluation samples may be submitted to the Analytical Laboratory for analysis, or the auditor may request that it provide results of the blind studies that the Analytical Laboratory must provide to its NELAP and/or NAVLAP accreditation agency on an annual basis. The performance audit is carried out without the knowledge of the analysts, to the extent practicable.

### **5.3 Follow-Up Actions**

Response to the system audits and performance audits is required when deviations are found.

### **5.4 Audit Records**

Audit records for all audits conducted will be retained in DUSA Central Files. These records will contain audit reports, written records of completion for corrective actions, and any other documents associated with the audits supporting audit findings or corrective actions.

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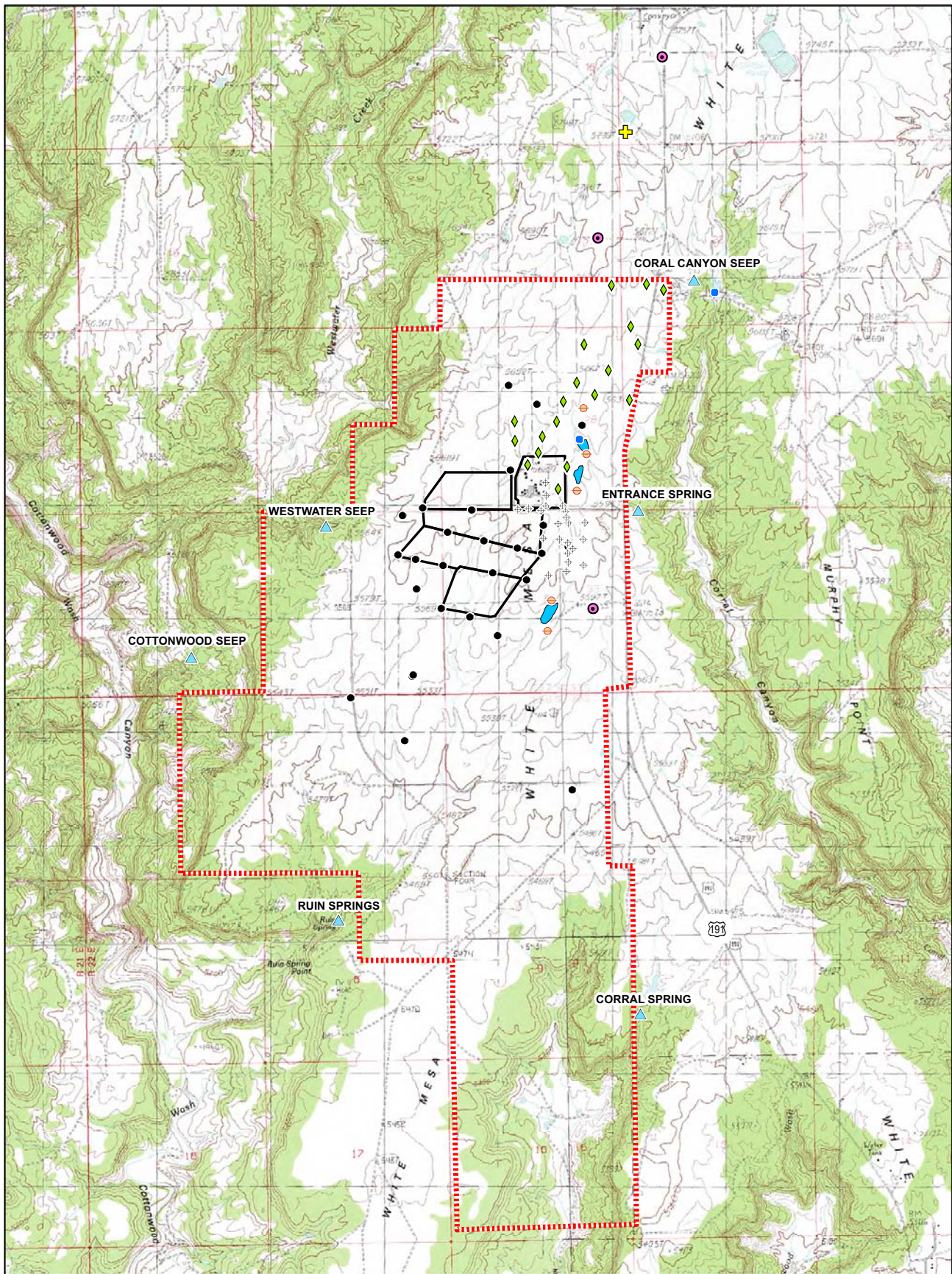


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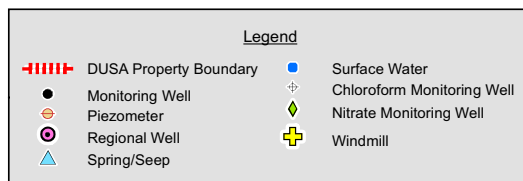
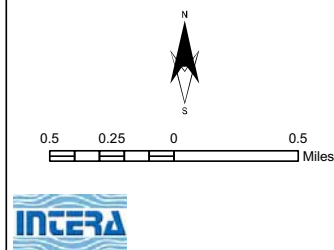


## Figures



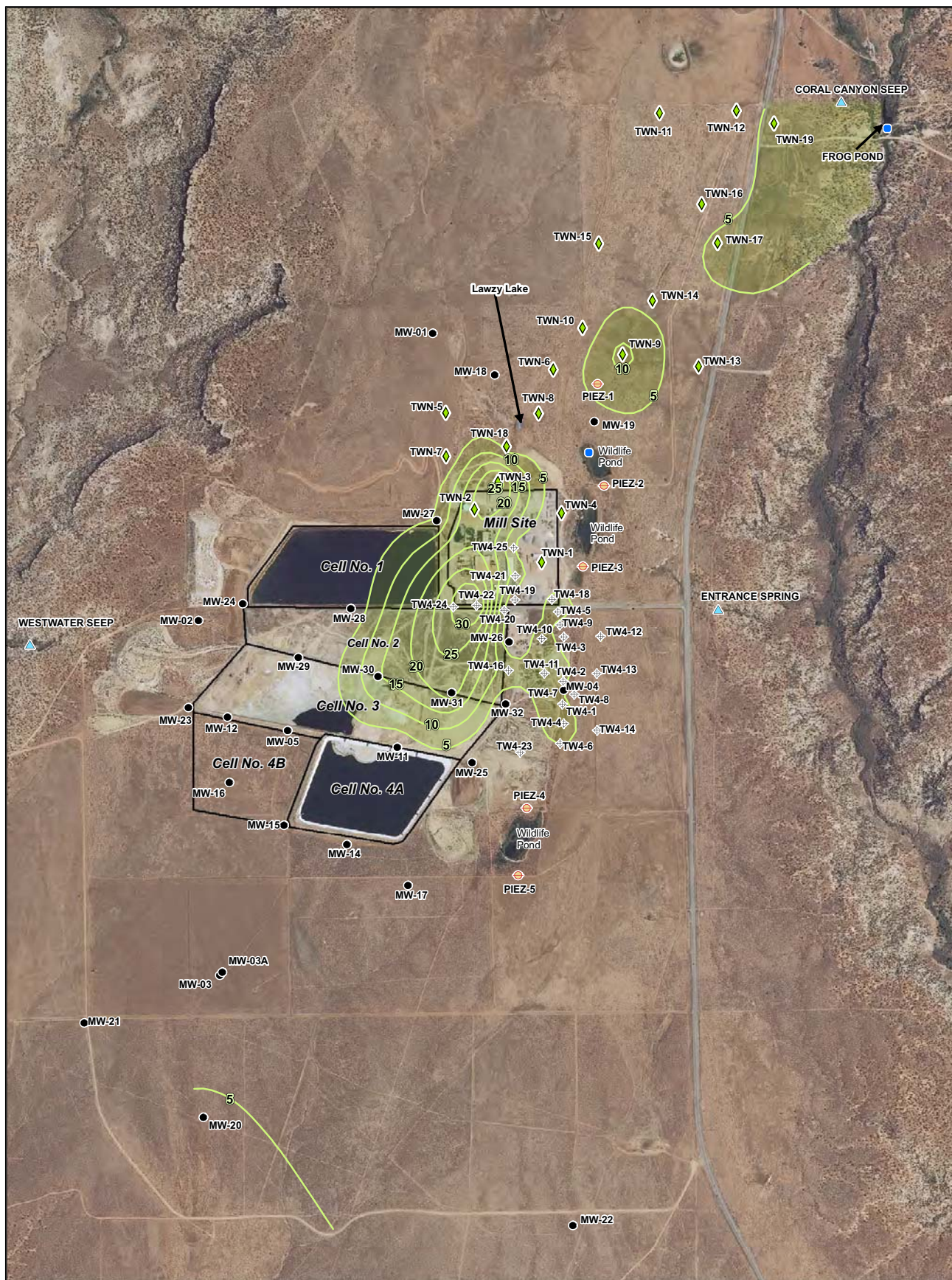


Source(s): Utah GIS Portal website



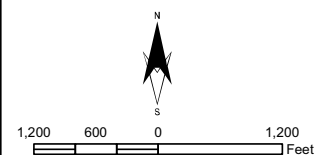
**Figure 1**  
Map Showing Location  
of Whate Mesa Mill Site  
Nitrate Investigation Revised  
Phase 2-5 Work Plan





Nitrate data from September, October, or November of 2009. A single data point was used for each well.

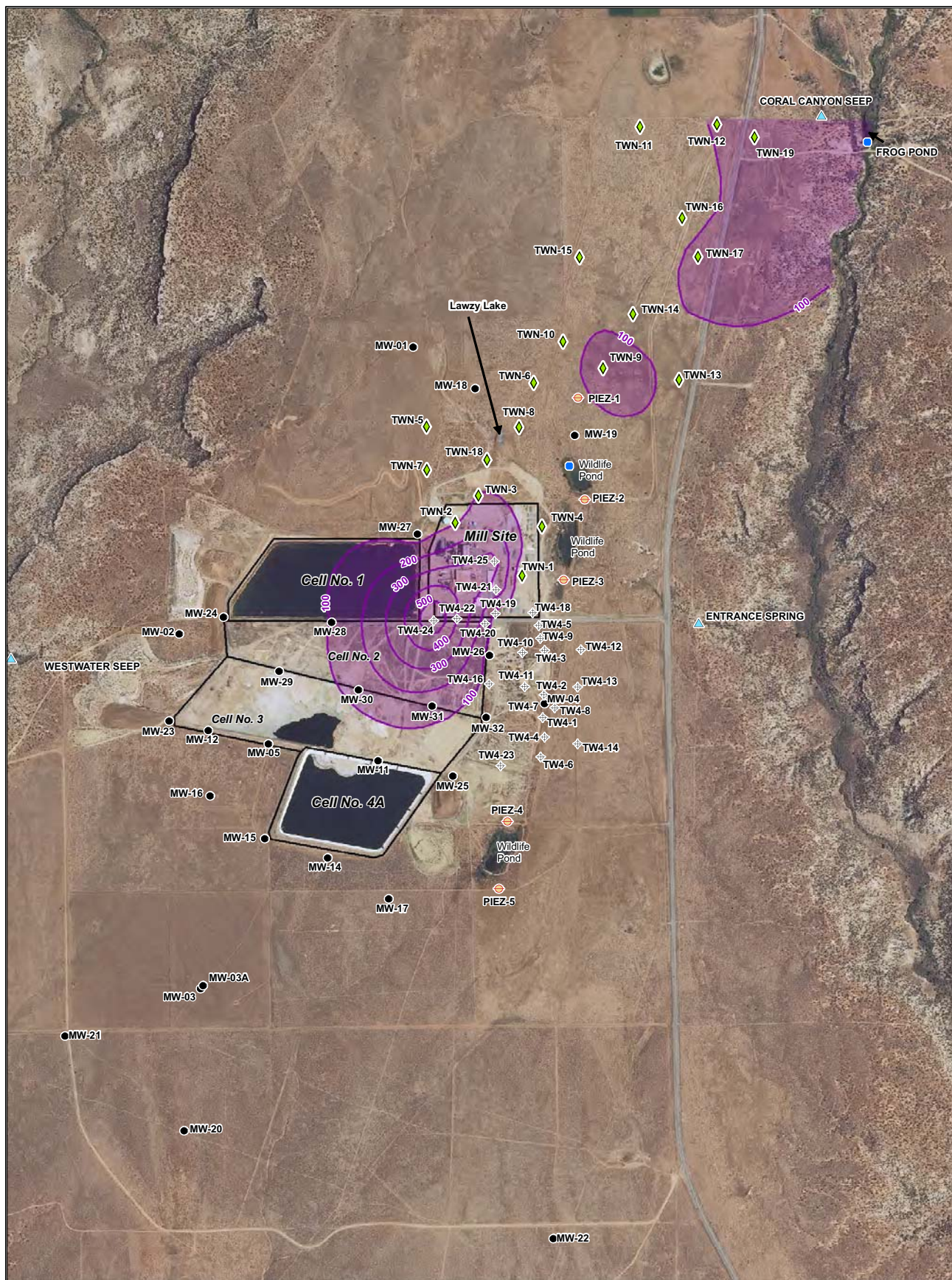
Source(s): Aerial – Utah GIS Portal website;  
Wells – HGC, Inc., May 2008 report.



Legend	
● Monitoring Well	● Surface Water
○ Piezometer	⊕ Chloroform Monitoring Well
▲ Spring/Seep	◆ Nitrate Monitoring Well
	— Nitrate Concentration (mg/L)

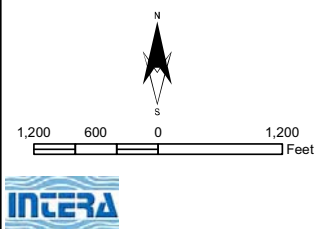
Figure 2  
Map Showing Nitrate Plume  
Nitrate Investigation Revised  
Phase 2-5 Work Plan





Chloride data from September, October, or November of 2009. A single data point was used for each well.

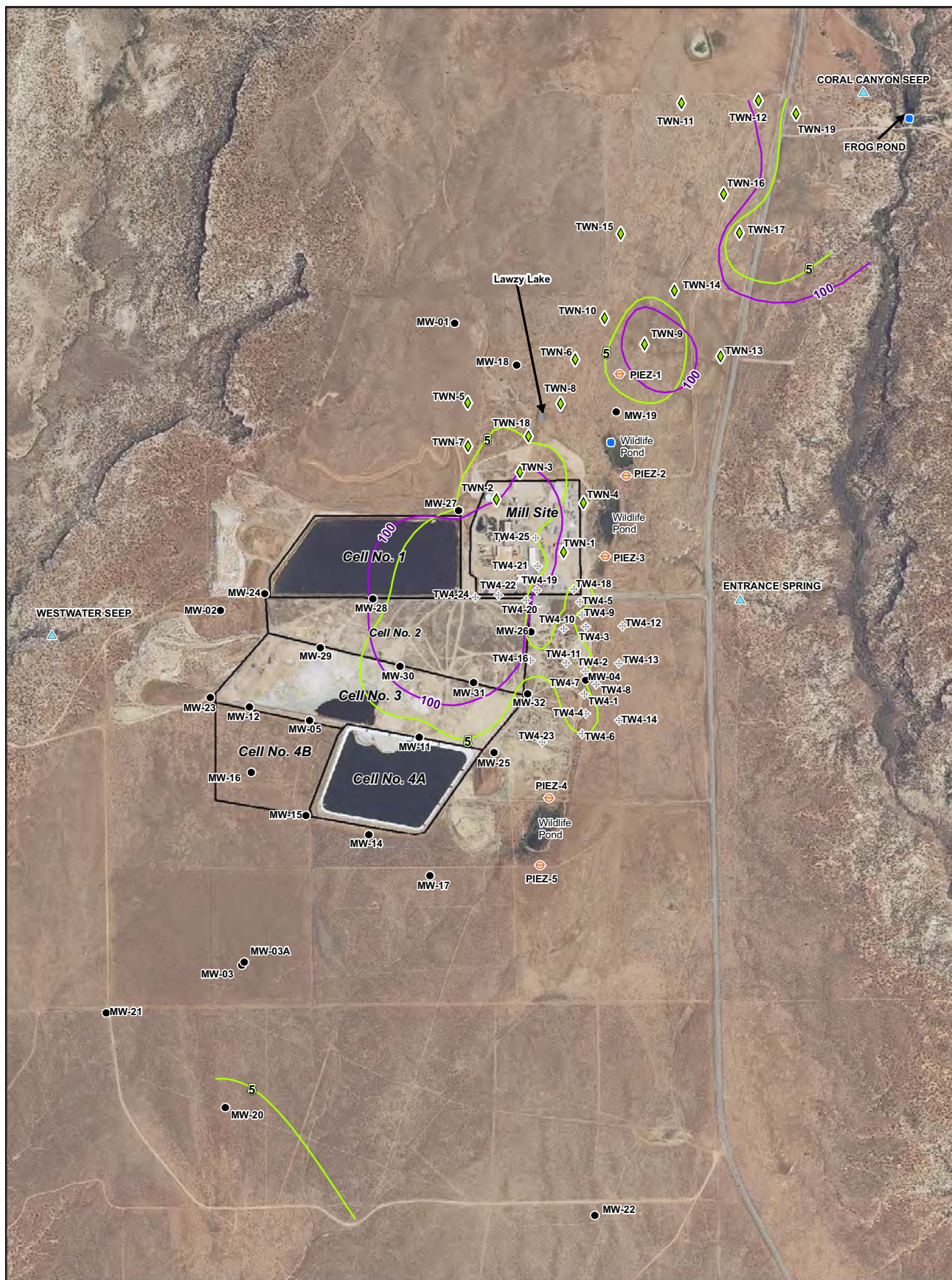
Source(s): Aerial – Utah GIS Portal website;  
Wells – HGC, Inc., May 2008 report.



Legend	
● Monitoring Well	● Surface Water
○ Piezometer	⊕ Chloroform Monitoring Well
▲ Spring/Seep	◆ Nitrate Monitoring Well
	— Chloride Concentration (mg/L)

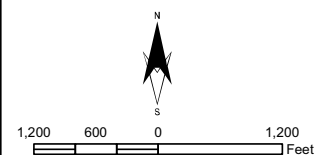
Figure 3  
Map Showing Chloride Plume  
Nitrate Investigation Revised  
Phase 2-5 Work Plan





Nitrate data from September, October, or November of 2009. A single data point was used for each well.

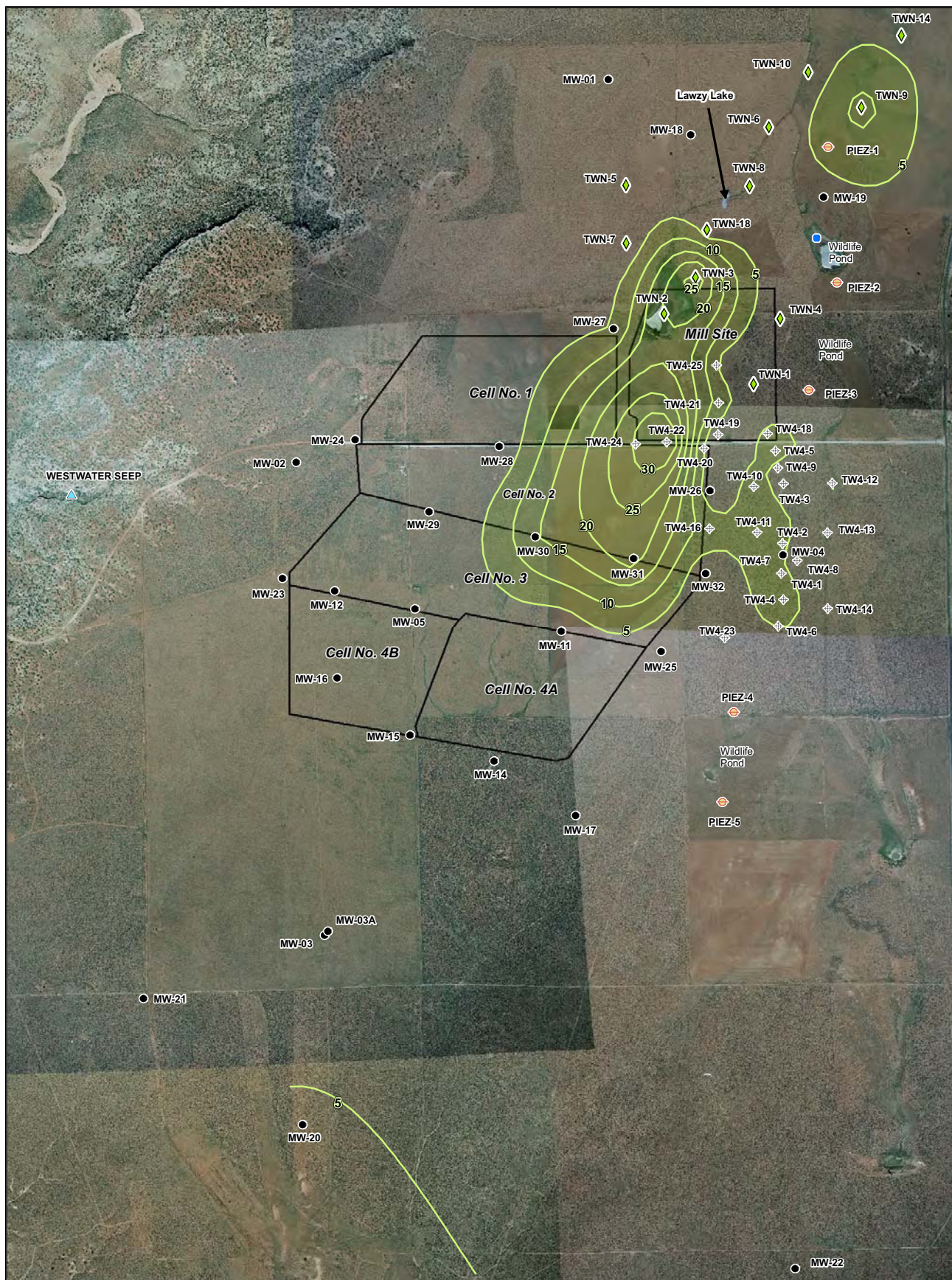
Source(s): Aerial – Utah GIS Portal website;  
Wells – HGC, Inc., May 2008 report.



Legend	
● Monitoring Well	● Surface Water
○ Piezometer	⊕ Chloroform Monitoring Well
▲ Spring/Seep	◆ Nitrate Monitoring Well
	— Nitrate Concentration (mg/L)
	— Chloride Concentration (mg/L)

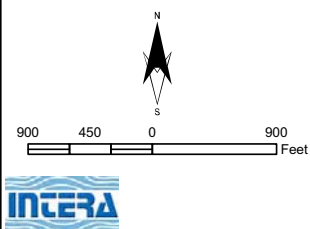
Figure 4  
Map Showing Nitrate and  
Chloride Plumes Together  
Nitrate Investigation Revised  
Phase 2-5 Work Plan





Nitrate data from September, October, or November of 2009. A single data point was used for each well.

Source(s): Aerial – EDAC, dated 1968;  
Wells – HGC, Inc., May 2008 report.



Legend	
● Monitoring Well	● Surface Water
○ Piezometer	⊕ Chloroform Monitoring Well
▲ Spring/Seep	◆ Nitrate Monitoring Well
	— Nitrate Concentration (mg/L)

**Figure 5**  
Nitrate Plume Overlain on  
1968 Aerial Photograph  
Nitrate Investigation Revised  
Phase 2-5 Work Plan



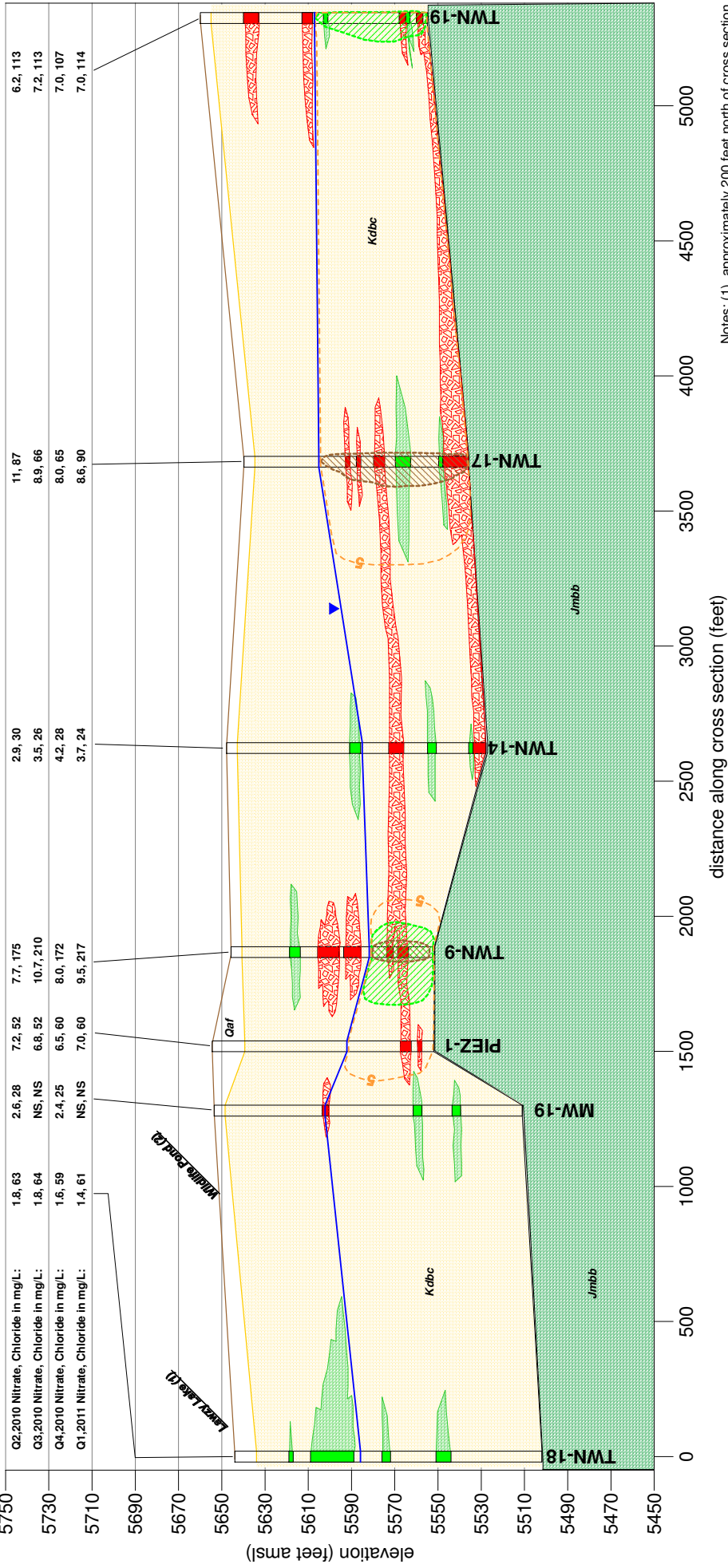






NE2

SW2

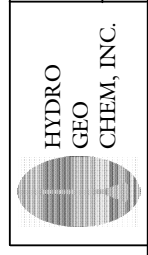


**EXPLANATION**

- Qaf Alluvium/Fill
- Kdbc Dakota Sandstone/  
Burro Canyon Formation
- Jmbb Brushy Basin Member of  
Morrison Formation
- Piezometric Surface
- Shale in Dakota /  
Burro Canyon Formation
- Conglomerate or Conglomeratic  
Sandstone in Dakota /  
Burro Canyon Formation
- Approximate 5 mg/L  
Nitrate Icocon
- Approximate Area  
> 10 mg/L Nitrate
- Approximate Area  
>100 mg/L Chloride

vertical exaggeration = 8 : 1

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



INTERPRETIVE NORTHEAST-SOUTHWEST CROSS SECTION (NE2-SW2) WHITE MESA SITE			
APPROVED	DATE	REFERENCE	FIGURE
SJS	5/24/11	H:\718000\dakota/ xsection\ne2sect\ne2sect_rev.srf	8

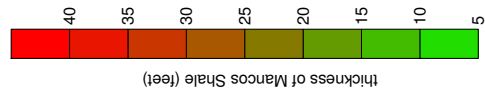


**Figures,  
continued.**

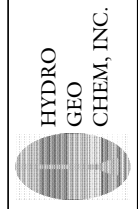
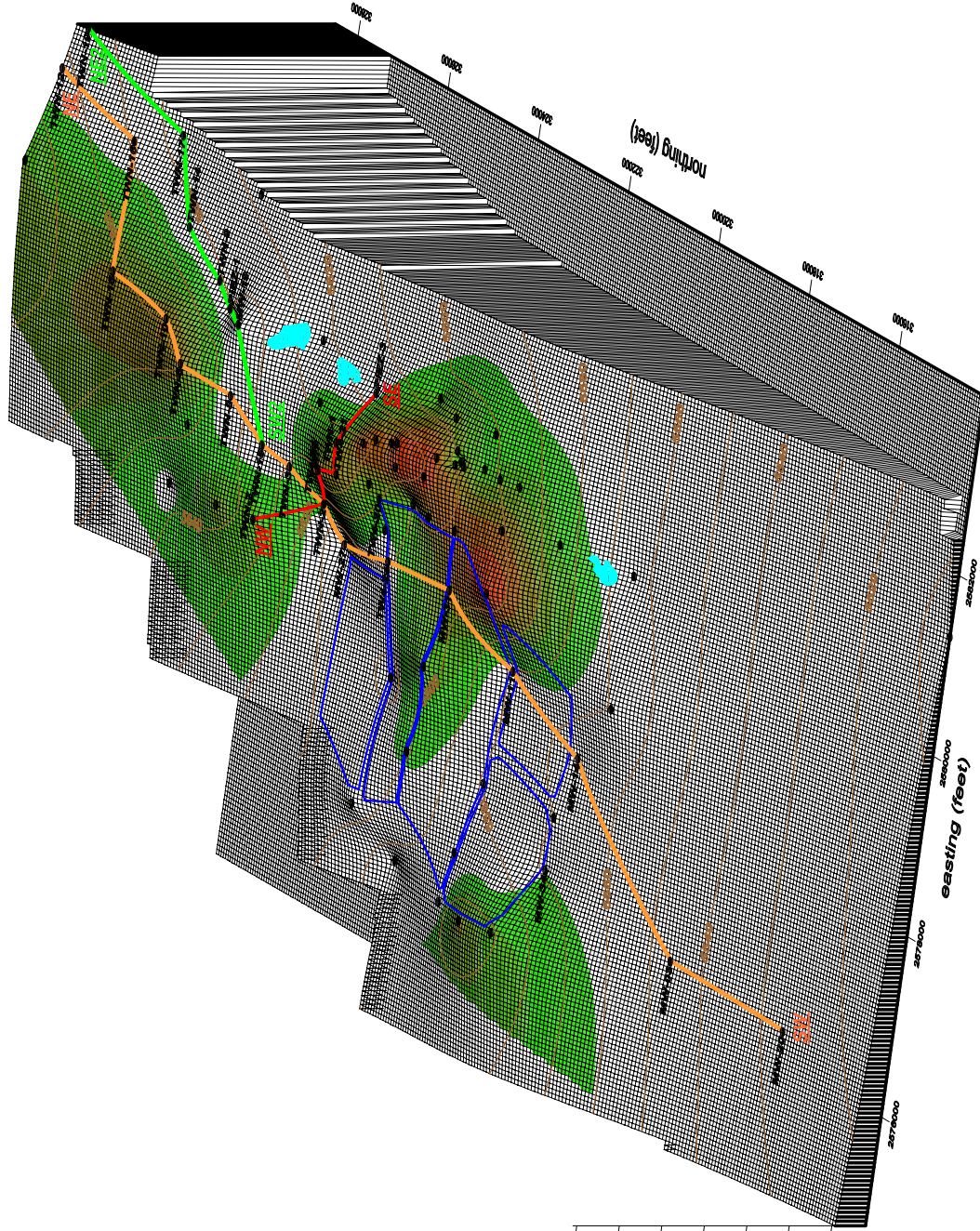


# EXPLANATION

- tailings cell outline projected onto bedrock surface
- wildlife pond
- perched monitoring well or piezometer location
- top of bedrock elevation contour



elevation (feet amsl)



ELEVATION OF BEDROCK SURFACE  
SHOWING THICKNESS OF MANCOS SHALE AND  
CROSS SECTIONS SW-NE, NW-SE, AND SW2-NE2

APPROVED	DATE	REFERENCE	FIGURE
SJS		H:\7718000\dakota\phbsr\mthck.srf	10

Nitrate at Potential Site Source  
Where Mancos is Thin  
(i.e., leach field, ammonia tanks,  
ammonium sulfate crystal tanks, etc.)

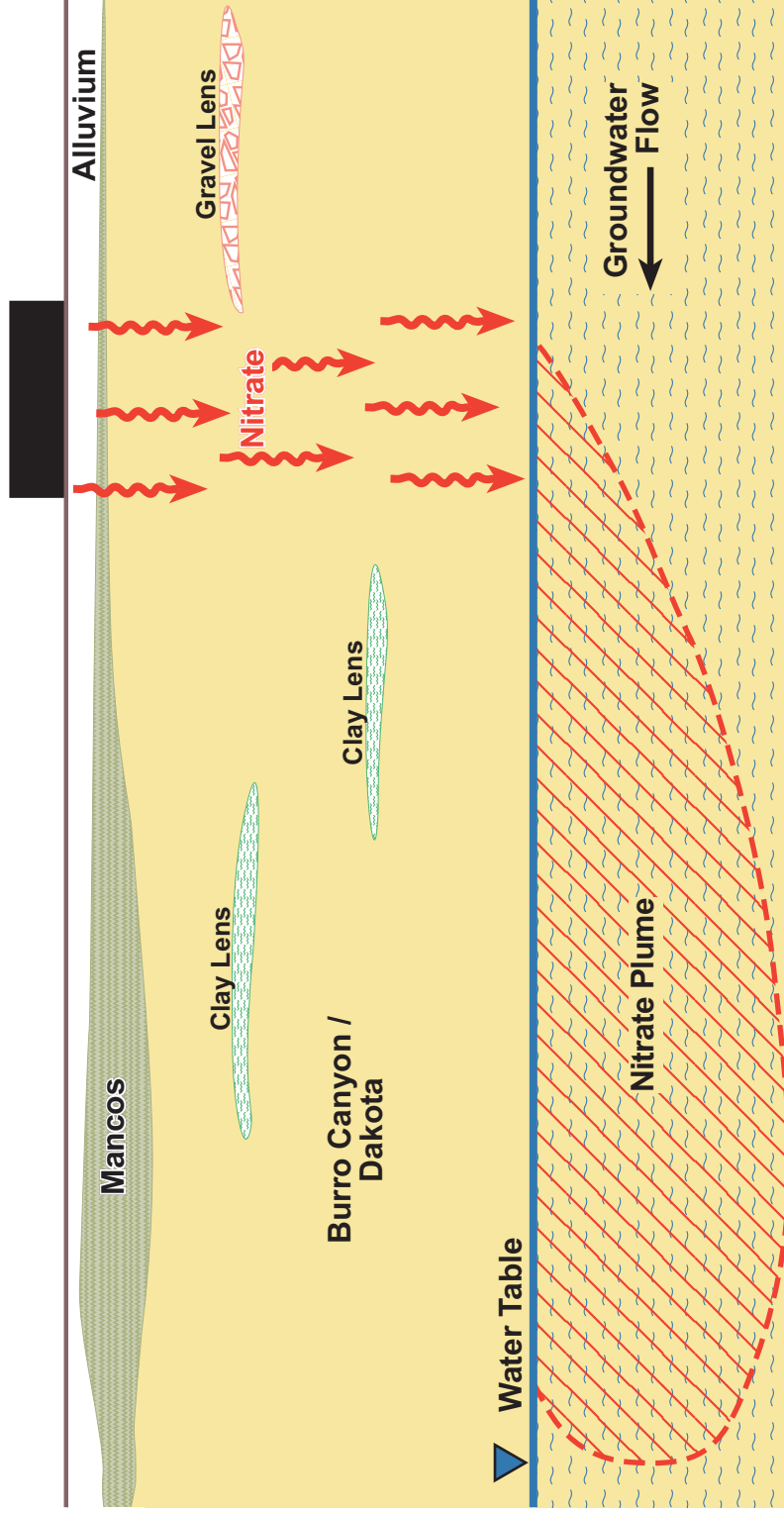


Figure 11  
Process Related Source  
Nitrate Investigation Revised  
Phase 2-5 Work Plan

Nitrate at Potential Site Source  
Where Mancos is Thick  
(i.e., leach field, ammonia tanks,  
ammonium sulfate crystal tanks, etc.)

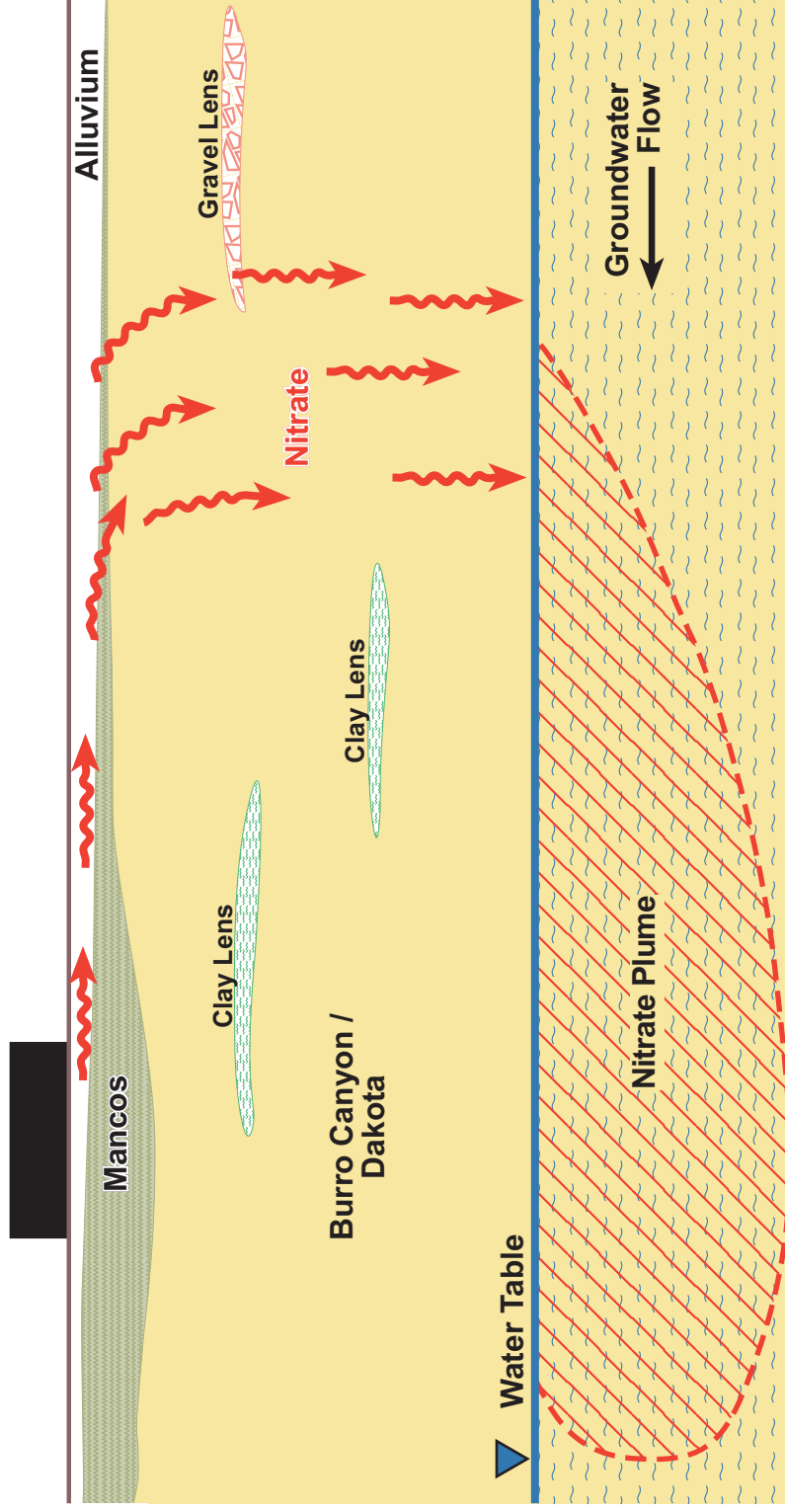


Figure 12  
Process Related Source  
Nitrate Investigation Revised  
Phase 2-5 Work Plan



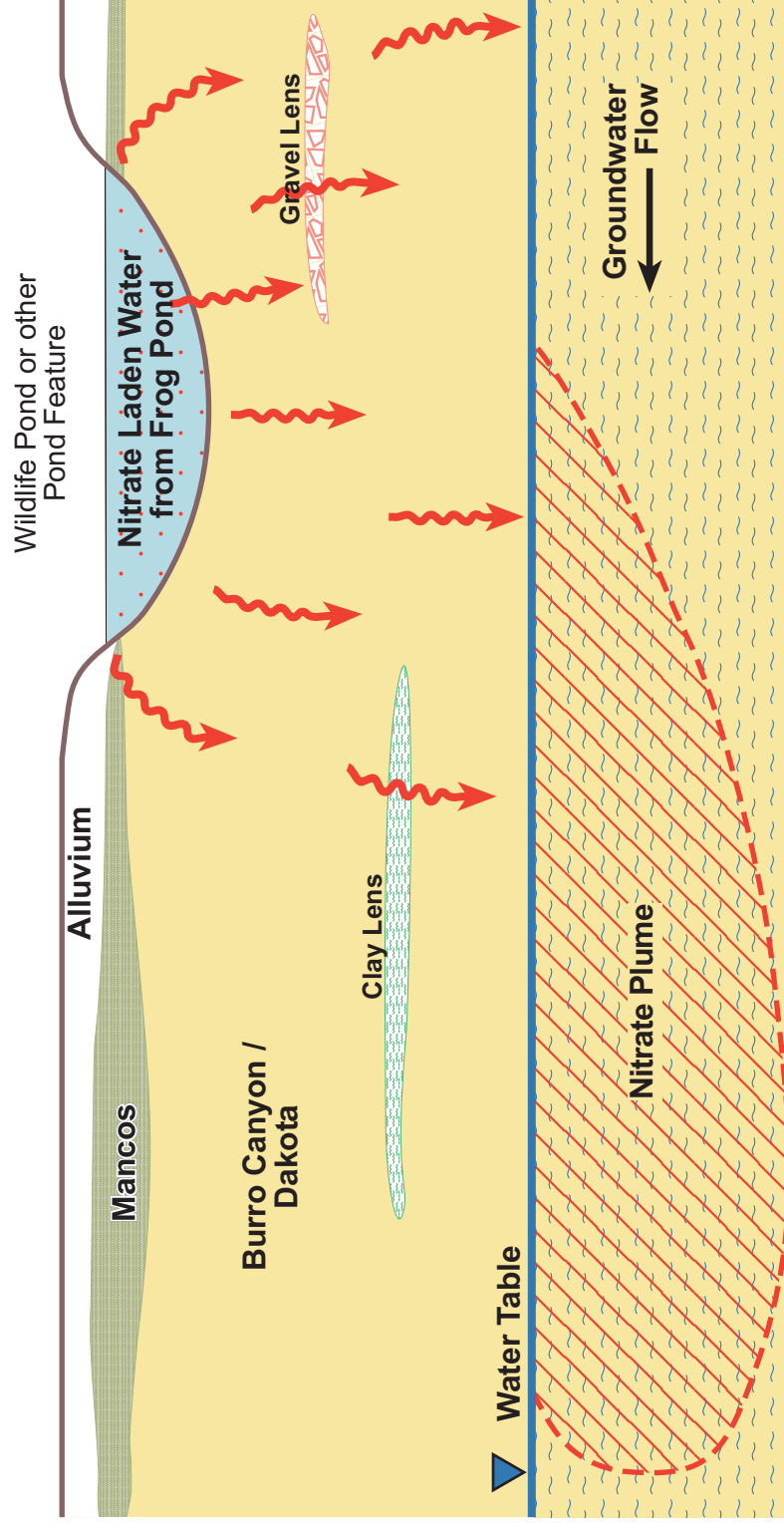


Figure 13  
Potential Pond or Pond-like Feature  
Nitrate Investigation Revised  
Phase 2-5 Work Plan

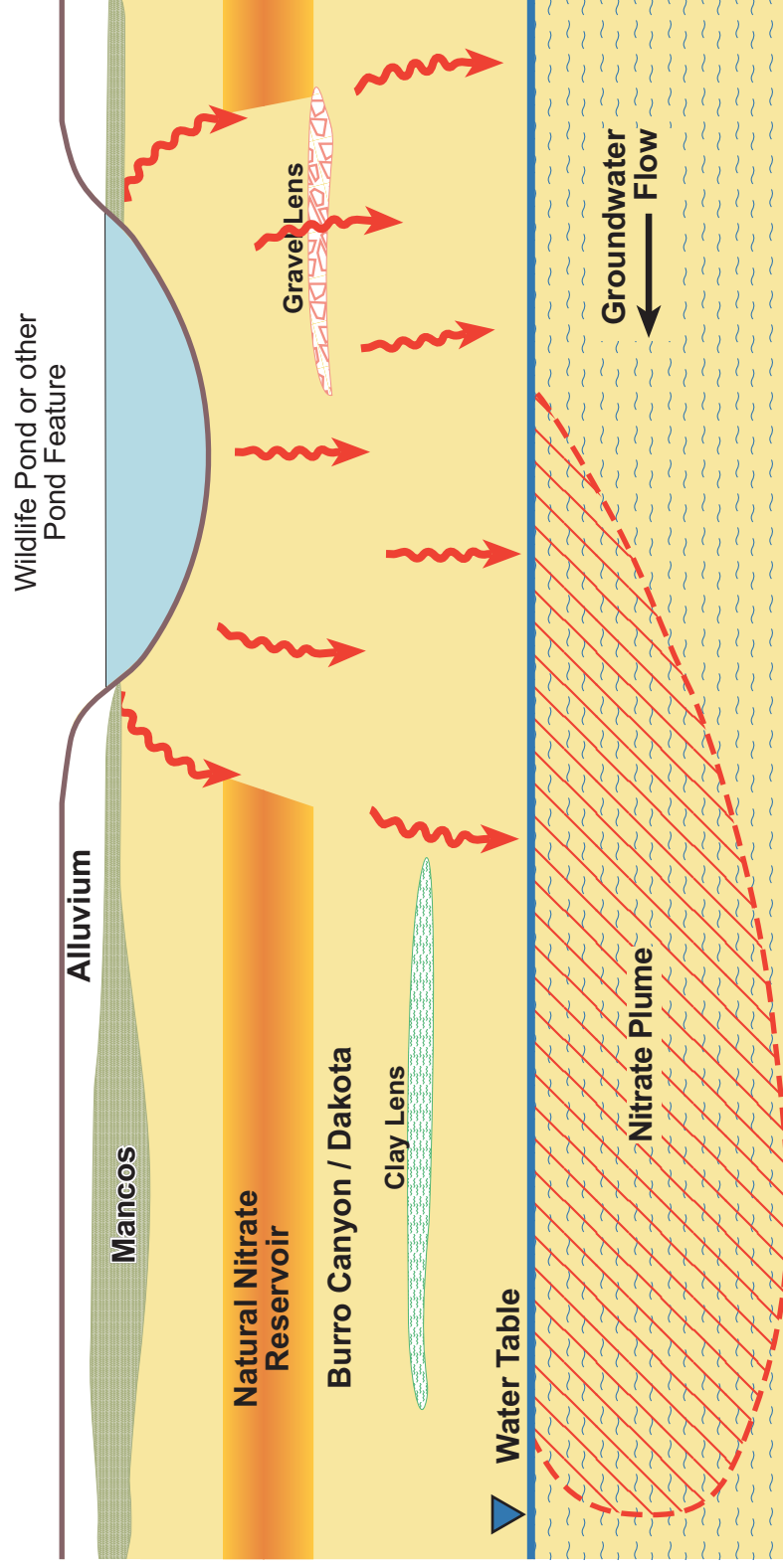
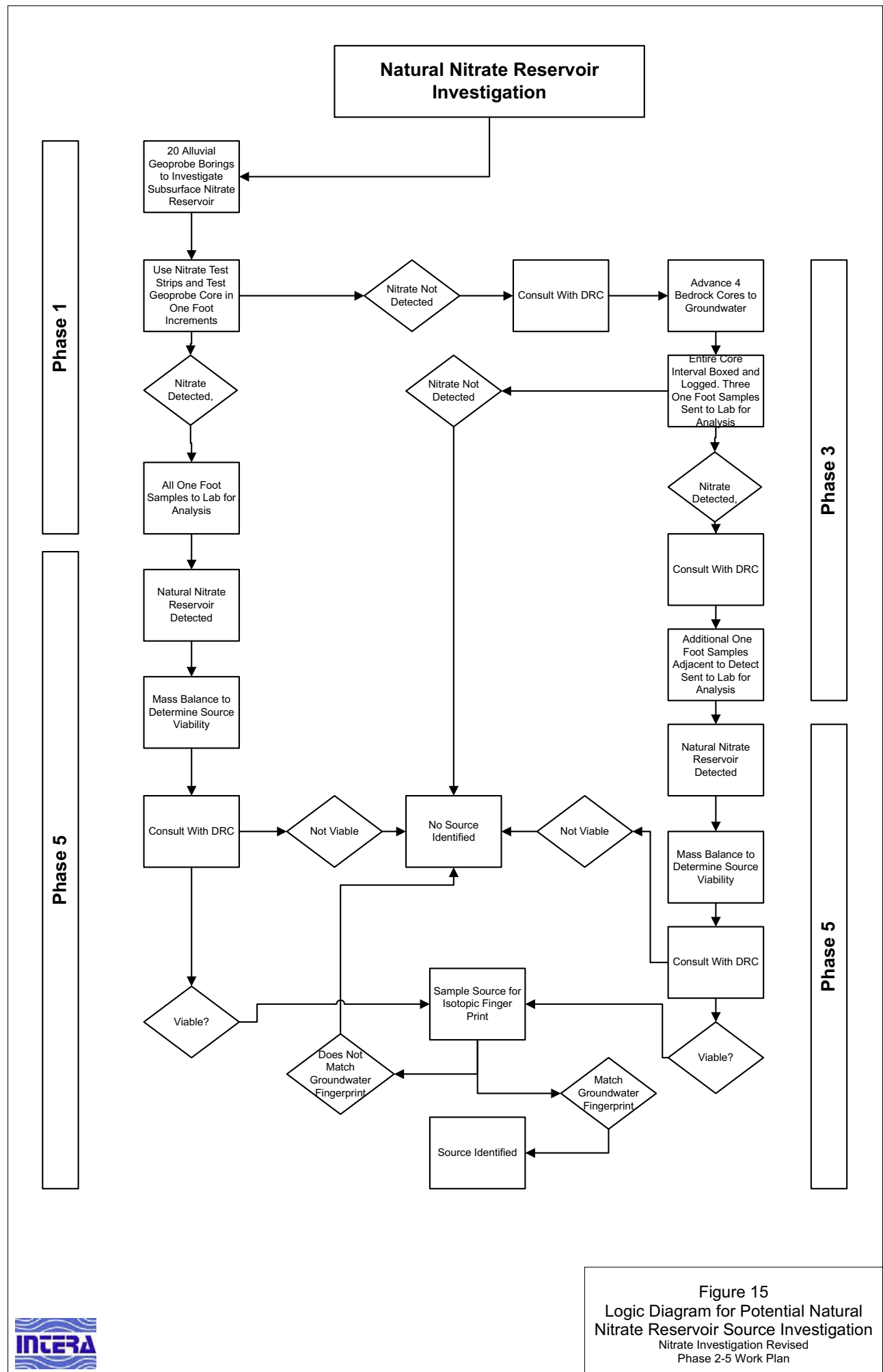
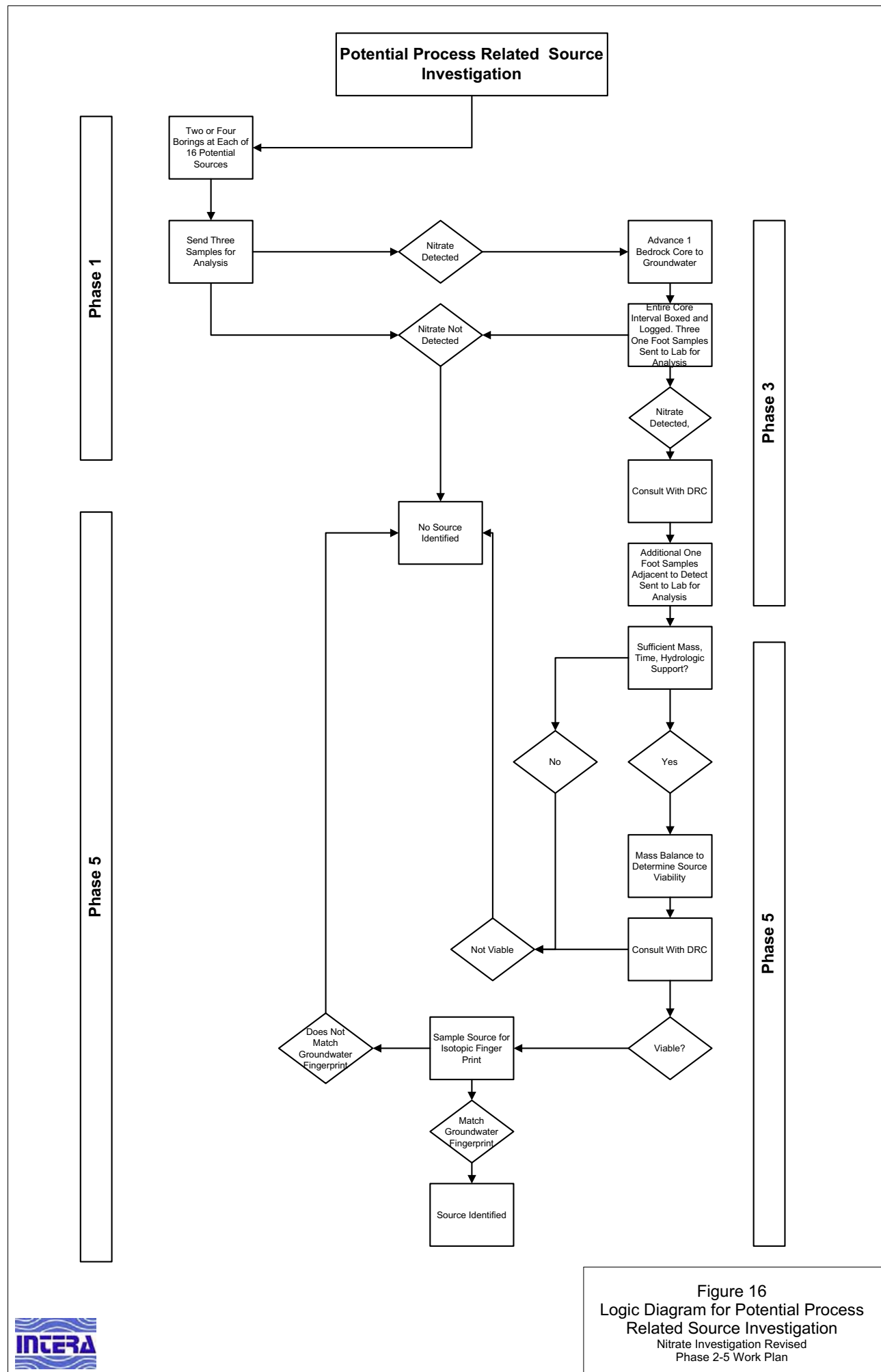
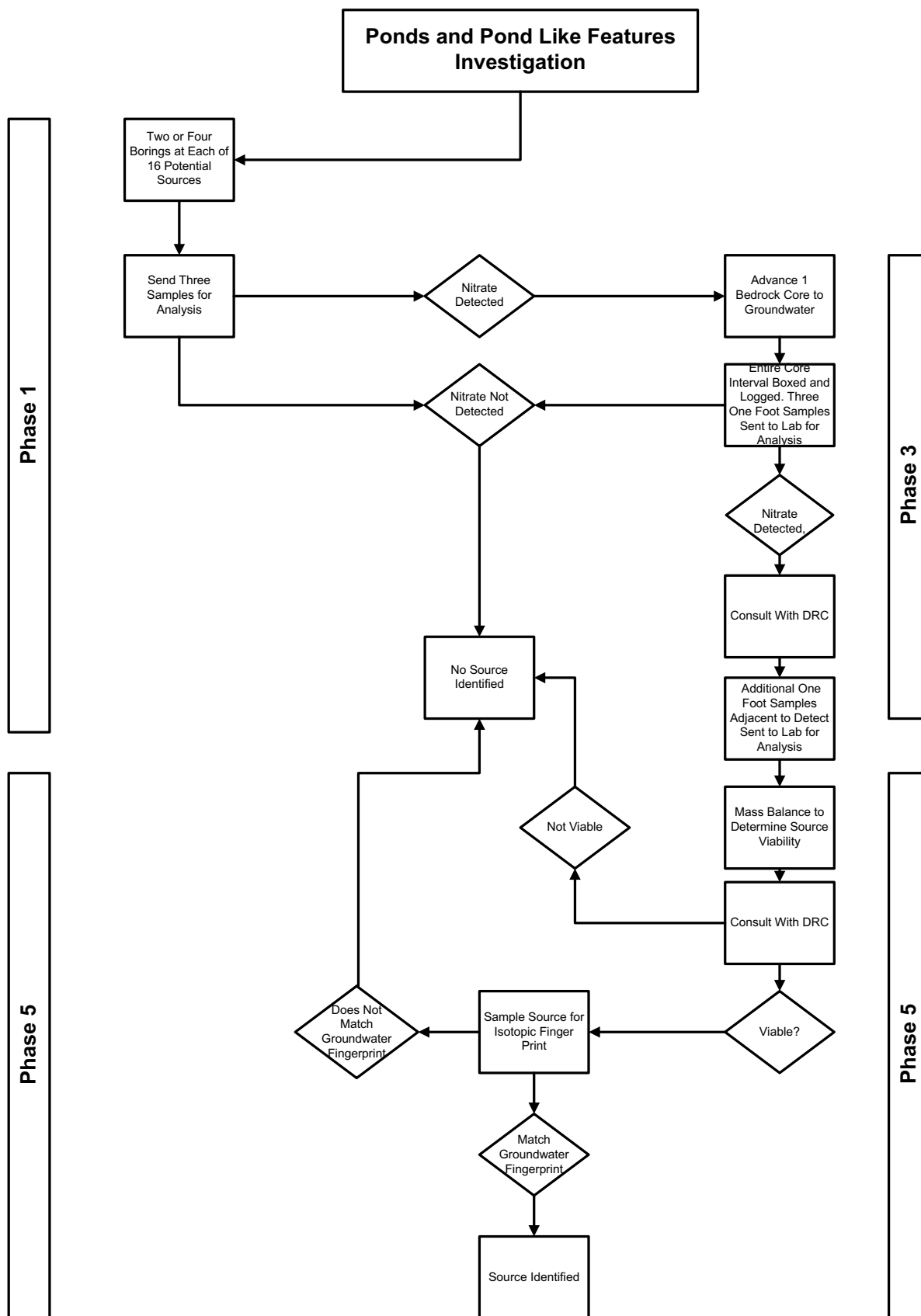


Figure 14  
 Natural Nitrate Reservoir Source  
 Nitrate Investigation Revised  
 Phase 2-5 Work Plan





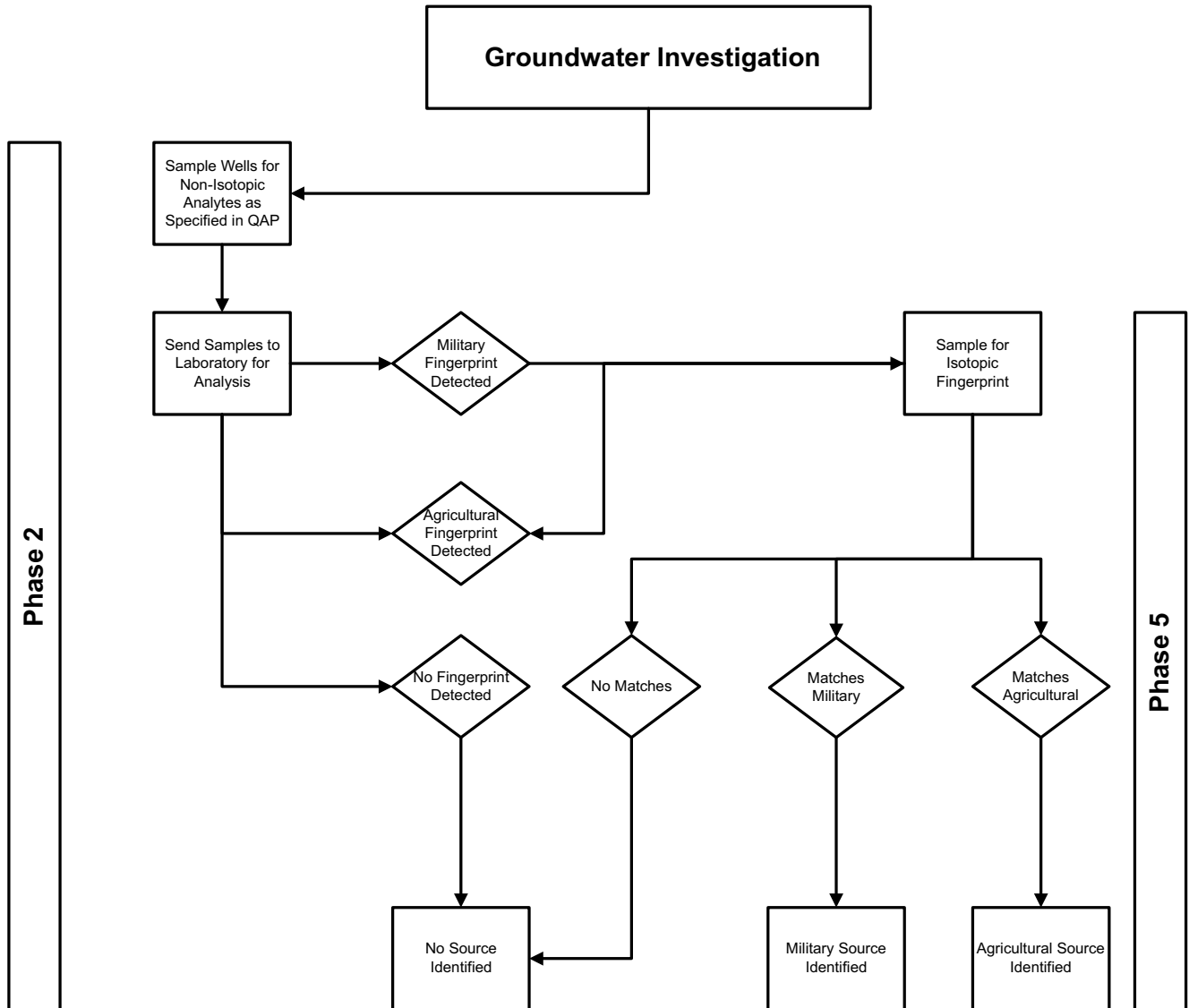




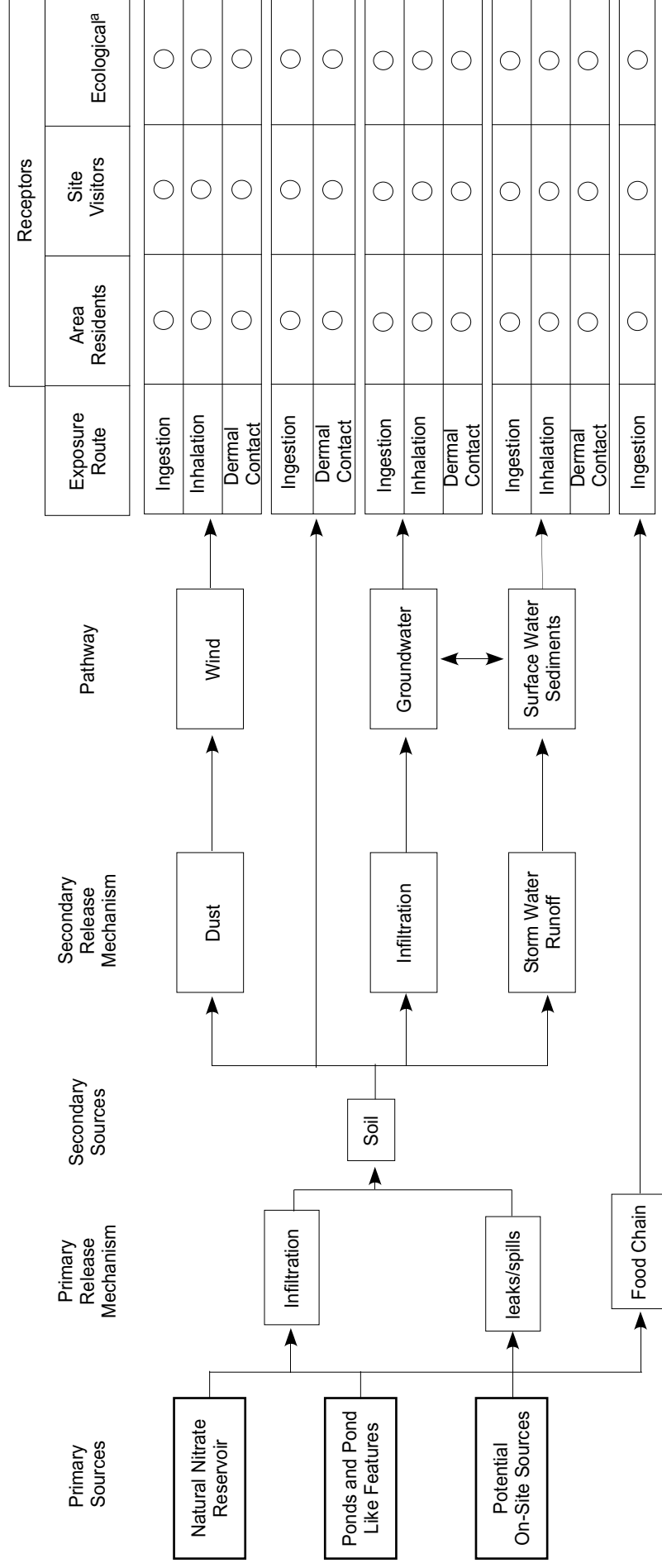
**Figure 17**  
**Logic Diagram Potential Pond**  
**and Pond-Like Source Investigation**  
 Nitrate Investigation Revised  
 Phase 2-5 Work Plan







**Figure 18**  
**Logic Diagram for**  
**Groundwater Investigation**  
 Nitrate Investigation Revised  
 Phase 2-5 Work Plan



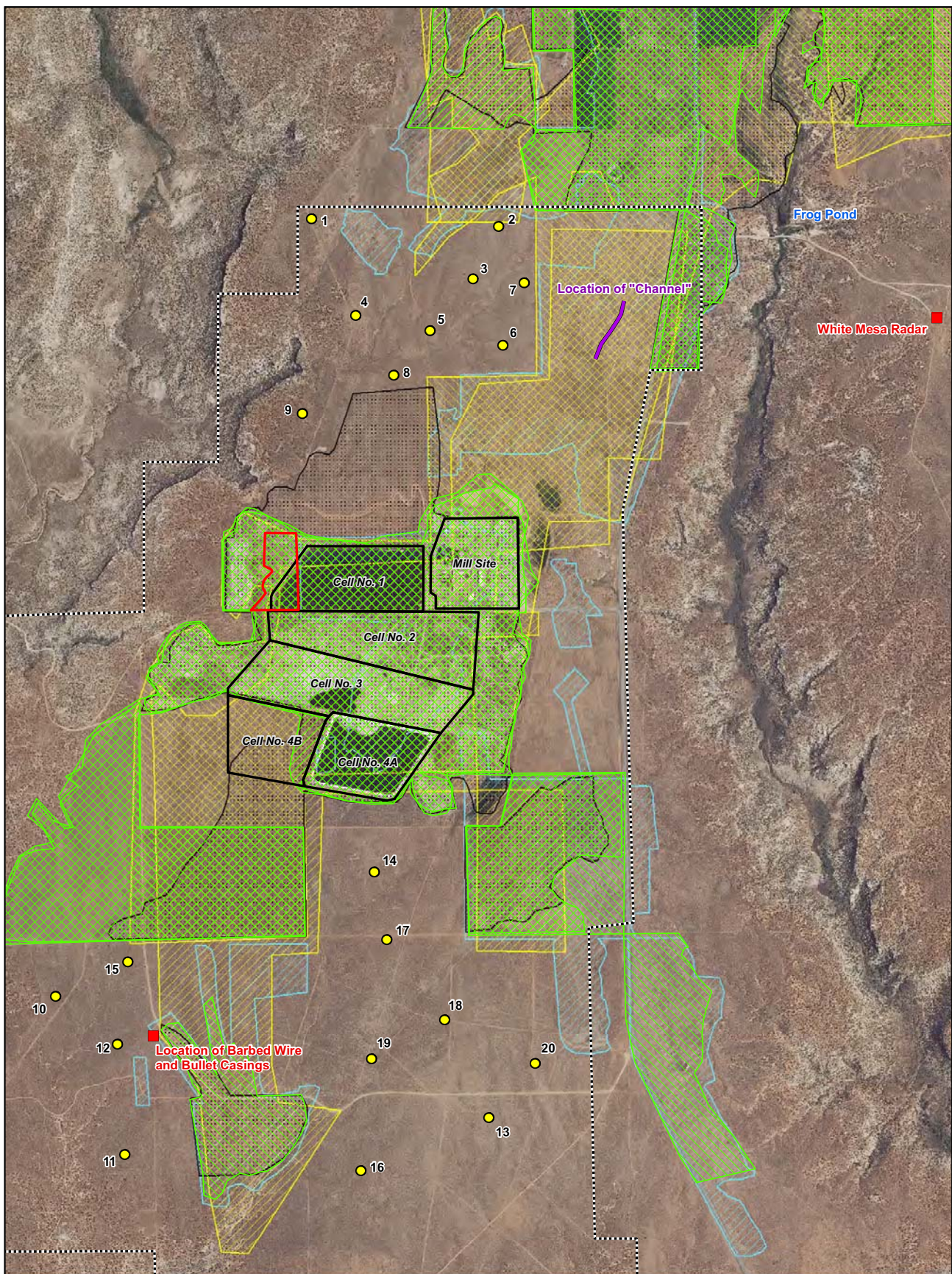
This diagram is based on Figure 2-2 of Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA and ASTM E1689-95.

- Pathway Complete, further evaluation recommended
- Pathway evaluated and found incomplete, no further evaluation recommended
- <sup>a</sup> Ecological receptors may include plants, insects, worms, mammals, and birds

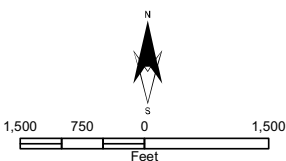


**Figure 19**  
**Diagram for Conceptual**  
**Model at White Mesa Mill**  
 Nitrate Investigation Phase 2-5  
 Revised Work Plan





Source(s): Utah GIS Portal website, dated 2009;  
U.S. Geological Survey



Legend	
<span style="color: yellow;">●</span> Geoprobe Boring Location	<span style="background-color: #d9ead3; border: 1px solid black;"> </span> Historical Disturbance (From 2009 Imagery)
<span style="border: 2px solid red;"> </span> Pershing Missile Staging Area	<span style="background-color: #f4cccc; border: 1px solid black;"> </span> Historical Disturbance (From 2006 Imagery)
<span style="border: 1px dashed black;"> </span> DUSA Property Boundary	<span style="background-color: #fce4d6; border: 1px solid black;"> </span> Historical Disturbance (From 1997 Imagery)
	<span style="background-color: #fff2cc; border: 1px solid black;"> </span> Historical Disturbance (From 1984 Imagery)
	<span style="background-color: #fff2cc; border: 1px solid black;"> </span> Historical Disturbance (From 1973 Imagery)
	<span style="background-color: #fff2cc; border: 1px solid black;"> </span> Historical Disturbance (From 1955 Imagery)

**Figure 20**  
**Coring Locations**  
Nitrate Investigation Revised  
Phase 2-5 Work Plan



## Tables

**Table 2: Summary of the Most Recent  
Chloride and Nitrate Concentrations in Groundwater**

Well	Date	Chloride (mg/L)	Qual	Nitrate (mg/L)	Qual
MW-1	11/18/2010	15		0.1	U
MW-2	11/17/2010	7		0.05	U
MW-3	11/19/2010	63		0.4	
MW-3A	11/22/2010	59		1.2	
MW-4	2/23/2011	40		4.6	D
MW-5	11/11/2010	52		0.2	
MW-11	2/2/2011	32		0.1	U
MW-12	11/19/2010	63		0.1	U
MW-14	2/7/2011	20		0.1	U
MW-15	11/11/2010	41		0.1	
MW-17	11/17/2010	38		0.9	
MW-18	11/18/2010	52		0.1	U
MW-19	11/18/2010	25		2.4	D
MW-20	2/16/2011	64		4.1	D
MW-22	2/8/2011	57		2.5	D
MW-23	11/22/2010	9		0.2	
MW-24	11/17/2010	48		0.1	
MW-25	2/2/2011	30		0.1	U
MW-26	2/16/2011	59		0.6	
MW-27	2/9/2011	46		6	D
MW-28	11/12/2010	107		0.2	
MW-29	11/9/2010	39		0.1	U
MW-30	2/1/2011	134		16	D
MW-31	2/1/2011	145		21	D
MW-32	11/10/2010	35		0.1	U
Piez-1	1/31/2011	60		7	D
Piez-2	1/31/2011	9		0.3	
Piez-3	1/31/2011	40		1.8	D
TW4-1	2/24/2011	41		6.6	D
TW4-10	2/23/2011	62		9	D
TW4-11	2/23/2011	46		6.5	D
TW4-12	2/15/2011	31		6.5	D
TW4-13	2/15/2011	60		5.5	D
TW4-14	2/15/2011	25		1.8	D
TW4-16	2/22/2011	86		7	D
TW4-17	2/23/2011	40		0.1	U
TW4-18	2/22/2011	52		10	D
TW4-19	2/17/2011	135		17	D
TW4-2	2/24/2011	46		7	D
TW4-20	2/23/2011	220		4.4	D
TW4-21	2/22/2011	303		9	D

**Table 2: Summary of the Most Recent  
Chloride and Nitrate Concentrations in Groundwater**

Well	Date	Chloride (mg/L)	Qual	Nitrate (mg/L)	Qual
TW4-22	2/23/2011	114		18	D
TW4-23	2/16/2011	44		0.1	U
TW4-24	2/17/2011	1100		31	D
TW4-25	2/16/2011	315		15	D
TW4-26	2/22/2011	30		10	D
TW4-3	2/15/2011	23		3.5	D
TW4-4	2/23/2011	41		7	D
TW4-5	2/22/2011	34		7	D
TW4-6	2/23/2011	40		0.7	
TW4-7	2/23/2011	45		3.6	D
TW4-8	2/16/2011	52		0.1	U
TW4-9	2/17/2011	41		1.3	
TWN-1	1/26/2011	17		0.5	
TWN-10	1/27/2011	40		0.3	
TWN-11	1/27/2011	84		1.4	
TWN-12	1/26/2011	87		4.2	D
TWN-13	1/25/2011	103		1.6	D
TWN-14	1/28/2011	24		3.7	D
TWN-15	1/27/2011	43		1.4	
TWN-16	1/27/2011	34		4.6	D
TWN-17	2/1/2011	90		8.6	D
TWN-18	1/27/2011	61		1.4	
TWN-19	2/1/2011	114		7	D
TWN-2	2/1/2011	93		43	D
TWN-3	2/1/2011	138		24	D
TWN-4	1/25/2011	21		0.9	
TWN-5	1/25/2011	47		0.4	
TWN-6	1/26/2011	18		1.1	
TWN-7	1/27/2011	6		1.3	
TWN-8	1/25/2011	13		0.1	U
TWN-9	2/1/2011	217		9.5	D
UWLP	1/31/2011	1		0.1	

Table 3: Phase 3 Coring Sample Locations

Boring Location <sup>a</sup>	Sample Location ID <sup>b,c</sup>	Date & Time Sampled	Number of Samples	DTW (ft bgs)	TD (ft bgs)	Sample Interval (ft bgs)	Sample Interval (ft bgs)	Sample Interval (ft bgs)	Sample Interval (ft bgs)	Duplicate Collected	Duplicate Location ID <sup>c</sup>	Matrix	Minimum Sample Mass/Volume	Sample Container <sup>d</sup>	Analyte (Method)	Comments
Phase 3A - Deep Bedrock Coring in Undisturbed Locations																
TBD	C-11A-tt-dd										C-11A-tt-dd	Rock	200 g	Ziploc Bag	Nitrate+Nitrite (EPA 353.2) Chloride and Sulfate (EPA 300.0) Ammonia (EPA 350.1)	
TBD	C-11A-tt-dd											Rock	200 g	Ziploc Bag	Nitrate+Nitrite (EPA 353.2) Chloride and Sulfate (EPA 300.0) Ammonia (EPA 350.1)	
TBD	C-11A-tt-dd											Rock	200 g	Ziploc Bag	Nitrate+Nitrite (EPA 353.2) Chloride and Sulfate (EPA 300.0) Ammonia (EPA 350.1)	
TBD	C-11A-tt-dd											Rock	200 g	Ziploc Bag	Nitrate+Nitrite (EPA 353.2) Chloride and Sulfate (EPA 300.0) Ammonia (EPA 350.1)	
TBD	C-11A-RB		1								NA	Aqueous	250 mL	Two (2) 4-oz. Plastic or Glass	Nitrate+Nitrite (EPA 353.2) Chloride and Sulfate (EPA 300.0) Ammonia (EPA 350.1)	
Phase 3B - Deep Bedrock Coring of Potential Nitrate Source Locations																
TBD	C-11B-tt-dd										C-11B-tt-dd	Rock	200 g	Ziploc Bag	Nitrate+Nitrite (EPA 353.2) Chloride and Sulfate (EPA 300.0) Ammonia (EPA 350.1)	
TBD	C-11B-tt-dd											Rock	200 g	Ziploc Bag	Nitrate+Nitrite (EPA 353.2) Chloride and Sulfate (EPA 300.0) Ammonia (EPA 350.1)	
TBD	C-11B-tt-dd											Rock	200 g	Ziploc Bag	Nitrate+Nitrite (EPA 353.2) Chloride and Sulfate (EPA 300.0) Ammonia (EPA 350.1)	
TBD	C-11B-tt-dd											Rock	200 g	Ziploc Bag	Nitrate+Nitrite (EPA 353.2) Chloride and Sulfate (EPA 300.0) Ammonia (EPA 350.1)	
TBD	C-11B-RB		1								NA	Aqueous	250 mL	Two (2) 250-mL Plastic	Nitrate+Nitrite (EPA 353.2) Chloride and Sulfate (EPA 300.0) Ammonia (EPA 350.1)	

<sup>a</sup> Locations to be determined upon receiving Phase 1 laboratory analytical results

<sup>b</sup> 11A is the location ID from Phase 1 and tt-dd is the sample depth interval

<sup>c</sup> Duplicate sample location and equipment blank sample location subject to change due to field conditions at discretion of field team leader

<sup>d</sup> Sample preservation methods and holding times shown in Table 5

**Table 4: Phase 3 Coring Laboratory Analytical Parameters**

Analyte	Analytical Method	Reporting Limit	Holding Time	Preservation	Temperature Requirement
SPLP Leachate	EPA 1312*	NA	28 days	None	Cool to ≤4°C
Nitrate+Nitrite	EPA 353.2	0.01 mg/L	28 days	H <sub>2</sub> SO <sub>4</sub> to a pH <2**	Cool to ≤4°C**
Chloride and Sulfate	EPA 300.0	Chloride – 0.1 mg/L Sulfate – 0.75 mg/L	28 days	None**	Cool to ≤4°C**
Ammonia as N	EPA 350.1	0.05 mg/L	28 days	H <sub>2</sub> SO <sub>4</sub> to a pH <2**	Cool to ≤4°C**

\* Extraction Fluid 3 will be used. Standard extraction requires the addition of nitric acid and sulfuric acid during the leaching process. Since the leachates will be analyzed for nitrate+nitrite and sulfate, the DI leaching process contemplated by the method (for cyanide containing samples) will be used in lieu of the standard leaching procedure.

\*\* Preservation and temperature requirements listed are for the leachates generated from the SPLP leaching procedure 1312 and for the equipment rinsate samples collected during drilling activities.



**Appendix A**  
**ASTM E1689 Standard Guidance for**  
**Development of a Conceptual Site Model**



## Standard Guide for Developing Conceptual Site Models for Contaminated Sites<sup>1</sup>

This standard is issued under the fixed designation E1689; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This guide is intended to assist in the development of conceptual site models to be used for the following: (1) integration of technical information from various sources, (2) support the selection of sample locations for establishing background concentrations of substances, (3) identify data needs and guide data collection activities, and (4) evaluate the risk to human health and the environment posed by a contaminated site. This guide generally describes the major components of conceptual site models, provides an outline for developing models, and presents an example of the parts of a model. This guide does not provide a detailed description of a site-specific conceptual site model because conditions at contaminated sites can vary greatly from one site to another.

1.2 The values stated in either inch-pound or SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 This guide is intended to apply to any contaminated site.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>2</sup>

**D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass**

#### 2.2 EPA Documents:<sup>3</sup>

*Guidance for Data Useability in Risk Assessment (Part A)*

*Final, Publication 9285.7-09A, PB 92-963356, April 1992*

*Guidance for Data Useability in Risk Assessment (Part B), OSWER Directive 9285.7-09B, May 1992*

*Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, OSWER Directive 9355.3-01, October 1988*

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *background concentration, n*—the concentration of a substance in ground water, surface water, air, sediment, or soil at a source(s) or nearby reference location, and not attributable to the source(s) under consideration. Background samples may be contaminated, either by naturally occurring or manmade sources, but not by the source(s) in question.

3.1.2 *conceptual site model, n*—for the purpose of this guide, a written or pictorial representation of an environmental system and the biological, physical, and chemical processes that determine the transport of contaminants from sources through environmental media to environmental receptors within the system.

3.1.3 *contaminant, n*—any substance, including any radiological material, that is potentially hazardous to human health or the environment and is present in the environment at concentrations above its background concentration.

3.1.4 *contaminant release, n*—movement of a substance from a source into an environmental medium, for example, a leak, spill, volatilization, runoff, fugitive dust emission, or leaching.

3.1.5 *environmental receptor, n*—humans and other living organisms potentially exposed to and adversely affected by contaminants because they are present at the source(s) or along contaminant migration pathways.

3.1.6 *environmental transport, n*—movement of a chemical or physical agent in the environment after it has been released from a source to an environmental medium, for example, movement through the air, surface water, ground water, soil, sediment, or food chain.

3.1.7 *exposure route, n*—the process by which a contaminant or physical agent in the environment comes into direct contact with the body, tissues, or exchange boundaries of an

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee E47 on Biological Effects and Environmental Fate and is the direct responsibility of Subcommittee E47.05 on Risk Assessment, Communication and Management.

Current edition approved Feb. 1, 2008. Published February 2008. Originally approved in 1995. Last previous edition approved in 2003 as E1689-95(2003)<sup>ε1</sup>. DOI: 10.1520/E1689-95R08.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from Standardization Documents Order Desk, Bldg 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.



environmental receptor organism, for example, ingestion, inhalation, dermal absorption, root uptake, and gill uptake.

3.1.8 *migration pathway, n*—the course through which contaminants in the environment may move away from the source(s) to potential environmental receptors.

3.1.9 *source, n*—the location from which a contaminant(s) has entered or may enter a physical system. A primary source, such as a location at which drums have leaked onto surface soils, may produce a secondary source, such as contaminated soils; sources may hence be primary or secondary.

## 4. Summary of Guide

4.1 The six basic activities associated with developing a conceptual site model (not necessarily listed in the order in which they should be addressed) are as follows: (1) identification of potential contaminants; (2) identification and characterization of the source(s) of contaminants; (3) delineation of potential migration pathways through environmental media, such as ground water, surface water, soils, sediment, biota, and air; (4) establishment of background areas of contaminants for each contaminated medium; (5) identification and characterization of potential environmental receptors (human and ecological); and (6) determination of the limits of the study area or system boundaries.

4.2 The complexity of a conceptual site model should be consistent with the complexity of the site and available data. The development of a conceptual site model will usually be iterative. Model development should start as early in the site investigation process as possible. The model should be refined and revised throughout the site investigation process to incorporate additional site data. The final model should contain sufficient information to support the development of current and future exposure scenarios.

4.3 The concerns of ecological risk assessment are different from those of human-health risk assessment, for example, important migration pathways, exposure routes, and environmental receptors. These differences are usually sufficient to warrant separate descriptions and representations of the conceptual site model in the human health and ecological risk assessment reports. There will be elements of the conceptual site model that are common to both representations, however, and the risk assessors should develop these together to ensure consistency.

## 5. Significance and Use

5.1 The information gained through the site investigation is used to characterize the physical, biological, and chemical systems existing at a site. The processes that determine contaminant releases, contaminant migration, and environmental receptor exposure to contaminants are described and integrated in a conceptual site model.

5.2 Development of this model is critical for determining potential exposure routes (for example, ingestion and inhalation) and for suggesting possible effects of the contaminants on human health and the environment. Uncertainties associated with the conceptual site model need to be identified clearly so that efforts can be taken to reduce these uncertainties to acceptable levels. Early versions of the model, which are

usually based on limited or incomplete information, will identify and emphasize the uncertainties that should be addressed.

5.3 The conceptual site model is used to integrate all site information and to determine whether information including data are missing (data gaps) and whether additional information needs to be collected at the site. The model is used furthermore to facilitate the selection of remedial alternatives and to evaluate the effectiveness of remedial actions in reducing the exposure of environmental receptors to contaminants.

5.4 This guide is not meant to replace regulatory requirements for conducting environmental site characterizations at contaminated (including radiologically contaminated) sites. It should supplement existing guidance and promote a uniform approach to developing conceptual site models.

5.5 This guide is meant to be used by all those involved in developing conceptual site models. This should ideally include representatives from all phases of the investigative and remedial process, for example, preliminary assessment, remedial investigation, baseline human health and ecological risk assessments, and feasibility study. The conceptual site model should be used to enable experts from all disciplines to communicate effectively with one another, resolve issues concerning the site, and facilitate the decision-making process.

5.6 The steps in the procedure for developing conceptual site models include elements sometimes referred to collectively as site characterization. Although not within the scope of this guide, the conceptual site model can be used during site remediation.

## 6. Procedure

6.1 *Assembling Information*—Assemble historical and current site-related information from maps, aerial images, cross sections, environmental data, records, reports, studies, and other information sources. A visit(s) to the site by those preparing the conceptual site model is recommended highly. The quality of the information being assembled should be evaluated, preferably including quantitative methods, and the decision to use the information should be based on the data's meeting objective qualitative and quantitative criteria. For more information on assessing the quality and accuracy of data, see *Guidance for Data Useability in Risk Assessment (Part A)* and *Guidance for Data Useability in Risk Assessment (Part B)*. Methods used for obtaining analytical data should be described, and sources of information should be referenced. A conceptual site model should be developed for every site unless there are multiple sites in proximity to one another such that it is not possible to determine the individual source or sources of contamination. Sites may be aggregated in that case. A conceptual model should then be developed for the aggregate.

6.2 *Identifying Contaminants*—Identify contaminants in the ground water, surface water, soils, sediments, biota, and air. If no contaminants are found, the conceptual site model should be used to help document this finding.

6.3 *Establishing Background Concentrations of Contaminants*—Background samples serve three major functions: (1) to establish the range of concentrations of an analyte attributable to natural occurrence at the site; (2) to establish the range of concentrations of an analyte attributable to source(s)



other than the source(s) under consideration; and (3) to help establish the extent to which contamination exceeds background levels.

6.3.1 The conceptual site model should include the naturally occurring concentrations of all contaminants found at the site. The number and location of samples needed to establish background concentrations in each medium will vary with specific site conditions and requirements. The model should include sufficient background samples to distinguish contamination attributable to the source(s) under consideration from naturally occurring or nearby anthropogenic contamination. The procedures mentioned in 6.2 and 6.3 are sometimes grouped under the general heading of contaminant assessment and may be performed as a separate activity prior to the development of a conceptual site model.

6.4 *Characterizing Sources*—At a minimum, the following source characteristics should be measured or estimated for a site:

6.4.1 Source location(s), boundaries, and volume(s). Sources should be located accurately on site maps. Maps should include a scale and direction indicator (for example, north arrow). They should furthermore show where the source(s) is located in relationship to the property boundaries.

6.4.2 The potentially hazardous constituents and their concentrations in media at the source.

6.4.3 The time of initiation, duration, and rate of contaminant release from the source.

6.5 *Identifying Migration Pathways*—Potential migration pathways through ground water, surface water, air, soils, sediments, and biota should be identified for each source. Complete exposure pathways should be identified and distinguished from incomplete pathways. An exposure pathway is incomplete if any of the following elements are missing: (1) a mechanism of contaminant release from primary or secondary sources, (2) a transport medium if potential environmental receptors are not located at the source, and (3) a point of potential contact of environmental receptors with the contaminated medium. The potential for both current and future releases and migration of the contaminants along the complete pathways to the environmental receptors should be determined. A diagram (similar to that in Fig. X1.4) of exposure pathways for all source types at a site should be constructed. This information should be consistent with the narrative portion and tables in the exposure assessment section of an exposure or risk assessment. Tracking contaminant migration from sources to environmental receptors is one of the most important uses of the conceptual site model.

6.5.1 *Ground Water Pathway*—This pathway should be considered when hazardous solids or liquids have or may have come into contact with the surface or subsurface soil or rock. The following should be considered further in that case: vertical distance to the saturated zone; subsurface flow rates; presence and proximity of downgradient seeps, springs, or caves; fractures or other preferred flow paths; artesian conditions; presence of wells, especially those for irrigation or drinking water; and, in general, the underlying geology and hydrology of the site. Other fate and transport phenomena that should be considered include hydrodynamic dispersion, inter-

phase transfers of contaminants, and retardation. Movement through the vadose zone should be considered.

6.5.2 *Surface Water and Sediment Pathway*—This pathway should always be investigated in the following situations: (1) a perennial body of water (river, lake, continuous stream, drainage ditch, etc.) is in direct contact with, or is potentially contaminated by a source or contaminated area, (2) an uninterrupted pathway exists from a source or contaminated area to the surface water, (3) sampling and analysis of the surface water body or sediments indicate contaminant concentrations substantially above background, (4) contaminated ground water or surface water runoff is known or suspected to discharge to a surface water body, and (5) under arid conditions in which ephemeral drainage may convey contaminants to downstream points of exposure.

6.5.3 *Air Pathway*—Contaminant transport through the air pathway should be evaluated for contaminants in the surface soil, subsurface soil, surface water, or other media capable of releasing gasses or particulate matter to the air. The migration of contaminants from air to other environmental compartments should be considered, for example, deposition of particulates resulting from incineration onto surface waters and soil.

6.5.4 *Soil Contact Pathway*—Contaminated soils that may come into direct contact with human or ecological receptors should be investigated. This includes direct contact with chemicals through dermal absorption and direct exposure to gamma radiation from radioactively contaminated soil. There is a potential for human and ecological receptors to be exposed to contaminants at different soil depths (for example, humans may be exposed to only surface and subsurface soils, whereas plants and animals may encounter contaminants that are buried more deeply). This should be considered when contaminated soils are being evaluated.

6.5.5 *Biotic Pathway*—Bioconcentration and bioaccumulation in organisms and the resulting potential for transfer and biomagnification along food chains and environmental transport by animal movements should be considered. For example, many organic, lipophilic contaminants found in soils or sediments can bioaccumulate and bioconcentrate in organisms such as plankton, worms, or herbivores and biomagnify in organisms such as carnivorous fish and mammals or birds. The movement of contaminated biota can transport contaminants.

6.6 *Identifying Environmental Receptors*—Identify environmental receptors currently or potentially exposed to site contaminants. This includes humans and other organisms that are in direct contact with the source of contamination, potentially present along the migration pathways, or located in the vicinity of the site. It is advisable to compile a list of taxa representative of the major groups of species present at the site. It will rarely be possible or desirable to identify all species present at a site. It is recommended that the conceptual site model include species or guilds representative of major trophic levels. The complexity and iterative nature of the conceptual site model has already been mentioned in 4.2.

6.6.1 *Human Receptors*—The conceptual site model should include a map or maps indicating the physical boundaries of areas within which environmental receptors are potentially or currently exposed to the source(s) or migration pathways;



separate maps may be prepared to illustrate specific contaminants or groups of contaminants. In addition, the human receptors should be represented in a figure similar to Fig. X1.4, which is based on *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*. Fig. X1.4 shows the potentially exposed populations, sources, and exposure routes. It represents a clear and concise method of displaying exposure information.

**6.6.2 Ecological Receptors**—The conceptual site model should include a map or maps identifying and locating terrestrial and aquatic habitats for plants and animals within and around the study area or associated with the source(s) or

migration pathways. Consult local and state officials, U.S. Environmental Protection Agency regional specialists, and Natural Resource Trustees to determine whether any of the areas identified are critical habitats for federal- or state-listed threatened or endangered species or sensitive environments. Identify all dominant, important, declining, threatened, endangered, or rare species that either inhabit (permanently, seasonally, or temporarily) or migrate through the study area.

## 7. Keywords

7.1 conceptual site model; ecological; hazardous waste site; human health; risk assessment; site characterization

## APPENDIX

### (Nonmandatory Information)

#### X1. OUTLINE FOR A CONCEPTUAL SITE MODEL FOR CONTAMINATED SITES

**X1.1** The conceptual site model should include a narrative and set of maps, figures, and tables to support the narrative. An outline of the narrative sections, along with an example for each section, is given below. The example is based on an hypothetical landfill site at which only preliminary sampling data are available. *The landfill site example is intentionally simplified and is for illustrative purposes only. Conceptual site models may contain considerably more detail than provided in this example.*

**X1.1.1 Brief Site Summary**—Summarize the information available for the site as this information relates to the site contaminants, source(s) of the contaminants, migration pathways, and potential environmental receptors. A brief description of the current conditions at the site (photographs optional) should be included. The inclusion of a standard 7.5-min United States Geological Survey topographic quadrangle map or geologic quadrangle map, or both, that shows the location of the site is recommended. All maps should contain directional information (for example, north arrow) and a scale.

**Example**—Geophysical surveys, aerial photographs, and subsurface exploration at Landfill No. 1 (LF-1) reveal the presence of at least one northeast-southwest trending waste trench. The trench is 300-ft (91-m) long and 100-ft (30-m) wide. Maximum depth of the trench indicated by the soil borings is 22 ft (7 m). As determined from the soil boring program, the waste material samples indicated that metal concentrations were at or below background concentrations, with the exception of cadmium and manganese in one sample. However, solvents (methylene chloride and trichloroethene (TCE) and pesticides (DDE, DDT, and DDD) were found at concentrations above background in soil boring samples. Soil samples taken from beneath the fill indicate that downward migration of contaminants has occurred. The surficial aquifer (ABC Formation) contains naturally high dissolved solids (>2000 mg/L) with yields of less than 4 gpm. Ground water flow in the surficial aquifer is toward the southeast at a rate of approximately 15 ft (5 m) per year. The terrain is flat with

seeded and natural grasses and small (15-ft (5-m)), widely spaced loblolly pine trees covering the site. The site is fenced and unused currently.

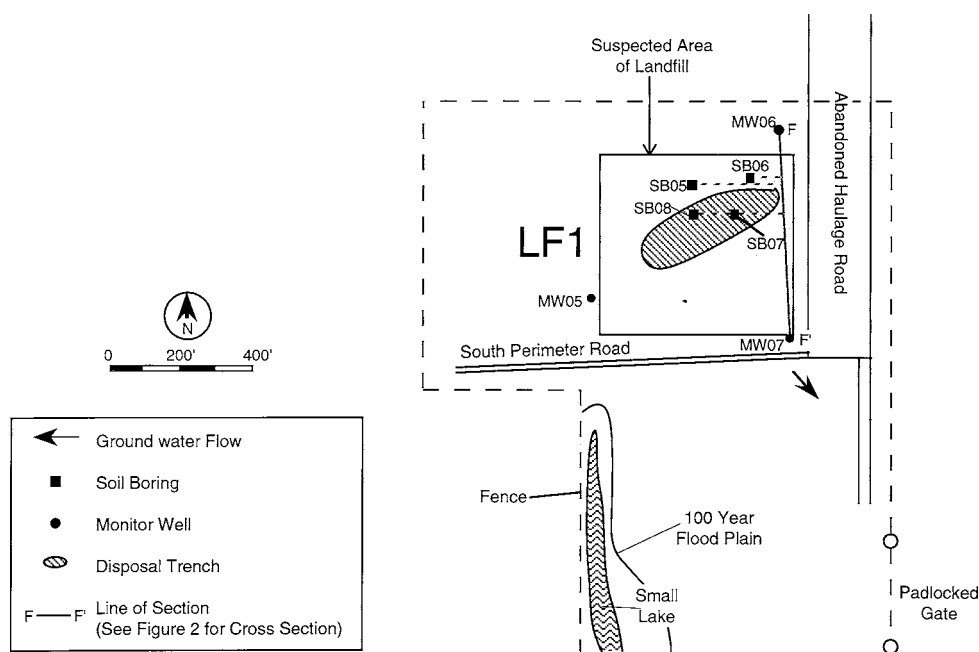
#### X1.1.2 Historical Information Concerning the Site:

**X1.1.2.1 Site Description**—Describe the history of the site, paying particular attention to information affecting the present environmental condition of the site.

**Example**—LF-1, operated from 1960 to 1968. This trench-type landfill was reportedly used for the disposal of construction rubble and debris, packing material, paper, paints, thinners, unrinsed pesticide containers, oils, solvents, and contaminated fuels. Most of the trenches for waste disposal were reportedly oriented east-west and were 75-ft (23-m) wide, 350-ft (107-m) long, and an estimated 20-ft (6-m) deep. A few empty containers presumably buried in the landfill have worked their way to the surface and are partially exposed at the site. The site was partly covered by an unpaved industrial haulage road. The site was fenced in 1985 and has been unused since.

**X1.1.2.2 Source Characterization**—Present site-specific information to identify and define the location, size, and condition of the source(s) of contamination at the site.

**Example**—Four soil borings were used to characterize the waste disposal units at LF-1. Fig. X1.1 illustrates the soil boring locations. The depth of the soil borings were SB05 = 28 (9 m), SB06 = 30 ft (9 m), SB07 = 30 ft (9 m) and SB08 = 30 ft (9 m) below ground surface. Two of the borings, SB07 and SB08, encountered refuse/waste material. In SB08, the refuse was encountered from approximately 8 to 22 ft (2 to 7 m) below ground surface. The material was noted to be burnt debris, glass, and organic matter. A much dryer and thinner waste zone was encountered at SB07. The base of the excavation at this location was approximately 10 ft (3 m). Material that appeared to be burnt trash was noted in the backfill. The remaining two borings, SB05 and SB06, did not encounter waste. One sample was collected from each of these borings (SB05 and -06). These samples were used as background samples. Additional samples were collected from SB07 and



**FIG. X1.1 Location Map for Landfill Number 1; Contours Showing the Potentiometric Surface from which Ground Water Flow Direction was Determined Could be Included in a Separate Figure to Avoid Clutter**

SB08, within the landfill, to characterize the source. Analytical results are summarized in [Table X1.1](#).

Petroleum hydrocarbons, which were suspected of being contaminants based on the site history, were not detected in any of the samples.

Volatile organic compounds found in the samples included methylene chloride and TCE. Methylene chloride was found in all soil samples in trace amounts (0.005 to 0.008 mg/kg).

The field quality control information suggests that methylene chloride may be a field artifact. The chlorinated solvent, TCE, was found significantly above background only at SB08 at a concentration of 0.05 mg/kg.

Organochlorine pesticides (DDE, DDD, and DDT), which were suspected of being present based on the site history, were not present above the detection limit in any of the samples.

Comparing metal concentrations of soil samples from SB05 and SB06 (background samples) with the remaining soil samples (SB07 and SB08) reveals that SB08 metals data exceeded the background soils data substantially for one analyte. That analyte was manganese (4320 mg/kg).

**X1.1.2.3 Migration Pathway Descriptions**—Describe the route(s) potentially taken by contaminants from the site as they migrate away from the source through the environmental media (ground water, surface water, air, sediment, soils, and food chain).

**Example: Ground Water Migration**—Three monitor wells (MWs) were installed at LF-1. The bedrock formation is typically nonwater-bearing and consists of thick clay and clay-stone ([Fig. X1.2](#)). The unconsolidated materials above the bedrock include a layer of fluvial terrace deposits. The sand

**TABLE X1.1 Summary of Analytical Results at LF-1<sup>A</sup>**

Parameter (Method)	Field Identification Number					
	DL <sup>B</sup>	Units	SB05 <sup>C</sup>	SB06	SB07	SB08
Moisture (Test Method <a href="#">D2216</a> )	N/A <sup>D</sup>	%	20.6	19.1	12.7	21.1
Petroleum hydrocarbons (SW3550/E418.1)	25	mg/kg	ND <sub>25</sub> <sup>E</sup>	ND <sub>25</sub>	ND <sub>25</sub>	ND <sub>25</sub>
Volatile organics (SW8240)						
Methylene chloride <sup>F</sup>	0.005	mg/kg	0.008	ND <sub>0.0050</sub>	ND <sub>0.0050</sub>	ND <sub>0.0050</sub>
Trichloroethene	0.005	mg/kg	0.006	ND <sub>0.0050</sub>	ND <sub>0.0050</sub>	0.05
Organochlorine pesticides (SW3550/8080)						
4,4-DDE	0.0033	mg/kg	ND <sub>0.0033</sub>	ND <sub>0.0033</sub>	ND <sub>0.0033</sub>	ND <sub>0.0033</sub>
4,4-DDD	0.0033	mg/kg	ND <sub>0.0033</sub>	ND <sub>0.0033</sub>	ND <sub>0.0033</sub>	ND <sub>0.0033</sub>
4,4-DDT	0.0033	mg/kg	ND <sub>0.0033</sub>	ND <sub>0.0033</sub>	ND <sub>0.0033</sub>	ND <sub>0.0033</sub>
Metals (SW3050/6010)						
Cadmium	0.5	ND <sub>0.5</sub>	ND <sub>0.5</sub>	ND <sub>0.5</sub>	ND <sub>0.5</sub>	ND <sub>0.5</sub>
Manganese	2	mg/kg	284	178	228	4320

<sup>A</sup> All results are expressed on a dry weight basis.

<sup>B</sup> DL = detection limit.

<sup>C</sup> SB = soil boring.

<sup>D</sup> N/A = not applicable.

<sup>E</sup> ND<sub>x</sub> = not detected at concentration x.

<sup>F</sup> Suspected laboratory contaminant.

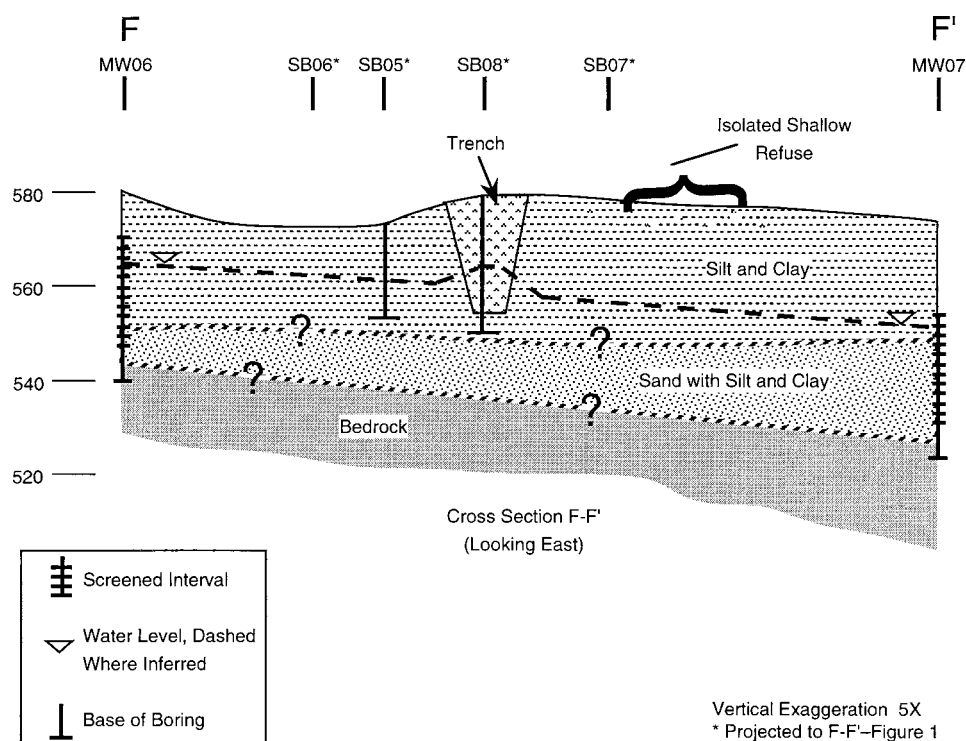


FIG. X1.2 Cross Section of Landfill Number 1

and gravels that lie above the bedrock contain water with flow velocities of approximately 13 to 18 ft/year (4 to 5 m/year). Flow velocities were estimated from permeability tests conducted at MW06. Recharge at the site is from runoff associated with the nearby area that pools and stagnates at and near the site. Table X1.2 contains the water quality analyses from samples of MW05, MW06 (upgradient), and MW07 (downgradient). The upgradient samples contained no contaminants

at concentrations above the detection limits, while the downgradient sample contained organic contaminants (pesticides). A comparison of metals from the downgradient and upgradient samples indicates that the concentration of metals in the downgradient ground water does not exceed background (upgradient) concentrations.

**Example: Surface Water and Sediment Migration**—The site surface water drainage map is shown in Fig. X1.3. Three

TABLE X1.2 Ground and Surface Water Quality Analysis at LF-1

Parameter	Field Identification Number						
	DL <sup>A</sup>	MW-05 µg/L	MW-06 µ g/L	MW-07 µg/L			
Volatile organics							
Trichloroethene	5	ND <sub>5</sub> <sup>B</sup>	ND <sub>5</sub>	ND <sub>5</sub>			
Methylene chloride	5	ND <sub>5</sub>	ND <sub>5</sub>	ND <sub>5</sub>			
Organochlorine pesticides							
4,4-DDE	0.1	ND <sub>0.1</sub>	ND <sub>0.1</sub>	1			
4,4-DDD	0.1	ND <sub>0.1</sub>	ND <sub>0.1</sub>	3			
4,4-DDT	0.1	ND <sub>0.1</sub>	ND <sub>0.1</sub>	4			
Metals							
Cadmium	5	ND <sub>5</sub>	ND <sub>5</sub>	ND <sub>5</sub>			
Manganese	15	ND <sub>15</sub>	ND <sub>15</sub>	ND <sub>15</sub>			
	DL Water	µg/L SW-02	µg/L SW-03	µg/L SW-04	mg/kg SD-02	mg/kg SD-03	mg/kg SD-04
Petroleum hydrocarbons	1000	ND <sub>1000</sub>	ND <sub>1000</sub>	ND <sub>1000</sub>	ND <sub>1000</sub>	ND <sub>1000</sub>	ND <sub>1000</sub>
Volatile organics							
Trichloroethene	1	ND <sub>1</sub>	ND <sub>1</sub>	ND <sub>1</sub>	ND <sub>1</sub>	ND <sub>1</sub>	ND <sub>1</sub>
Methylene chloride	2	ND <sub>2</sub>	ND <sub>2</sub>	ND <sub>2</sub>	ND <sub>2</sub>	ND <sub>2</sub>	ND <sub>2</sub>
Organochlorine pesticides							
4,4-DDE	0.04	ND <sub>0.04</sub>	ND <sub>0.04</sub>	ND <sub>0.04</sub>	ND <sub>0.04</sub>	ND <sub>0.04</sub>	ND <sub>0.04</sub>
4,4-DDD	0.1	ND <sub>0.1</sub>	ND <sub>0.1</sub>	ND <sub>0.1</sub>	ND <sub>0.1</sub>	ND <sub>0.1</sub>	ND <sub>0.1</sub>
4,4-DDT	0.1	ND <sub>0.1</sub>	ND <sub>0.1</sub>	ND <sub>0.1</sub>	ND <sub>0.1</sub>	ND <sub>0.1</sub>	ND <sub>0.1</sub>
Metals							
Cadmium	5	ND <sub>5</sub>	ND <sub>5</sub>	ND <sub>5</sub>	ND <sub>0.5</sub>	ND <sub>0.5</sub>	ND <sub>0.5</sub>
Manganese	20	ND <sub>20</sub>	ND <sub>20</sub>	ND <sub>20</sub>	ND <sub>2</sub>	ND <sub>2</sub>	ND <sub>2</sub>

<sup>A</sup> DL = detection limit.

<sup>B</sup> ND<sub>x</sub> = not detected at concentration x.



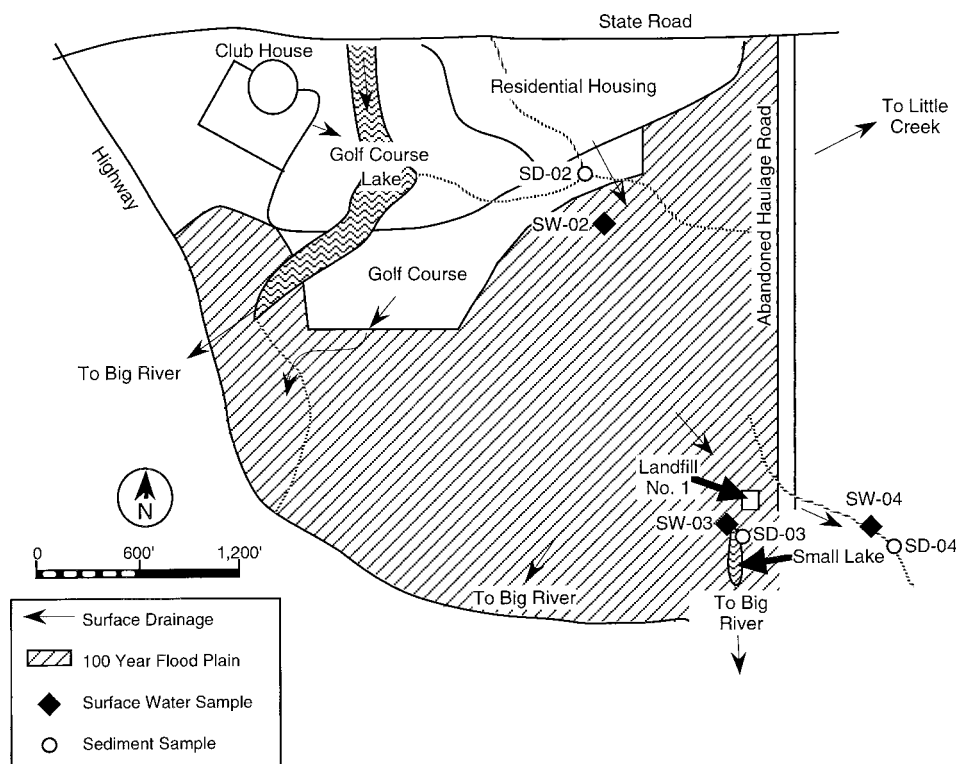


FIG. X1.3 Surface Drainage Pattern around Landfill Number 1

surface water runoff samples and three sediment samples were collected at locations shown on the map. Samples SW-02 and SD-02 were collected to determine background, while SW-03, SW-04, SD-03, and SD-04 were placed downstream of the site. The analytical results given in Table X1.2 indicate that no contaminants are present above background in any of the samples. There appears to be no contamination entering the surface water pathway from the site.

**Example: Air Migration**—No air samples were taken since there was no indication that vapor or dust can enter the air pathway. The contamination is buried and effectively prevented from reaching the air pathway, and the site is covered by a thick layer of vegetation, which effectively acts as a natural cap and prevents dust from becoming airborne. Qualitative air monitoring showed no evidence of any organic vapors being present at the site during the initial stages of the site investigation.

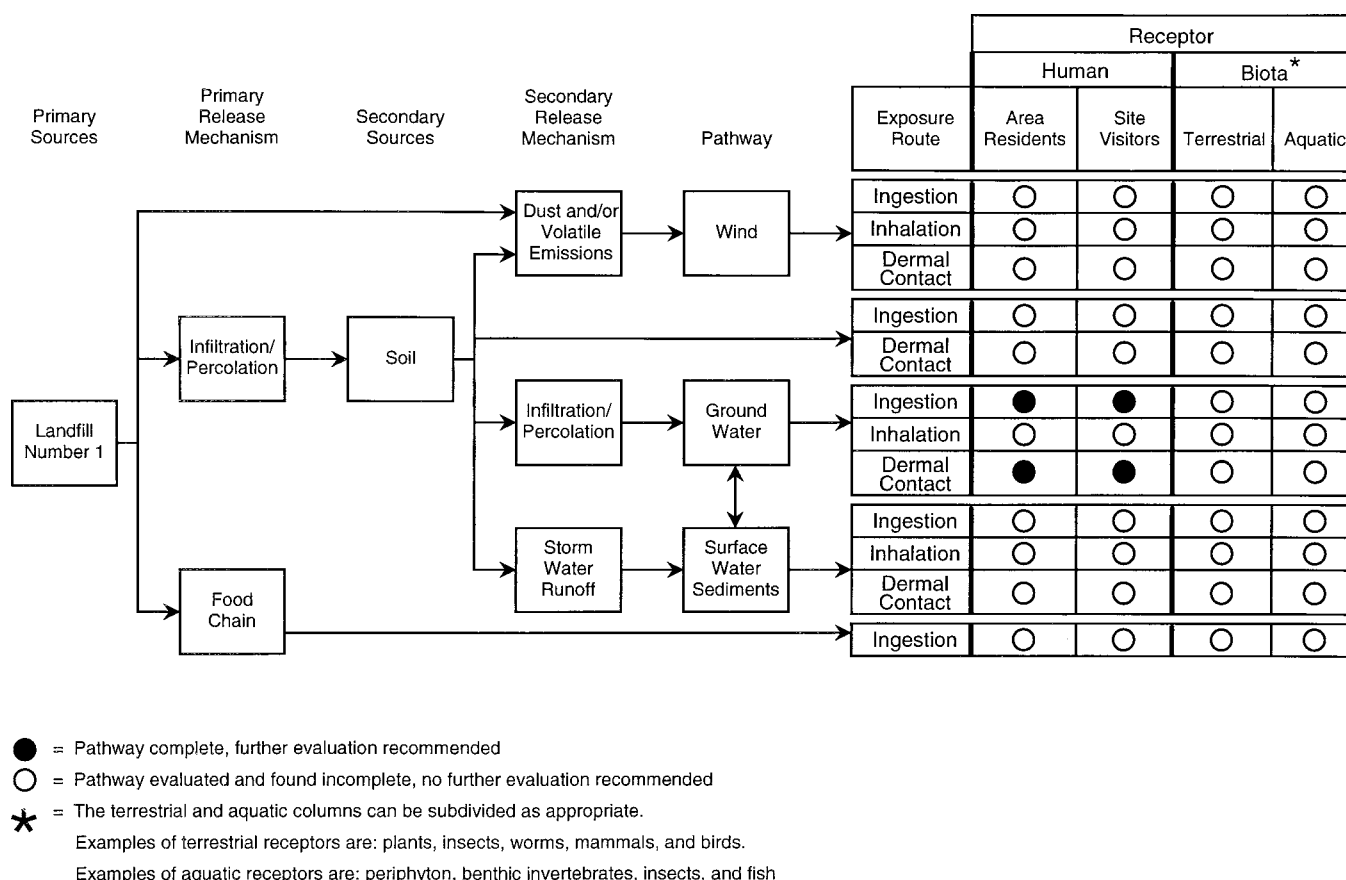
**Example: Soils**—This pathway is not complete for humans because the site is surrounded by a 6-ft (2-m) fence with a padlocked gate and posted with no trespassing signs. Soil and sediment samples taken for the surface water pathway did not indicate the presence of contamination above background concentrations. Also, there was no loose soil at the site since the site was covered by a thick layer of vegetation. Exposed, empty containers have been tested for the presence of contaminant residues, and none have been found. The site was inspected for evidence of burrowing mammals and other small mammals, reptiles, amphibians, or birds that might not be deterred by the fence. There was no evidence of any threat to ecological receptors from the soils or direct contact.

**Example: Food Chain Transfer**—Samples collected from surface water, sediment, and soils indicate that there are no

contaminants present at concentrations above background. There is therefore no concern for food chain transfer (biomagnification) in and around the landfill.

**X1.1.2.4 Environmental Receptor Identification and Discussion**—Current and future human and ecological receptor groups should be identified and located on site maps. The migration pathways and source(s) that place or potentially place the environmental receptors at risk should be discussed.

**Example:** The only residential housing in the vicinity of the site is approximately 2100 ft northwest of the landfill. The surficial aquifer is not used as a source of drinking water by the residents, and the ground water flow is toward the southeast and away from the residential housing. There is an active golf course just to the west of the residential housing. Golf Course Lake is recharged from north of the lake and is not influenced by LF-1. The golf course does not use the surficial aquifer for a drinking water source or for irrigating the golf course. There are no other human receptors in the vicinity of the site. There are no local, state, or federally designated declining, endangered, or rare species that inhabit or migrate through the vicinity of the study area. Other wildlife species that were observed on-site show no evidence of harm from the site. Plants on-site include seeded, cool-season grasses, and volunteer native grasses; herbian vegetation; upland shrubs; and coniferous trees. None of the vegetation shows signs of stress. The most likely potentially threatened aquatic habitats are Small Lake and Big River, south of the landfill. However, environmental sampling of surface water and sediments (Table X1.2) has not shown any evidence of contaminant migration from the landfill to the lake or river. Fig. X1.4 illustrates the relationships among the elements of the conceptual site model,



NOTE 1—This example is based on Figure 2-2 of *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*.

FIG. X1.4 Example Diagram for a Conceptual Model at Landfill Number 1

including the sources, release mechanisms, pathways, and environmental receptors.

## X1.2 Examples of Maps, Tables, and Figures:

**X1.2.1 Maps**—The use of maps in a conceptual site model is important. The maps may include United States Geological Survey topographic and geologic maps, site sketch maps, and maps drawn to scale. The maps should identify and locate key elements of the conceptual site model including source(s); ground water, surface water, sediment, soil and air pathway routes (direction of flow); and areas covered by environmental receptor populations and migration pathways. Morphological and geological features relevant to the environmental assessment of the site should be included on a map.

**Example:** Figs. X1.1-X1.3 are examples of sketch maps that contain a scale, a north arrow, and a legend.

**X1.2.2 Tables and Figures**—Tables and figures should be simple and easy to read, with explanations of qualified data and abbreviations. All tables and figures should be referred to in the narrative.

**Examples:** Tables X1.1 and X1.2 and Figs. X1.1-X1.3 are examples of simple summary tables and site maps. Fig. X1.4 is an example of a diagram illustrating the relationships between primary and secondary sources, release mechanisms, exposure routes, and environmental receptors.

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## **Appendix B**

### **Field Forms**



LOG OF BORING

(Page of )

Project Name:	Date Started :	Driller :
	Date Completed :	Depth to Water :
	Drilling Method :	Logged By :
Project #:	Sampling Method :	Northing :
	Drilling Company :	Easting :

Depth in Feet	Sample Interval	Pen./Rec.	Nitrogen (ppm)	Chloride (ppm)	DESCRIPTION	USCS
0						
5						
10						
15						
20						
25						
30						
35						
40						

Notes:  
Coordinate System –

Site Location: \_\_\_\_\_ Drilling Co: \_\_\_\_\_ Boring No.: \_\_\_\_\_

Drilling Method: \_\_\_\_\_ Driller: \_\_\_\_\_ Total Depth (ft): \_\_\_\_\_ Date: \_\_\_\_\_

Drilling Equipment: \_\_\_\_\_ Northing: \_\_\_\_\_ Easting: \_\_\_\_\_ Borehole Diameter: \_\_\_\_\_ Drilling Finish: \_\_\_\_\_

Soil Boring Log (Field)										Split Spoon Length:				Coord. System			
Depth in Feet (BLS)	uscs	Descriptor	Soil Type	Color	Partical Size	Grading	Angularity/shape	Density	Plasticity	Moisture	Odor	PID/FID	% Rec.	Sample No./Int.	Comments		
		Sandy	SAND		very fine	poor	angular	(sand or gravel) very loose	non-plastic	dry	none						
		Clayey	CLAY		fine	well	subangular	loose dense	slightly plastic	moist	organic						
		Silty	SILT		medium		subrounded	very dense	plastic	wet	hydrocarbon						
Depth in Feet (BLS)		Gravelly	GRAVEL		coarse		rounded	(silt or clay) very soft	very plastic								
								soft									
								hard									
								very hard									
Depth in Feet (BLS)	uscs	Descriptor	Soil Type	Color	Partical Size	Grading	Angularity/shape	Density	Plasticity	Moisture	Odor	PID/FID	% Rec.	Sample No./Int.	Comments		
		Sandy	SAND		very fine	poor	angular	(sand or gravel) very loose	non-plastic	dry	none						
		Clayey	CLAY		fine	well	subangular	loose dense	slightly plastic	moist	organic						
		Silty	SILT		medium		subrounded	very dense	plastic	wet	hydrocarbon						
Depth in Feet (BLS)		Gravelly	GRAVEL		coarse		rounded	(silt or clay) very soft	very plastic								
								soft									
								hard									
								very hard									
Depth in Feet (BLS)	uscs	Descriptor	Soil Type	Color	Partical Size	Grading	Angularity/shape	Density	Plasticity	Moisture	Odor	PID/FID	% Rec.	Sample No./Int.	Comments		
		Sandy	SAND		very fine	poor	angular	(sand or gravel) very loose	non-plastic	dry	none						
		Clayey	CLAY		fine	well	subangular	loose dense	slightly plastic	moist	organic						
		Silty	SILT		medium		subrounded	very dense	plastic	wet	hydrocarbon						
Depth in Feet (BLS)		Gravelly	GRAVEL		coarse		rounded	(silt or clay) very soft	very plastic								
								soft									
								hard									
								very hard									
Depth in Feet (BLS)	uscs	Descriptor	Soil Type	Color	Partical Size	Grading	Angularity/shape	Density	Plasticity	Moisture	Odor	PID/FID	% Rec.	Sample No./Int.	Comments		
		Sandy	SAND		very fine	poor	angular	(sand or gravel) very loose	non-plastic	dry	none						
		Clayey	CLAY		fine	well	subangular	loose dense	slightly plastic	moist	organic						
		Silty	SILT		medium		subrounded	very dense	plastic	wet	hydrocarbon						
Depth in Feet (BLS)		Gravelly	GRAVEL		coarse		rounded	(silt or clay) very soft	very plastic								
								soft									
								hard									
								very hard									



# LOG OF SOIL BORING: SB-03

(Page 1 of 1)

Project Name:  
Santa Fe River Assessment

Date Started : 10/23/09  
Date Completed : 10/23/09  
Drilling Method : HSA (7-3/4 OD)  
Sampling Method : continuous (5' interval)  
Drilling Company : Rodgers & Co., Inc.

Driller : J. Aguire  
Depth to Water : NA  
Logged By : E. Romesser  
X Coordinate : 1731486.02990  
Y Coordinate : 1705469.01180

Project #: NME-VR2-SR

Depth in Feet	Sample Interval	Pen./Rec.	PID (ppm)	DESCRIPTION	USCS	GRAPHIC
0		NA	NA	SILTY SAND trace Cobbles, brown (5YR 4/6)		
5		60/24	<1	Fill: SILTY SAND little Gravel (up to 2"), dark brown (7.5YR 3/2), fine to medium gravel, coal & brick pieces	SM	
10				SAND some Gravel & Cobbles, reddish (2.5YR 7/6), fine- to medium-grained sand, fine to coarse gravel & cobbles	SW	
				Not Sampled: boulder, augered down to 11.5' bgs		
15		30/30	<1	Tesuque formation contact SAND, reddish (2.5YR 7/6), fine-grained sand (little medium grained), subangular, moist SAND, reddish (2.5YR 5/8), fine-grained sand, subangular, dry	SP	
20		60/43	<1	SAND trace Gravel, reddish (2.5YR 4/8), fine- to coarse-grained sand, subangular, fine gravel, subangular SAND little Gravel, reddish (2.5YR 4/8), fine- to coarse-grained sand, fine gravel, strongly cemented, laminar layers at ~12" from bottom		
25		60/48	<1	SAND, reddish (2.5YR 4/8), fine- to coarse-grained sand, subangular to subrounded, 2" cobble, dry		
30		60/44	<1	SAND little Gravel, reddish (2.5YR 4/8), fine- to coarse-grained sand, subangular to subrounded, fine to coarse gravel, subangular to subrounded, strongly cemented, dry	SW	
35		60/29	<1	SAND little Gravel, reddish (2.5YR 4/8), fine- to coarse-grained sand, subangular to subrounded, fine to coarse gravel, subangular to subrounded, strongly cemented, 2" cobbles, dry		
				SAND, reddish (2.5YR 4/8), fine-grained sand, very thin laminar	SP	
		18/24	<1	SAND, reddish (2.5YR 4/8), fine- to coarse-grained sand, subangular, strongly cemented (sample taken w/ 2' split spoon)	SW	
40				Bottom of Boring at 35.5' bgs		

## Notes:

1. Post hole 0-4' bgs.
2. NA = Not Applicable.
3. Refusal at 35.5' bgs, Split Spoon: blow counts 15-69-175.
4. X = Sample interval sent for laboratory analysis.

5. Groundwater not encountered - monitoring well not installed. Soil boring abandoned with bentonite/cement slurry on 10/23/09.



## LOG OF SFRMW-01

(Page 1 of 1)

Project Name:  
Santa Fe River Assessment

Date Started : 10/20/09  
Date Completed : 10/20/09  
Drilling Method : HSA (7-3/4 OD)  
Sampling Method : continuous (5' interval)  
Drilling Company : Rodgers & Co., Inc.

Driller : J. Aguire  
Depth to Water : 21' bgs  
Logged By : E. Romesser  
X Coordinate : 1731606.54850  
Y Coordinate : 1705086.39280

Project #: NME-VR2-SR

Depth in Feet	Sample Interval	Pen./Rec. (inches)	PID (ppm)	DESCRIPTION	USCS	GRAPHIC
0		NA	NA	Cuttings: SAND w/ Gravel, trace cobbles, dark brown (7.5YR 3/2), fine-grained sand, fine to coarse gravel, road-base engineered fill, dry		
5		60/10	<1	SAND trace Gravel, brown (5YR 4/2), fine- to medium-grained sand, fine to coarse gravel, subangular, dry	SW	
10		60/18	<1	SAND trace Gravel, brown (5YR 4/2), fine- to medium-grained sand, fine to coarse gravel, subangular, subangular cobbles, dry		
15		60/32	-	SAND trace Gravel, reddish-brown (5YR 5/6), fine- to medium-grained sand, subangular, fine gravel, subangular, dry		
20		60/19	-	Tesque formation contact SAND, whitish brown (10YR 8/3), fine-grained sand, subangular, dry		
25		60/36	3.0	SAND, same as previous; reddish brown (5YR 7/8), fine-grained sand, subangular, moist	SP	
30		30/18	1.1	SAND, reddish brown (5YR 6/8), fine-grained sand, subangular, wet		
35				SAND, reddish brown (5YR 5/8), fine-grained sand, subangular, saturated		
				Bottom of Boring at 31.5' bgs		

SFRMW-01:  
Flush Grade,  
24" Dia. Flush  
Concrete Pad

Locking  
Well CapBentonite  
Grout2" SCH.40  
PVC CasingBentonite  
Plug10-20  
Silica Sand  
Filter0.020"  
Screen

## Notes:

1. Post hole 0-4' bgs.
2. NA = Not Applicable.
3. X = Sample interval sent for laboratory analysis.
4. - = PID malfunction.





# FIELD GUIDE FOR SOIL AND STRATIGRAPHIC ANALYSIS V.2

midwest  
GEOSCIENCES  
www.midwestgeo.com group

## START HERE

### DENSITY OR CONSISTENCY

COARSE GRAINED DEPOSITS		N-VALUE		FINE GRAINED DEPOSITS		N-VALUE	$q_u$ (tsf)	
		0-4	▶ VERY LOOSE			0-2	<0.25	▶ VERY SOFT
		5-10	▶ LOOSE			3-4	0.25-0.50	▶ SOFT
		11-29	▶ MEDIUM DENSE			5-8	0.50-1.0	▶ MEDIUM
		30-49	▶ DENSE			9-15	1.0-2.0	▶ STIFF
		>50	▶ VERY DENSE			16-30	2.0-4.0	▶ VERY STIFF
						>30	>4.0	▶ HARD

### COLOR

Use Standard Munsell Color Notation

IS THE COLOR A MATRIX COLOR?

YES

#### MATRIX COLOR

List in sequence, dominant first

NO

IS THE COLOR FROM A COATING OR CONCENTRATION?

YES

#### COATING or CONCENTRATION

Note frequency, color, and size

NO

#### MOTTLE

Note contrast, color, and size

## CLASSIFICATION

Unified Soil Classification System - adopted ASTM D2488

### COARSE-GRAINED DEPOSITS

>50% coarse-grained sediments, <50% fines

#### STEP 1:

IS SEDIMENT COARSE GRAINED OR FINE GRAINED?

>50% fines, <50% coarse-grained sediments

### FINE-GRAINED DEPOSITS (organic and inorganic)

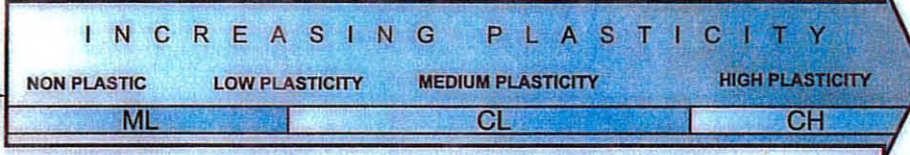
## STEP 2: DETERMINE SAND VS. GRAVEL RATIO



#### STEP 3:

CONTINUE WITH SAND OR GRAVEL ON FLOW CHART (REVERSE)

## STEP 2: DETERMINE PLASTICITY AND ASSIGN USCS GROUP SYMBOL



#### STEP 3:

CONTINUE WITH GROUP SYMBOL ON FLOW CHART (REVERSE)

### MOISTURE

MOISTURE ABSENT ▶ DRY  
DAMP ▶ MOIST  
VISIBLE WATER ▶ WET

FOR NON-PLASTIC FINES

WATER RISES TO SURFACE SLOWLY ▶ SLOW DILATENCY  
WATER RISES TO SURFACE QUICKLY ▶ RAPID DILATENCY

### PLASTICITY

(Use with CLASSIFICATION)

WILL NOT SUPPORT 6mm DIAMETER ROLL IF HELD ON END  
6mm DIA. ROLL CAN BE REPEATEDLY ROLLED AND SUPPORTS ITSELF, 4mm DIA. ROLL DOES NOT  
4mm DIA. ROLL CAN BE REPEATEDLY ROLLED AND SUPPORTS ITSELF, 2mm DIA. ROLL DOES NOT  
2mm DIA. ROLL CAN BE REPEATEDLY ROLLED AND SUPPORTS ITSELF

▶ NON-PLASTIC  
▶ LOW PLASTICITY  
▶ MEDIUM PLASTICITY  
▶ HIGH PLASTICITY

6mm  
4  
2

### COHESIVENESS

6mm DIAMETER ROLL CANNOT BE FORMED ▶ NONCOHESIVE  
6mm DIAMETER ROLL CAN BE FORMED ▶ COHESIVE

### SEDIMENTARY STRUCTURE

UNIFORM BEDS >30cm  
BEDS 3cm to 30cm  
BEDS 0.5cm to 3cm  
BEDS <0.5cm

▶ MASSIVE  
▶ THICKLY BEDDED  
▶ BEDDED  
▶ THINLY BEDDED  
▶ LAMINATED

SECONDARY SOIL STRUCTURE (IN SOLUM ONLY)

Spheroidal peds or granules usually packed loosely  
Irregular, roughly cubelike peds with planar faces (angular or subangular)  
Flat and horizontal peds  
Vertical, pillarlike peds with flat tops  
Vertical, pillarlike peds with curved tops (which are commonly "bleached")

▶ GRANULAR  
▶ BLOCKY  
▶ PLATY  
▶ PRISMATIC  
▶ COLUMNAR

### WEATHERING ZONE ABBREVIATION

MODIFIER SYMBOL (if present)		1st SYMBOL		2nd SYMBOL		LAST SYMBOL (if present)	
MOTTLED	▶ M	OXIDIZED	▶ O	LEACHED	▶ L	SECONDARY	
JOINTED	▶ J	REDUCED	▶ R	UNLEACHED	▶ U	CARBONATE	▶ 2
		UNOXIDIZED	▶ U				

#### EXAMPLE

solom  
OJL  
MOJL  
MOJL2  
MOJU

MRJU  
RJU  
RU  
UU

### SECONDARY GRAIN SIZE INFORMATION

< 5% ▶ TRACE  
6% to 15% ▶ LITTLE  
16% to 30% ▶ FEW  
31% to 49% ▶ SOME



▶ UNIFORM (poorly graded)  
▶ NON-UNIFORM (well graded)

▶ FINE SAND  
▶ MEDIUM-GRAINED SAND  
▶ COARSE-GRAINED SAND  
▶ FINE GRAVEL  
▶ COARSE GRAVEL

FOR GLACIAL DIAMICTONS ▶ CLAST FRACTION  
CLAST LITHOLOGY

### DEPOSITIONAL ENVIRONMENT

VARIOUS DEPOSITIONAL ENVIRONMENTS (interpretation)  
▶ EOLIAN (LOESS)  
▶ FLUVIAL  
▶ ALLUVIAL  
▶ LACUSTRINE  
▶ COASTAL  
▶ RESEDIMENTED

GLACIAL DEPOSITIONAL PROCESSES

▶ SUBGLACIAL  
▶ GLACIOFLUVIAL  
▶ GLACIOLACUSTRINE  
▶ RESEDIMENTED

GENERALIZED RESEDIMENTATION PROCESSES

▶ MASS SLUMP  
▶ SEDIMENT FLOW  
▶ COLLUVIUM

### STRATIGRAPHIC NAME

USE FORMAL STATE GEOLOGICAL SURVEY NOMENCLATURE WHEN POSSIBLE;  
IF NOT POSSIBLE, ASSIGN SITE-SPECIFIC UNIT NAME ACCORDING TO DEPOSITIONAL ENVIRONMENT / FACIES ASSEMBLAGE

### STRATIGRAPHIC CONTACT

< 10 cm  
> 10 cm (Note transition interval)

▶ SHARP (or ABRUPT for pedogenic alternation)  
▶ GRADATIONAL (or TRANSITIONAL for weathering zone change)

010106



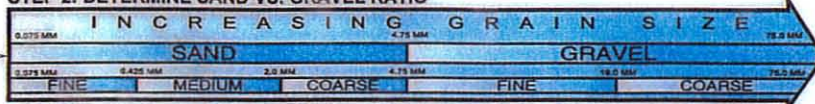
**STEP 1:**  
IS SEDIMENT  
COARSE GRAINED  
OR  
FINE GRAINED?

# UNIFIED SOIL CLASSIFICATION SYSTEM

FOR COMMON INORGANIC AND ORGANIC SEDIMENTS

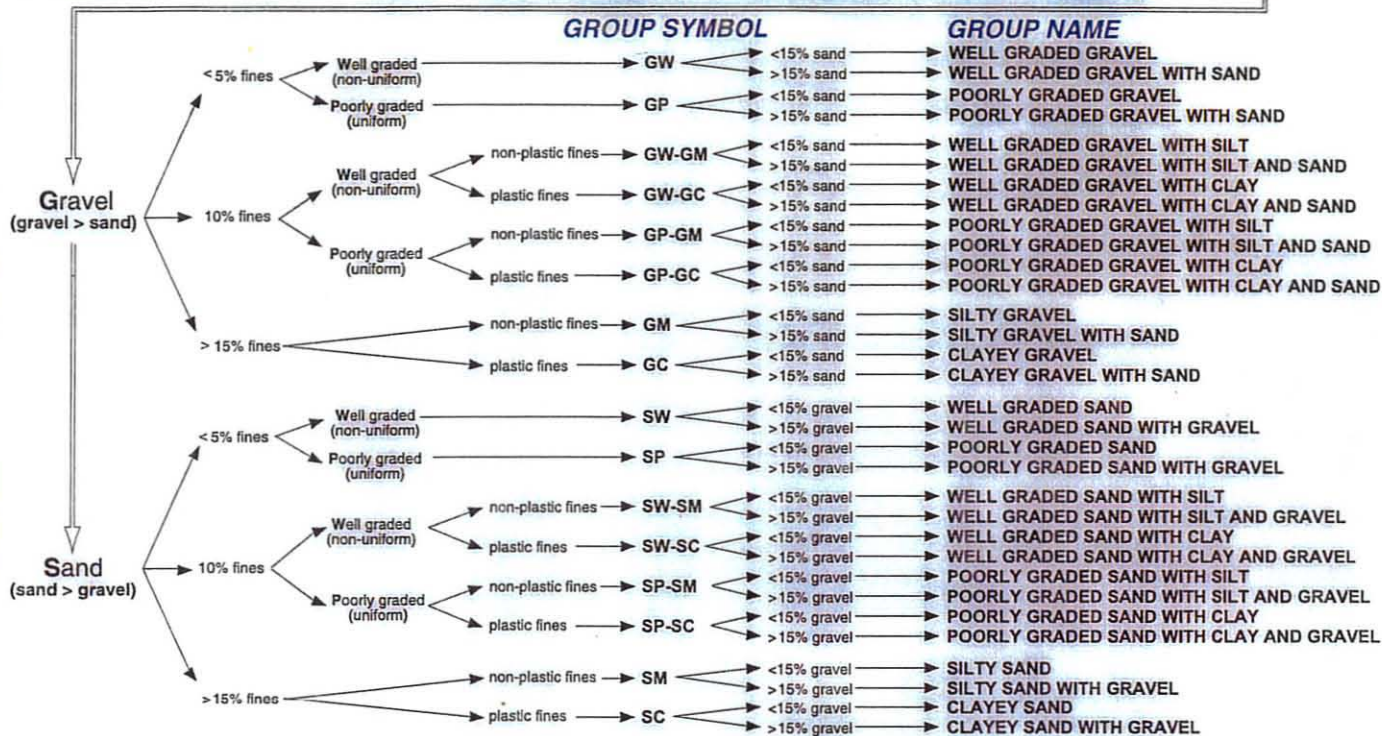
Modified from ASTM

**STEP 2: DETERMINE SAND VS. GRAVEL RATIO**



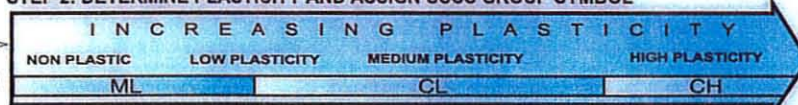
**STEP 3:**  
CONTINUE WITH  
"SAND" OR "GRAVEL"  
AND FOLLOW FLOW CHART  
TO ASSIGN A GROUP SYMBOL  
AND A GROUP NAME

**COARSE-GRAINED DEPOSITS**  
(>50% coarse-grained, <50% fine sediments)



**FINE-GRAINED DEPOSITS**  
(>50% fines, <50% coarse-grained sediments)

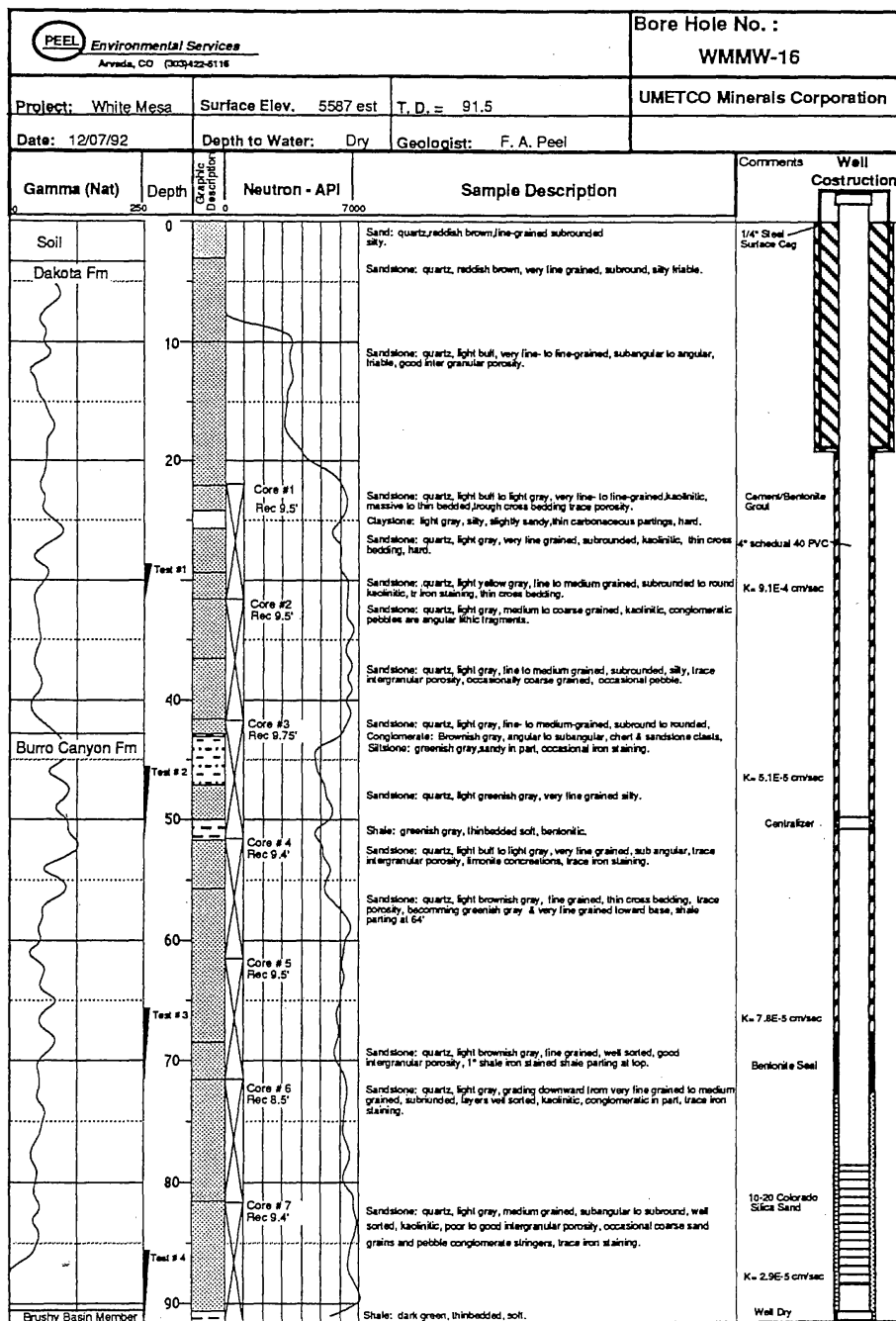
**STEP 2: DETERMINE PLASTICITY AND ASSIGN USCS GROUP SYMBOL**



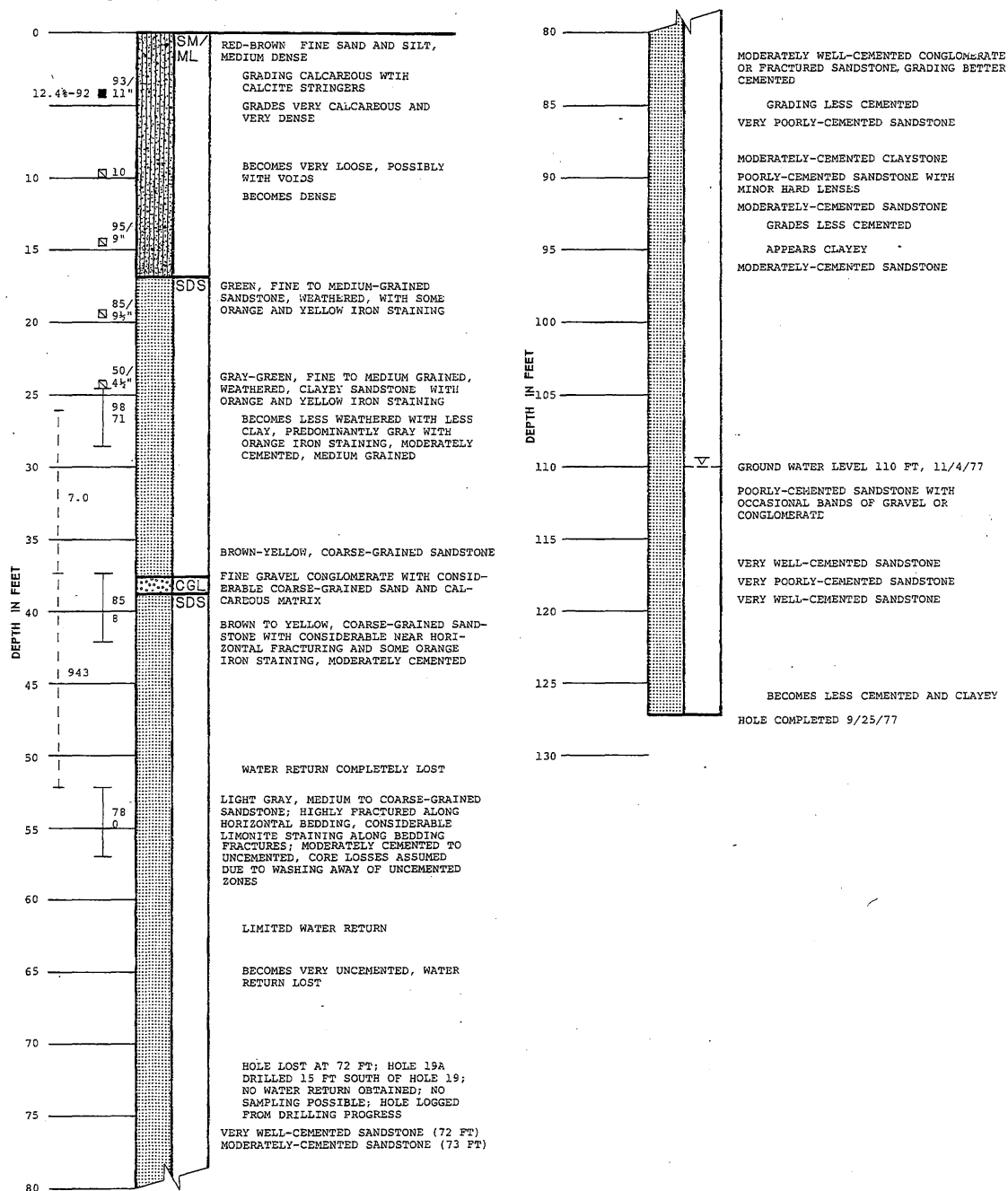
**STEP 3:**  
CONTINUE WITH  
GROUP SYMBOL  
AND FOLLOW FLOW CHART  
TO ASSIGN A GROUP NAME

**STEP 4:**  
DOES ORGANIC CONTENT  
INFLUENCE SOIL PROPERTIES?





BORING NO. 19  
EL. 5600.3 FT.



LOG OF BORINGS

DAMES & MOORE