VOLUME II - APPENDICES

HYDROGEOLOGICAL AND GEOCHEMICAL SITE CHARACTERIZATION REPORT

Prepared For:

Sequoyah Fuels Corporation
I-40 & Highway 10
Gore, Oklahoma 74435

Prepared By:

MFG
consulting scientists and engineers

3801 Automation Way, Suite 100
Fort Collins, Colorado 80525

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APPENDIX A

HYDROGEOLOGICAL CHARACTERIZATION WORK PLAN

SOPS

HEALTH AND SAFETY PLAN

HYDROGEOCHEMICAL CHARACTERIZATION WORKPLAN

Prepared For:
Sequoyah Fuels
I-40 and Highway 10
Gore, Oklahoma 74435

Prepared By:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, Colorado 80525

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SHEPHERD MILLER

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1.0 INTRODUCTION

Shepherd Miller, Inc. (SMI) submitted the "*Database Review and Conceptual Model Revision Report*" to Sequoyah Fuels (SF) in March 2001. In their report, SMI first reviewed the contents of the SF hydrogeologic and geochemical databases to better understand the hydrogeologic and geochemical transport system at the site. Subsequently, SMI updated the geochemical site conceptual model by preparing 2-dimensional contour maps of the key constituents (uranium, arsenic, and nitrate) within the key hydrostratigraphic units. In this draft workplan, SMI proposes additional site characterization efforts to provide the data necessary to support defensible ground water flow and constituent modeling at the SF site, and to refine the geochemical site conceptual model.

2.0 GEOPHYSICAL INVESTIGATION

The spatial and geometric characterization of two potential subsurface features need to be addressed. One feature is a paleochannel suspected in the Unit 1 Sandstone south of the Main Process Building and extending southward towards Fertilizer Pond #4. This paleochannel may represent a potential pathway from the source area to potential receptors and, if present, would offer a preferential pathway of contaminant migration. The second feature is the eastward extension of the 005 drainage underlying fill material in the northwest of the Industrial Area. Both the paleochannel and the subsurface expression of the 005 drainage should be characterized to determine their geometry and their potential to influence off-site migration of contaminants. The cost of providing the desired level of characterization using conventional drilling techniques would be prohibitive. Geophysical methods, however, would provide a cost-effective method of acquiring the desired data.

Several geophysical methods were investigated to determine an appropriate method for identifying the paleochannel. Methods investigated included seismic reflection, seismic refraction, and both electromagnetic and electrical resistivity surveys. Seismic reflection was eliminated because the method assumes an increasing density with depth. The hard sandstone formations would cause "blind zones" to develop in the data and render the deeper data unreliable. Seismic refraction was considered and would provide data on the paleochannel,

providing that a sufficient velocity contrast exists between the terrace deposits and the underlying formation, as currently believed. However, seismic refraction would provide no data on the consolidated sediments below the first encountered, and was therefore eliminated. Electromagnetic methods, such as a combination of EM-31 and EM-34 techniques, would provide data on the suspected paleochannel topography; however, electromagnetic methods would provide little, if any, data on the underlying lithology, and was therefore eliminated.

Of the four geophysical methods considered, SMI recommends the use of electrical resistivity methods for geophysical data collection over the suspected paleochannel (see suggested profile locations on Drawing 1). Electrical resistivity would provide data on the topography of the subcropping sandstone situated beneath the postulated paleochannel, in addition to the underlying deeper lithologies. Electrical resistivity would also be an appropriate method to determine the geometry of the 005 drainage beneath overlying unconsolidated material (see suggested profile locations on Drawing 1). The method is relatively inexpensive and will provide data for the topography of the underlying sandstone and the underlying lithology to depths of about 60 feet. Electrical resistivity has an added advantage of providing field data that can be interpreted immediately after the data are collected. If the method proves to be inadequate for identifying the either the paleochannel or the buried 005 drainage, a decision to terminate data collection can be made after the first day, instead of collecting all of the data and discovering later that is unsuitable.

3.0 HYDROGEOLOGIC INVESTIGATION

Additional data are recommended to support defensible groundwater flow and constituent transport modeling at the site. A hydrogeologic investigation is proposed to acquire additional data on the extent and depths of the stratigraphic units, and to acquire data to characterize the hydrologic properties of the various aquifers, as listed below:

(a) Reconnaissance field mapping should be performed to constrain the extent of various geologic units occurring in outcrop.

(b) Inspection of selected existing drill cores (as available) to confirm the accuracy of identification of stratigraphic units.

(c) Hydrogeologic characterization using slug tests and pumping tests should be performed for the various hydrostratigraphic units.

(d) Hydrogeologic investigation using core holes and monitoring wells should be conducted.

Hydrologic characterization of the aquifers will require the use of both existing and new wells and coreholes. A total of nineteen wells and four coreholes are proposed to help facilitate the hydrologic characterization of the aquifers. A list of all existing and proposed wells and coreholes to be used in this characterization is given in Table 3.1. Also listed are wells and coreholes to be used for geochemical characterization. Most of the proposed wells will be used to carry out a variety of characterization tasks, both in this study and in any possible future studies. These tasks include slug tests, water level monitoring, and groundwater sampling. Table 3.1 lists proposed characterization objective to be obtained from each of the proposed wells, as well as existing wells.

Sparse lithologic and hydrologic data exists in most areas south of the Fertilizer Pond Area (Drawing 1). Core drilling is needed to define the stratigraphic conditions in this area and three cores are proposed at locations south and southwest of the Fertilizer Pond Area (Locations No. 2, No. 5 and No. 6, Drawing 1). At each location, core will be retrieved from Shale 4, if encountered. Monitoring wells should be installed in alluvium and Shale 4 to help define the aquifer properties hydrologic properties southward of the Fertilizer Pond Area (Locations No. 5 and No. 6, Drawing 1). These wells would also be available for possible groundwater sampling as needed. Hydrologic data is also needed for Shale Units 1, 2, and 3 south of the Industrial Area and north of the Fertilizer Pond Area. A monitoring well in each shale unit, at Locations No. 11, No. 13, and No. 14, are proposed. If the geophysical survey locates a paleochannel, Location No. 13 should be located as near to the paleochannel as possible.

Additional geologic and hydrologic data may be needed to ascertain the extent of any contamination in the alluvium north of the Solid Waste Burial Area #2. One core hole completed as a well in alluvium is proposed for this area (Location No. 1, Drawing 1).

Slug tests and aquifer-pumping tests would be appropriate to characterize the hydrologic properties of Shale Units 1, 2, 3, and 4, as well as the overlying alluvium. Wells to be used include existing and proposed wells. A large number of existing wells exist throughout the site, however most of these wells are unsuitable for hydrologic characterization of a single aquifer because well screen and/or filter pack spans two or more aquifers. Existing wells selected for hydrologic characterization have been chosen because well screen and/or filter pack interval is within a single shale unit. Slug test are proposed for the following wells

1. Seven slug tests for Shale 1, one each at the following existing wells: MW008, MW016, MW026, MW073, MW076, MW086, and MW102 and one at proposed well No. 13 (Drawing 1 and Figure 3.1).
2. Seven slug tests for Shale 2, one each at the following existing wells: MW035A, MW040A, MW042A, MW047A, and MW085A, and one each at the following proposed wells: No. 4 and No. 14 (Drawing 1 and Figure 3.2).
3. Seven slug tests for Shale 3, one each at the following existing wells: MW037A, MW084A, MW089, and 2346, and one each at the following proposed wells: No. 3, No. 4, and No. 11 (Drawing 1 and Figure 3.3).
4. Five slug tests for Shale 4, one each at the following proposed wells: 2, No. 3, No. 4, No. 5, and No. 6 (Drawing 1 and Figure 3.4)
5. Five slug tests in the alluvium, one each at the following proposed wells: No. 1, No. 2, No. ,5, No. 6, and No. 12 (Drawing 1 and Figure 3.5)

Also, a falling-head permeability test should be performed at a well with well screen and filter pack entirely within a sandstone unit. MW063, south of the Initial lime Neutralization Area, is a suitable well to carry out this task.

In addition, pumping tests are proposed to investigate the hydrologic properties of Units 3 and 4. The pumping tests should take place in wells that are relatively isolated from most existing wells to avoid potential influence of hydraulic connection from these wells. Locations for these pumping tests include the floodplain (Location No. 2, Drawing 1), and in the area adjacent to the southwest corner of Pond #2 (Location No. 3, Drawing 1). Location No. 2 consists of a cluster of three wells, a pumping and observation well in Shale 4, and an observation well in the overlying alluvium. Location No. 3 consists of a cluster of four wells, a pumping and observation well in Shale 3, and a pumping and observation well in Shale. A total of seven 2-

inch wells would need to be constructed for the pumping tests, four at Location No. 2 and three at Location No. 3. Design and implementation of the pumping tests will depend on the conditions encountered at each location.

It should be noted that all new data collection locations are conceptual and will be field located considering site access and other logistical considerations.

4.0 GEOCHEMICAL INVESTIGATION

Additional geochemical data collection is needed: (1) to refine the existing site geochemical conceptual model by collecting the data needed to understand the geochemical processes controlling constituent migration, and (2) to determine site-specific distribution coefficients (K_d) for arsenic and uranium to support potential future geochemical transport modeling.

4.1 Conceptual Model Refinement

Examination of the SF geochemical database and preparation of 2-dimensional contour maps that depict the distribution of site constituents within the key hydrostratigraphic units have been performed. However, a revised site geochemical conceptual model is needed due to the sparse data relating to geochemical conditions within the aquifer. In order to revise the conceptual geochemical model for the system, the factors controlling constituent migration must first be understood. In addition to the pH and concentrations of uranium, arsenic, and nitrate that have already been measured, additional important parameters need to be characterized and evaluated. These parameters are: (1) the major ion composition of selected ground waters, including geochemical speciation of selected analytes, (2) the oxidation-reduction potential (Eh) of the system, and (3) the potential solid (mineral) phases that act to control the concentrations of the various constituents. In this way, the relative rates of movement of arsenic, uranium, and nitrate can generally be predicted as constituents migrate through the aquifer.

Understanding the Eh of the system and the distribution of the various redox species of arsenic and uranium are requisite to understanding geochemical controls and the ultimate development of a geochemical conceptual model. A detailed list of proposed analytes for selected wells is given in Table 4.1. These data will be input into the geochemical speciation model PHREEQC

(Parkhurst and Appelo, 1999) which will calculate the distribution and activities of all solution species, in addition to the saturation indices for various potential controlling mineral phases. Understanding the major ion chemistry of the water, as well as the concentrations of constituents of concern, is necessary because it affects the activity and ultimate behavior of the constituents of concern, both directly and through literally hundreds of competing geochemical reactions. The output from PHREEQC will then be coupled with the current 2-dimensional contour maps prepared by SMI. The result will be a complete geochemical conceptual model that incorporates the current spatial distribution of constituents with plausible geochemical mechanisms to explain current chemical distributions and to predict relative future migration rates on a conceptual level. SMI also proposes to analyze for aluminum, arsenic, iron, manganese, and uranium on unfiltered samples (Table 4.1) to evaluate the role of suspended particulates, such as clay-sized aluminosilicate and oxide minerals, as a potential colloidal transport mechanism for uranium and arsenic.

In addition to detailed geochemical analyses of the ground waters, mineralogical analyses will be conducted on samples of contaminated aquifer material that will be collected to determine transport model parameters (discussed in Section 4.2). Material will be collected during core drilling in Layers 1, 2, 3, and 4 (Corehole locations No. 7, 8, 9, and 10, Drawing 1 and Table 4.2). The mineralogical analyses will serve to verify modeling results and also to identify potential solid phases that may be present but are not predicted by the model to precipitate. X-ray diffraction and electron microprobe analyses will allow identification and semi-quantification of secondary mineral phases of uranium and arsenic that may be present in the aquifer. This information will strengthen our understanding of the potential solid-phase controls on uranium and arsenic mobility in the aquifer.

4.2 Determining Partition Coefficients (K_d) for Uranium and Arsenic

Additional geochemical data collection with regard to uranium and arsenic partitioning in aquifer materials will be needed to support future geochemical transport modeling efforts. Geochemical modeling would be incorporated into a non-mechanistic transport model (such as MT3D, compatible with MODFLOW) that utilizes a partition coefficient (K_d) to calculate retardation factors for uranium and arsenic. Although more rigorous geochemical transport modeling using

one-dimensional chemical equilibria transport models (such as PHREEQC) may model individual chemical species more accurately, the level of site geochemical characterization required, and the associated cost, is high. Based on our current understanding of site conditions, mechanistic modeling approaches using simple K_d values should be sufficient to meet regulatory and environmental management objectives.

The method used for determination of the K_d values will be consistent with the regulatory objectives. Laboratory experiments will be carried out to understand the long-term concentrations of uranium and arsenic in the ground water as controlled by partitioning to aquifer materials as clean water migrates through the formation. Samples of contaminated aquifer materials will first be collected from Shale Units 1,2, 3, and 4 at selected locations (see Drawing 1 and Table 4.2). Samples of the aquifer material from each corehole will be reacted in batch vessels with clean site groundwater collected upgradient. Groundwater will be collected from Shale Units 2, 3, and 4 at proposed well location No. 4 (see Drawing 1). For each corehole, subsamples of the aquifer material (< 2mm) will be reacted in series with clean groundwater at increasing solution:solid ratios. The samples will be agitated for 48 hours, centrifuged, filtered (0.45 micron pore size), and analyzed for dissolved uranium and arsenic. A plot of K_d versus the solid:solution ratio will generate a simple, site-specific rinsing or "desorption" curve that will provide a long-term K_d for use in the transport model.

5.0 REFERENCES

Parkhurst, D.L. and C.A.J. Appelo. 1995. User's Guide to PHREEQC (Version 2)– A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations. *U.S. Geological Survey Water-Resources Investigations Report 99-4259.*

Table 3.1 Proposed Well Locations for Hydrologic and Geochemical Testing

Well Location	Objective	Unit
Location No. 1	Monitoring Well and Lithology Corehole	Terrace Alluvium
Location No. 2	Pumping and Observation Well	Shale 4
	Observation Well	Alluvium
	Lithology Corehole	Shale 4
Location No. 3	Pumping and Observation Well	Shale 3
	Pumping and Observation Well	Shale 4
Location No. 4	Monitoring Well	Shale 2
	Monitoring Well	Shale 3
	Monitoring Well	Shale 4
	Lithology Corehole	Shales 2 to 4
Location No. 5	Monitoring Well	Alluvium
	Monitoring Well	Shale 4
	Lithology Corehole	Alluvium to Shale 4
Location No. 6	Monitoring Well	Alluvium
	Monitoring Well	Shale 4
	Lithology Corehole	Alluvium to Shale 4
Location No. 7	Geochemistry Corehole	Shales 1, 2, and 3
Location No. 8	Geochemistry Corehole	Shales 2, 3, and 4
Location No. 9	Geochemistry Corehole	Shales 3 and 4
Location No. 10	Geochemistry Corehole	Shale 1
Location No. 11	Monitoring Well	Shale 3
Location No. 12	Monitoring Well	Terrace Alluvium
Location No. 13	Monitoring Well	Shale 1
Location No. 14	Monitoring Well	Shale 2

Note: Slug tests will be performed at all new wells, except at Locations 2 and 3.

Table 4.1 Suggested Analyte List for Selected Ground Water Monitoring Wells. [1]

Dissolved Analytes (filtered sample)	Total Analytes (unfiltered sample)	In Situ (unfiltered sample)
Aluminum	Aluminum	Dissolved Oxygen
Alkalinity	Arsenic	Electrical Conductivity
Ammonia-N	Iron	Oxidation-Reduction Potential (Eh)
Arsenic(III)	Manganese	pH
Arsenic(V)	Total Suspended Solids (TSS)	Temperature
Calcium	Uranium	
Chloride		
Dissolved Organic Carbon		
Fluoride		
Iron (II)		
Iron (total)		
Magnesium		
Manganese		
Nitrate-N		
Nitrite-N		
Orthophosphate-P		
Potassium		
Radium		
Silica		
Sodium		
Sulfate		
Sulfide (H_2S)		
Uranium		

[1] To be analyzed on samples from Wells MW025 and MW075 (Layer 1), MW025A and MW042A (Layer 2), MW012A and MW057A (Layer 3), MW067A and MW064A (Layer 4).

Table 4.2 Proposed Corehole and Auger Locations for Geochemical Testing

Location	Type	Layers Sampled
Near MW025 (#7)	Corehole	1,2,3
Near MW042A (#8)	Corehole	2,4
Near MW057A (#9)	Corehole	3,4
Near MW075 (#10)	Auger	1

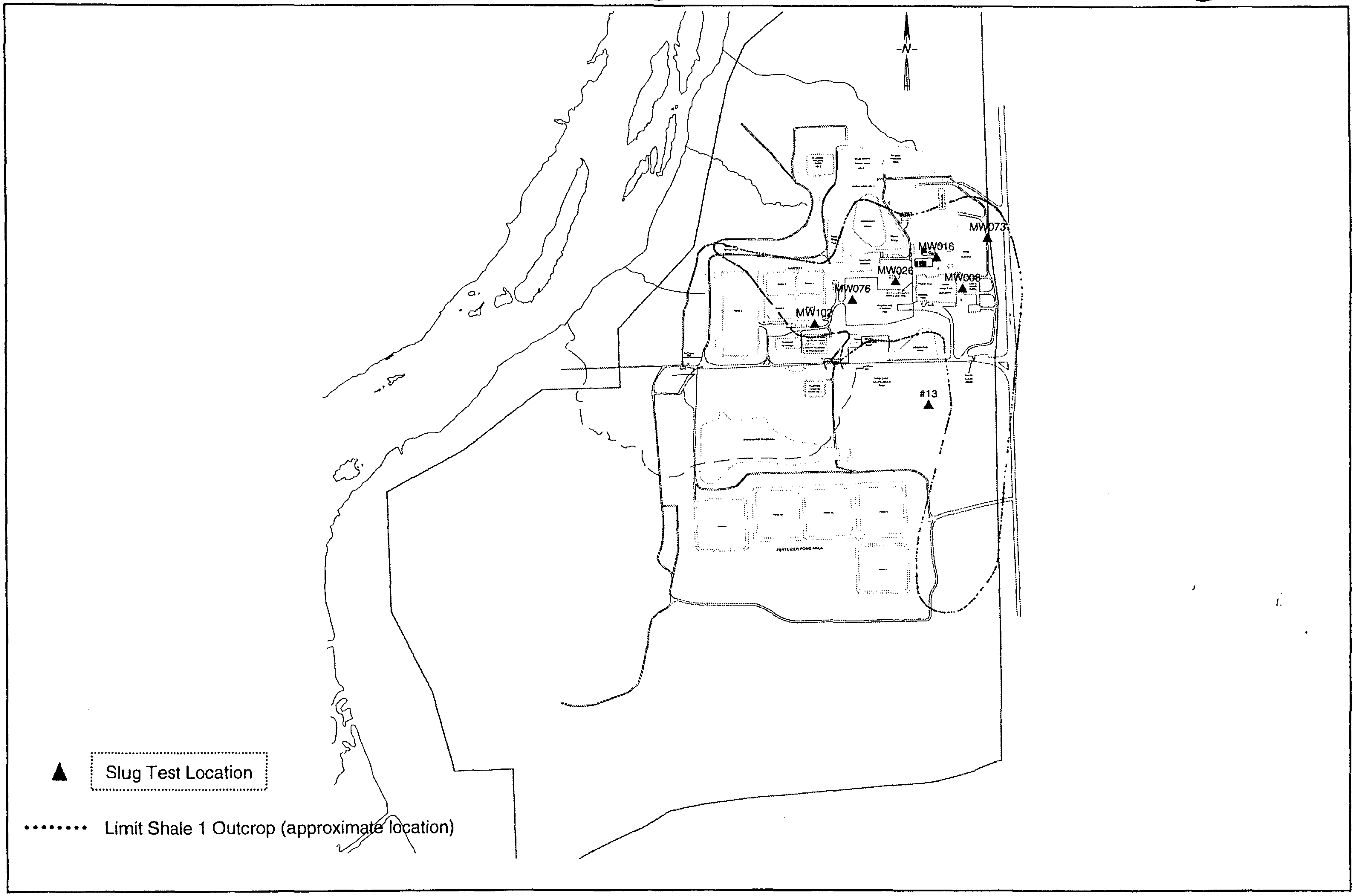

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Figure 3.1
Slug Test Locations-Shale 1

Date:	APRIL 2001
Project:	100734
File:	Hydroeo/slug

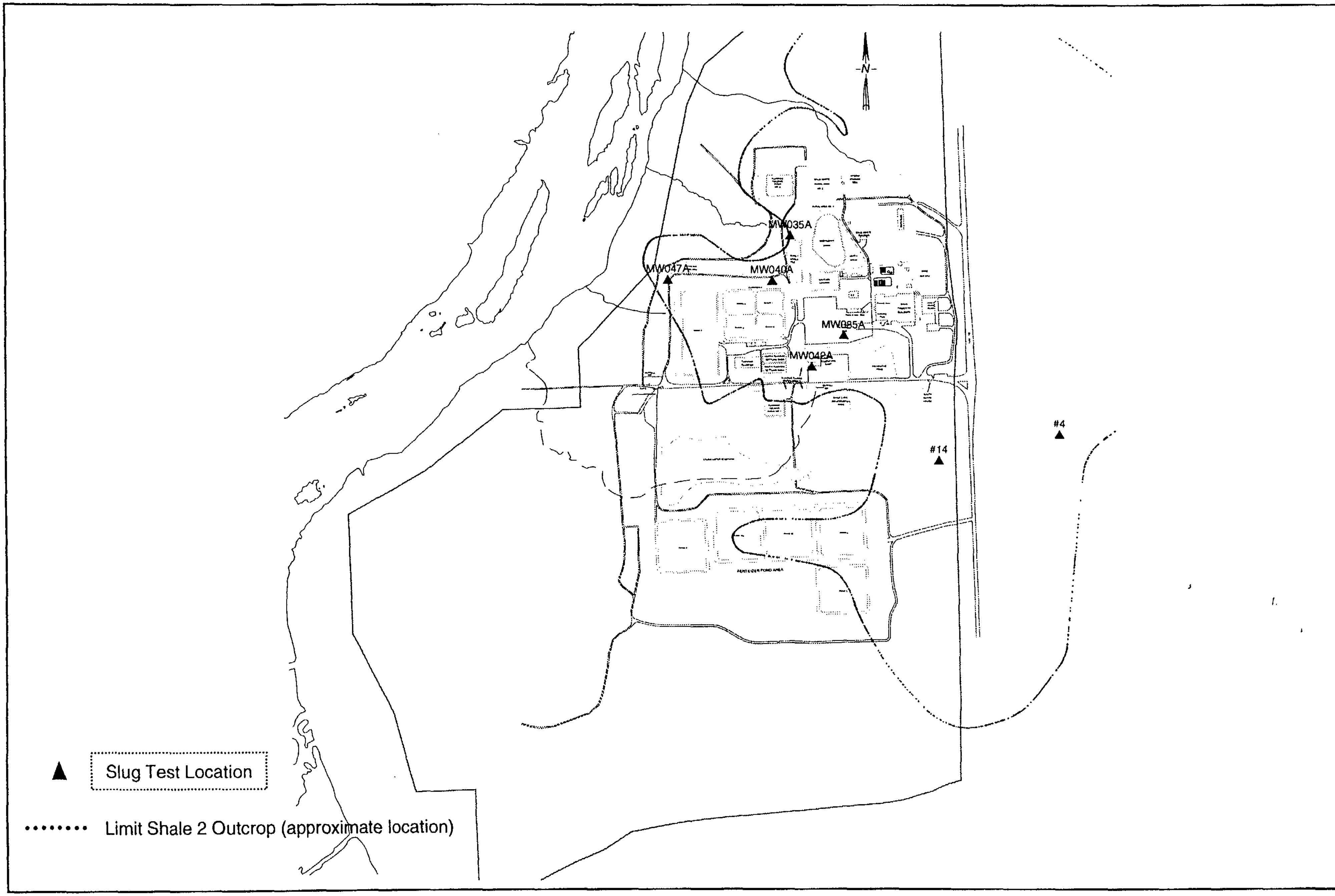

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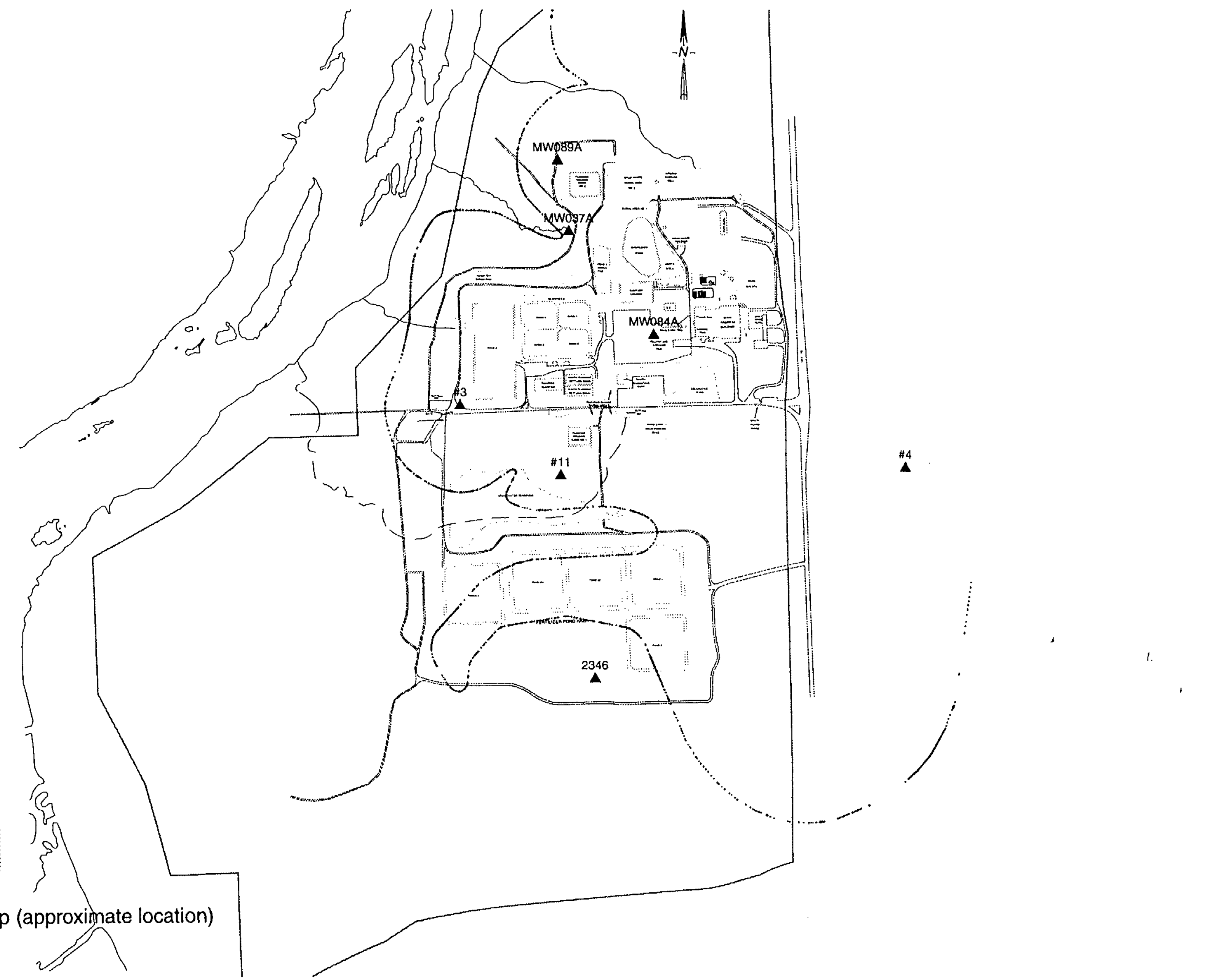
Figure 3.2
Slug Test Locations-Shale 2

Date:	APRIL 2001
Project:	100734
File:	Hydroeo/slug



▲ Slug Test Location

•••••••• Limit Shale 3 Outcrop (approximate location)

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Figure 3.3
Slug Test Locations-Shale 3

Date:	APRIL 2001
Project:	100734
File:	Hydroeo/slug

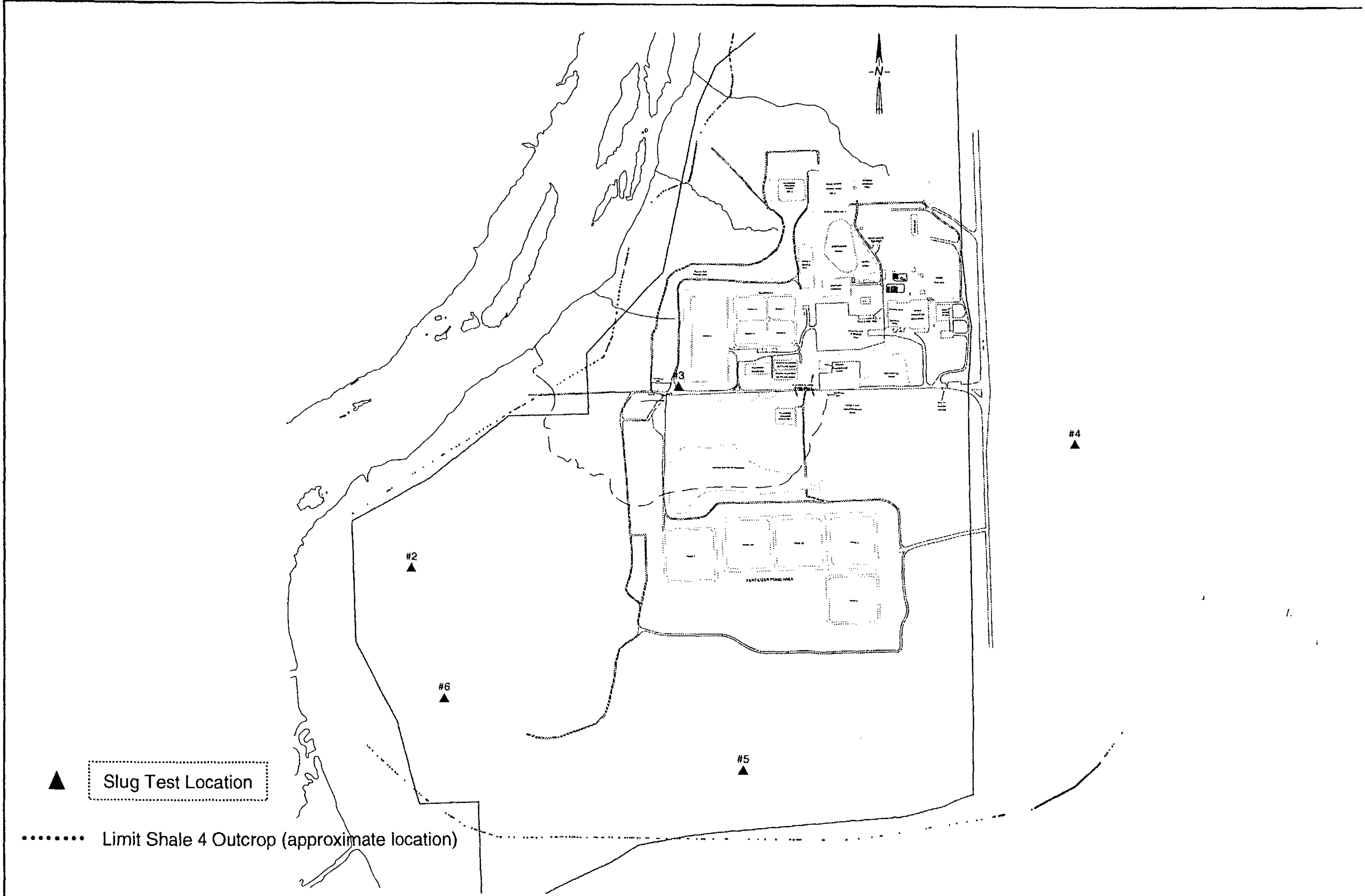

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Figure 3.4
Slug Test Locations-Shale 4

Date:	APRIL 2001
Project:	100734
File:	Hydroeo/slug

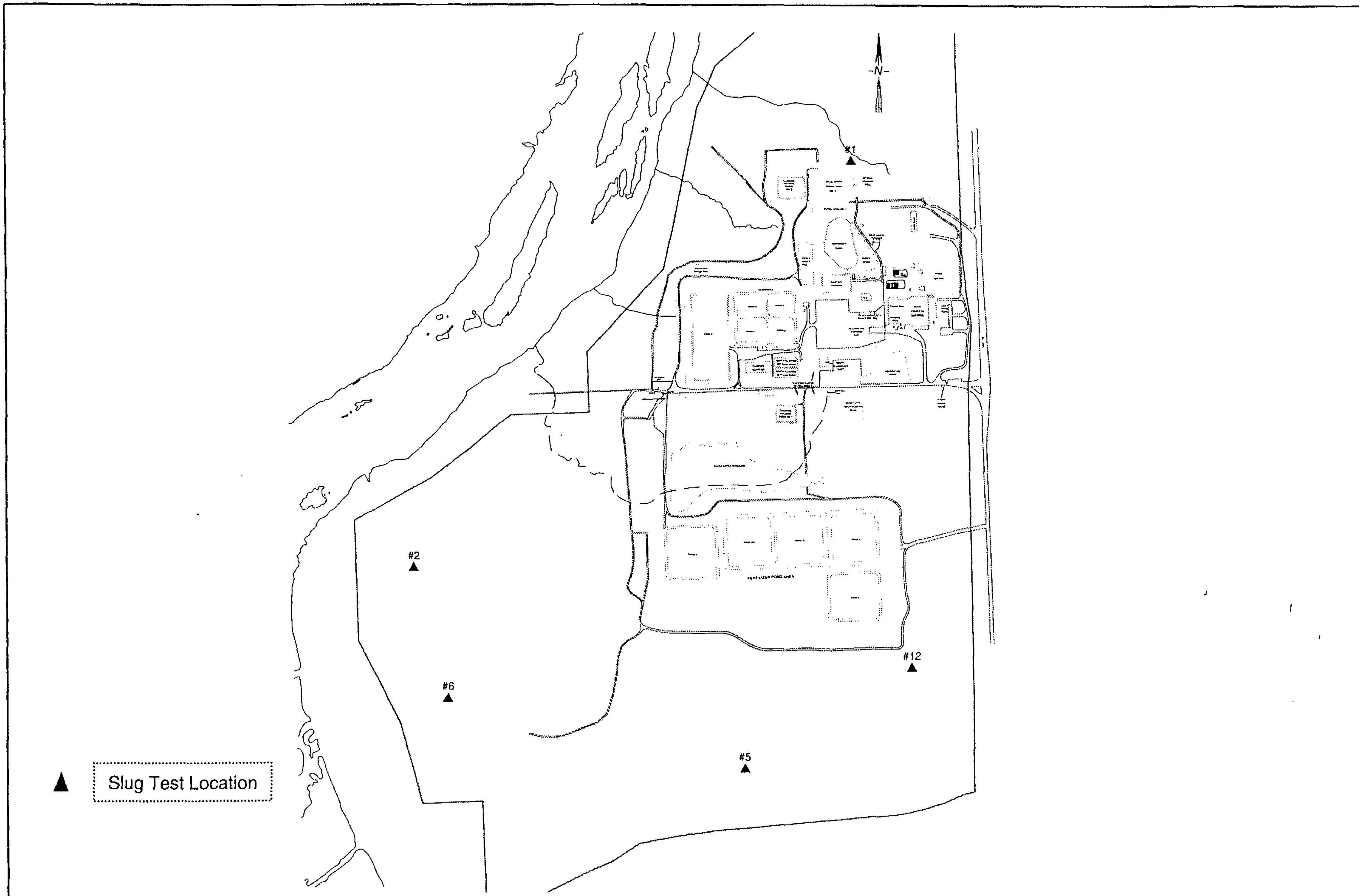

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Figure 3.5
Slug Test Locations-Alluvium

Date:	APRIL 2001
Project:	100734
File:	Hydroeo/slug

Prepared for
Sequoyah Fuels

STANDARD OPERATING PROCEDURE NO. 1
GROUNDWATER MONITORING WELL INSTALLATION

Sequoyah Fuels Site
Gore, Oklahoma

April 2001

Prepared by
Shepherd Miller, Inc.

STANDARD OPERATING PROCEDURE NO. 1

GROUNDWATER MONITORING WELL INSTALLATION

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1.0 PURPOSE AND SCOPE

The purpose of this document is to define the standard operating procedure (SOP) for installing groundwater monitoring wells. This SOP will explain the necessary equipment and procedures for well installation. The well installation procedures in this SOP are not specific to a particular drilling method or formation.

This is a generalized SOP that presents several options for procedures, equipment, and materials. Site-specific conditions must be evaluated to select the most appropriate options. When referencing this SOP, also specify the site-specific procedure, equipment, and materials that have been selected for the site.

Due to the variability of site-specific conditions, well designs, and drilling methods, a complete description of all procedures and options for well installation are beyond the scope of this SOP. For more detailed well installation procedures, refer to the National Water Well Association (NWWA) "Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells," "Groundwater and Wells" (Second Edition), and The American Society for Testing and Materials (ASTM) Design and Installation of Groundwater Monitoring Wells in Aquifers (D 5092-90).

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOP:

- SOP No. 3 Equipment Decontamination

3.0 GENERAL DRILLING PROCEDURES

Boreholes can be drilled using various methods and equipment depending on the conditions and requirements of specific projects. The general drilling and well construction procedures listed below will apply to most drilling methods.

3.1 Premobilization Activities

Before mobilizing the drill rig to the site, do the following:

- Inspect the site for buried utilities and overhead power lines and obtain clearances from the appropriate companies and government agencies.
- Determine the applicable state and/or county regulations regarding borehole drilling and well construction.
- Obtain state and/or county well permits (if required) and ensure they will be available for inspection at the site.
- If a licensed well driller is required by the state, obtain the driller's license number.
- Verify that the drilling company has appropriate insurance as Shepherd Miller, Inc. (SMI) or the client requires (i.e., obtain copies of their insurance certificates).
- Verify that drilling personnel have appropriate (OSHA or MSHA) safety training and that their certifications are up to date (i.e., obtain copies of their certifications).
- Obtain copies of applicable plans, which may include SOPs, the Scope of Work (SOW), the Sampling and Analysis Plan (SAP), the Quality Assurance Project Plan (QAPP), and the Health and Safety Plan (HASP).
- Obtain all appropriate Material Safety Data Sheets (MSDS).
- Determine the types of lubricants and drilling fluids to be used and verify that they will not bias resulting data.

3.2 Pre-Drilling Site Activities

Perform the following site activities on-site before drilling:

- Conduct a health and safety meeting before performing any work. Document the health and safety meeting and have all drill company personnel sign to acknowledge the meeting and plan.
- Decontaminate all downhole equipment as specified in SOP No. 3. To prevent cross-contamination, perform the decontamination at a location other than the drill site. Once at the drill site, inspect equipment to verify that decontamination has been properly performed.

- Perform a safety check of the drill rig (see the HASP).
- Verify that oil/fuel spill containment equipment is available.

3.3 Preventing Cross Contamination

The most important aspect of drilling and completing monitoring wells is to ensure that representative samples will be obtained and that the samples will not be significantly biased due to the procedure, equipment, or materials used to drill or complete the well. Carefully evaluate all procedures, equipment, and materials used as a potential source of contamination. Proper equipment decontamination as specified in SOP No. 3 is essential in preventing cross-contamination. Common sources of contamination encountered during drilling and well installation include:

- Pipe lubricants that are used should not introduce contaminants into the borehole. Lubricants that are environmentally acceptable include Green Stuff, King Stuff, Crisco, and some Teflon-based lubricants. Lubricants that are not acceptable include petroleum and most metal-based lubricants. SMI will pre-approve lubricants that will be used and the MSDS sheets for these lubricants shall be provided for approval.
- Drilling fluids, if used, should not introduce contaminants into the borehole. Drilling fluids that are acceptable include air and potable water. When possible, only air or air/mist should be used during drilling. The use of bentonite or other drilling fluids will result in significantly increased development times and possible contamination, so these fluids should not be used if possible. The project manager shall approve the use of bentonite or other drilling fluids.
- Oil from air compressors can contaminate the borehole when drilling with air. Use in-line air filters that remove air compressor oil.
- Obtain water to be used during drilling from a potable source. Before use, flush water tanks that will be used to transport the water to remove accumulated sediments and contamination.
- Wear clean gloves, preferably rubber or latex (clean cotton gloves are acceptable), when handling decontaminated equipment. Change or decontaminate gloves frequently and always after contacting contaminated material.
- Dirty tools can be a source of contamination. Keep all tools that contact downhole drilling equipment clean and off the ground.

- Take great care when fueling equipment to prevent spillage.
- Do not use contaminated downhole drilling equipment.

3.4 Necessary Equipment

The following equipment is necessary to drill boreholes and install wells:

- Drill rig capable of installing wells to the desired depth in the expected formation materials and subsurface conditions
- Well casing, well screen and end caps
- Bentonite pellets and bentonite chip
- Cement and powdered bentonite for grouting
- Stainless steel centralizers (optional)
- Protective well casing with locking cap
- Steel guard post (optional)
- Gallon Ziploc® freezer bags
- Self-adhesive labels
- Weighted tape measure
- Appropriate health and safety equipment
- Log book
- Boring log sheets.

The following equipment is necessary to measure water levels:

- Electric water level probe capable of producing measurements to a precision of 0.01 feet
- Replacement batteries for water level probe
- Field logbook, field data sheets, and black pen

- Engineers tape (10ths, 100ths feet)
- Additional stainless steel weight
- Paper cups and/or turkey baster
- Appropriate health and safety equipment, minimum of safety glasses and latex gloves.

The following equipment may be needed to perform decontamination:

- Brushes
- Wash tubs (plastic)
- Buckets (plastic)
- Scrapers
- Steam cleaner or hot water washer
- Paper towels
- Liquinox detergent (or equivalent)
- Potable water
- Deionized water
- Garden-type water sprayers
- Laboratory wash bottles
- Clean plastic sheeting and/or trash bags.

3.5 Drilling and Well Installation Procedures

3.5.1 Drilling Techniques

SMI typically uses the following three types of drilling systems:

- Auger rigs
- Casing advance

- Dual tube reverse.

Conductor casing must sometimes be installed to isolate shallow aquifers, contamination, or to stabilize the borehole. In some cases, it may be necessary to install a bentonite plug in the end of the conductor casing to keep shallow contamination out of the conductor casing. Drive the conductor casing into a confining layer and/or cement it in place with cement/bentonite.

The minimum borehole diameter shall be at least 4 inches greater than the diameter of the casing installed. This applies to both the conductor casing and the well casing/screen.

Water production and water level measurements that are collected during drilling are a very important part of a monitoring well program. Generally, monitoring wells are designed to be screened in the upper 10 to 20 feet of the aquifer, so it is important to accurately determine the top of the aquifer. Determine the upper aquifer water level by air lifting, measuring water levels within the drill string and in nearby piezometers, or inspecting split barrel core samples for saturation. When drilling with air, the borehole will be air lifted until water production stabilizes at the depths determined by the onsite SMI employee. Air lifting will sometimes be performed as frequently as every 10 feet near the top of the aquifer. It may occasionally be necessary to cease drilling, air lift the borehole, allow the aquifer to recover, and measure the depth to water.

Record observations made by the driller, because they can provide valuable information regarding borehole conditions. These observations can include the following:

- Depth to competent bedrock
- Depth to water
- Location of voids and fractures
- Location of boulders
- Loss of circulation
- Drilling rates and "soft" or "hard" drilling
- Zones of water production and production rates

- Changes in formations.

3.5.2 Stratigraphic Logging

Borehole stratigraphy will be logged by SMI personnel by examining the sample cuttings, undisturbed split barrel samples (in soil), or core samples.

When performing hollow stem augering, collect soil samples using a split-barrel sampler according to ASTM Method D-1586. Describe the samples on the data sheets and archive them in sealed and labeled plastic bags. Split-barrel samplers may fitted with 6-inch long brass sleeves that are capped and sealed on-site for later geotechnical analysis.

3.5.3 Field Notes

Logging will be performed on borehole log forms or in the field book. Data recorded in the field book shall include the following information:

- Project name and number
- Drilling company name
- Date drilling started and finished
- Type of bit and size
- Casing sizes and depths
- Well completion details
- Driller's name
- Geologist's name
- Type of drill rig
- Boring number
- Surface elevation (if available)
- Sample depths and times

- Water levels
- Drilling observations
- Other pertinent information.

3.5.4 Well Materials Specifications

The following subsections describe well material specifications in general terms. Site-specific material specifications will be presented in the project scope of work or project work plan.

3.5.4.1 Well Casing and Screen

Well casing (riser pipe) and screens will consist of new, threaded, flush-joint pipe. Typically, 2- or 4-inch inner diameter (ID), Schedule 40 or 80 PVC casing is used. The casing diameter is usually based on sampling/testing equipment that will be used. Smaller diameter wells are preferred due to cost savings, but larger diameter wells are sometimes required to accommodate standard-size electric submersible pumps that may be required due to water depths or the quantity of water required.

Casing thickness (e.g., Schedule 40 or 80) is determined based on the expected well depths and hydrostatic heads. Carefully review technical specifications of the casing in order to select the appropriate size and strength casing. Tensile strength, compressive strength, and collapse strength shall be considered when evaluating casing strength.

Well screen can be constructed from factory-machined slotted casing or specially manufactured continuous slot well screen. The continuous slot well screen has significantly more open area and is preferred for production wells or wells designed for aquifer tests. The well screen slot size is determined based on the gradation of the filter pack material, which is based on the gain size analysis of the formation material present at the completion interval. Generally, a 0.020-inch slot (20 slot) is acceptable with 10-20 Colorado Silica Sand.

If the well casing is not certified clean by the manufacturer, delivered clean, or maintained clean at the site, clean the casing immediately prior to installation using potable water with a steam cleaner or a high pressure washer.

3.5.4.2 Casing Centralizers

Evaluate the use of casing centralizers on a well by well basis. Although casing centralizers do help center well casings within the borehole, they can interfere with the tremmie pipe and with placing materials within the annulus. In some cases, centralizers will not fit within the annulus. Some states/counties require centralizers at specific intervals.

Casing centralizers will consist of stainless steel or PVC and will be firmly attached to the casing. When used, attach centralizers at the base and top of the well screen and at minimum 40-foot intervals on the blank casing, or at intervals specified by state/county regulations.

3.5.4.3 Filter Pack

The filter pack will consist of clean silica sand of selected grain size and gradation, and in most cases will extend approximately 3 feet above the top of the screen. Unless the well is less than 30 feet deep, install the filter pack through a tremmie pipe. Water can be used to facilitate placement if its quality is known. To demonstrate the absence or presence of voids, monitor the volume of filter pack installed and compare it to the calculated volume.

Before well installation, pour a small amount of filter pack over the well screen. Observe the amount of filter pack that passes through the well screen to verify that the sand size is not too small for the selected well screen.

3.5.4.4 Bentonite Seal

Install a bentonite seal above the filter pack. The seal will consist of a layer of commercially available 1/4-inch bentonite pellets or medium chip bentonite that is approximately 3 to 5 feet thick as measured immediately after placement, without allowance for swelling. Specially manufactured 1/4-inch bentonite pellets that are coated to retard swelling are now available. The

coated bentonite pellets will fall further through water before swelling and are less likely to bridge. Depending on borehole conditions, install bentonite pellets or chips bentonite by gravity feed directly down the annulus or through a tremmie pipe installed to above the water level. Add at least 5 gallons of potable water to the bentonite, and let the bentonite hydrate for 1 hour or until a retained sample hydrates.

Use bentonite slurry seals only when bentonite pellets or chips cannot be placed in the annulus. The bentonite slurry will be 20 percent to 30 percent solids by weight and will be weighed with a mud scale before placement. The bentonite slurry seal will extent at least 10 feet and preferably longer above the filter pack. Install slurry seals with a side discharge tremmie pipe and let them hydrate for at least 2 hours before continuing. Slurry seals that are longer than 100 feet may cause collapse of PVC casing. The collapse strength of the casing should be evaluated before placing seals longer than 100 feet.

Fine sand (80 or 100 mesh) may be installed on top of the filter pack to prevent infiltration of the bentonite into the filter pack. Fine sand may also be installed on top of the bentonite slurry to facilitate measuring the top of the bentonite slurry. Monitor the volume of bentonite installed and compare it to the calculated volume to demonstrate the absence or presence of voids. Note that bentonite slurries sometimes lose significant amounts to the formation and fractures.

3.5.4.5 Cement/Bentonite Grout

Grout the annular space between the well casing and the borehole from the top of the bentonite seal to the ground surface. If the grout seal will be placed on top of a bentonite slurry seal, wait 2 hours between placing the bentonite and the grout seal. If bentonite pellets or chips were used to make the seal, do not place cement/bentonite grout on the seal for at least 1 hour or until a retained bentonite sample hydrates at the surface. The grout mixture will consist of 10 parts cement to a maximum one-half part bentonite (equivalent to one 94-pound bag of cement to about 4½ pounds of bentonite powder); the bentonite powder should not exceed 5 percent of total weight with approximately 8 gallons of potable water per 94-pound bag of cement. The slurry should be made as thick as possible while still being able to be pumped.

Prepare the grout in an aboveground rigid container by first mixing the bentonite powder thoroughly with the water and then mixing in the cement. For deep holes where large volumes of grout are necessary, the grout may be mixed off-site and transported to the site by truck. Specific state/county well construction standards may dictate minimum depth requirements for the grout seal or may specify a neat cement grout (i.e., cement with no added bentonite) of a minimum density.

Place grout in the well annulus with a side discharge tremmie pipe located within about 10 feet of the top of the bentonite seal. Keep the tremmie submerged within the grout throughout the grouting process. Pump the grout through the tremmie pipe, which will be removed incrementally, until undiluted grout flows from the annular space at ground surface.

Let the initial batch of grout set for at least 12 hours before placing the next grout batch in the annulus or until a retained grout sample has setup. Measure the depth to the top of each batch. For PVC casing, no batch will exceed more than 100 feet of annulus displacement.

Do not mix additives, such as calcium chloride, with the grout mixture to accelerate cement set time. The excess heat generated can melt PVC casing.

Monitor the volume of installed cement and compare it to the calculated volume to demonstrate the absence or presence of voids.

3.5.4.6 Above Ground Completion

Determine the above ground completion based on the well location and site-specific needs. After initial annular grout placement, install a protective, steel casing over the portion of the monitoring well casing which projects above the ground surface. The casing will have a lockable steel cap, will be at least 5 feet long (depending on the depth of frost), and will have a diameter of at least 8 inches for 4-inch wells or 6 inches for 2-inch wells. Set the protective casing before the final set of the grout approximately 6 inches above the top of the well casing. Fill the annular space to immediately above ground level with cement grout, mortar mix, or dry bentonite. Drill a 1/4-inch weep hole in the protective casing immediately above the annular

seal. Install sand or pea gravel in the annulus to above the weep hole to prevent insects from entering.

Depending on site requirements, a 0.5-foot thick coarse gravel (3/4-inch to 3-inch particle size) blanket or cement pad will extend approximately 4 feet radially from the protective casing.

Four 3-inch diameter steel posts or four 4- by 4-inch wooden posts may be installed around the well. Locate the posts approximately 4 feet from the center of the well casing and approximately 2.5 feet below the ground surface, and be sure the posts extend at least 2.5 feet above ground exposure. In areas of high vegetation, flag the posts.

3.5.5 Measurements

Take and record measurements of the boring during drilling and well construction and of well construction materials. Measure the depth to the top of the sand pack, the top of the bentonite seal, and the top of each cement/bentonite grout batch to confirm volume and placement depth to the nearest 0.1 foot. Measure PVC casing and screen to the nearest 0.01 foot.

After construction, survey the horizontal location to the nearest 0.1 foot in reference to local, documentable coordinates. Survey the elevations of the top of the protective casing, ground surface, and water level measuring point to the nearest 0.01 foot in reference to a documentable bench mark.

3.5.6 Borehole Drilling and Well Installation Procedure

Use the following procedure to install alluvial wells using hollow stem augers or the dual tube method:

- Decontaminate all drilling equipment according to SOP No. 3.
- Before drilling begins, inventory all materials on-site and record the totals in the field book. Measure bits, augers, dual-tube pipes, or drill rods before they go down the borehole. Keep a running total in the field book of the drilling equipment that is downhole.

- Advance the boring to the planned depth using hollow stem augers, dual tube reverse circulation, or other applicable method. Collect drill cuttings at 5-foot intervals when using the dual tube and other applicable method, or when encountering changes in lithology. Collect split barrel soil samples at minimum intervals of 5 feet or when encountering changes in lithology. Collect split barrel samples according to ASTM Method D-1586 when using hollow stem augers.

- Measure depth of completed boring using a weighted tape or measured tremmie pipe.

- Decontaminate all well casing, screens, and centralizers according to SOP No. 3 unless they have been certified clean by the manufacturer, delivered, and maintained clean at the site.

- Measure each joint of casing, screen, and cap to nearest 0.01 foot.

- Assemble screen and casing as it is lowered into the borehole. Verify that o-rings are present at each casing union. Attach centralizers as required. When tightening a threaded joint, do not use a conventional pipe wrench. The jagged edge of the pipe wrench's jaws can cut deep scars on the outside of the casing that could cause cracks and failure in the future. Careful use of a strap or chain wrench when tightening will prevent this. In many cases, hand tightening will be sufficient.

- Lower screen and casing until they are installed at the proper interval. Do not allow the full weight of casing/screen to support itself. Casing must be suspended, when possible, throughout well construction.

- Record level of top of casing and calculate the screened interval. Adjust the screen interval by raising or lowering the assembly to the desired interval, if necessary, and add sand to come to the base of the cap.

- Calculate the volume of filter pack, bentonite seal, and grout required for idealized borehole conditions, and record the volume.

- Begin adding filter pack around the annulus of the casing through the tremmie pipe (if depth to bottom of sand is greater than 50 feet) in 5-foot increments. Take repeated depth soundings to monitor the level of the sand. In very muddy water or when using fine sand, sand should be added slowly. If present, remove hollow stem augers or other temporary casing incrementally throughout the well construction procedure. Remove the hollow stem augers or temporary casing to prevent or minimize exposure of the well casing/screen to the open borehole.

- Before measuring the sand level, allow sufficient time for the filter sand to settle through the water column outside the casing.

- In most cases, extend the filter pack to approximately 3 feet above the top of the well screen. In some cases with very long screened intervals, the filter pack should extend longer than 3 feet to allow for settlement during development.

- Following sand pack placement, install a minimum 3-foot-thick seal of bentonite pellets (preferred), chips, or slurry. Install bentonite slurries through a tremmie pipe. Install bentonite pellets/chips through a tremmie pipe or by gravity feed directly down the annulus, depending on water level and borehole conditions. Measure the thickness of the completed bentonite seal before the bentonite hydrates. Before proceeding with the grouting operation, let the completed bentonite seal hydrate for at least 1 hour if pellets or chips are used or for at least 2 hours if a slurry is used. In some cases, bentonite will extend to 5 to 10 feet from the ground surface.

- Slurry seals that are longer than 100 feet may cause collapse of PVC casing. The collapse strength of the casing should be evaluated before placing seals longer than 100 feet.

- Fine sand (80 or 100 mesh) may be installed on top of the filter pack to prevent infiltration of the bentonite into the filter pack. Fine sand may also be installed on top of the bentonite slurry to facilitate measuring the top of the bentonite slurry. Monitor the volume of bentonite installed and compare it to the calculated volume to demonstrate the absence or presence of voids. Note that bentonite slurries sometimes lose significant amounts to the formation and fractures.

- After placing the bentonite seal, grout the remaining annulus from the top of the bentonite seal to the ground surface. If this distance is more than 100 feet, a second grout pour will be required. Pour the grout through the tremmie pipe (if depth to top of bentonite is greater than 35 feet) into the borehole until the annulus is completely filled. Place the base of the tremmie pipe approximately 10 feet above the bentonite seal.

- Before the grout sets, center the protective steel casing on the well casing and insert it into the grouted annulus. Insert a temporary spacer between the protective casing locking lid and the well cap to prevent the protective casing from settling onto the well cap. Place the well number on the well casing and on the cap.

- Wait until either the last grout that was poured has set for 12 hours or a retained sample has setup, and then check the grout for settlement. If necessary, add grout to top off the annulus.

- After 12 hours, install the mortar collar; weep hole, gravel blanket, and guard posts according to Section 3.5.4. Paint the protective casing and posts red, write the well designation with white paint, and lock.

- Do not begin development activities for at least an additional 24 hours.

4.0 DOCUMENTATION

Record observations and data acquired in the field during drilling and installation of wells to provide a permanent record. Record these observations with waterproof black ink in a bound weatherproof field book with consecutively numbered pages. Record notes daily when in the field. Include at least the following information:

- Project name and number
- Location
- Observer's name
- Drilling company name
- Driller's and helper's names
- Type of drill rig
- Date drilling started and finished
- Type of bit used and its size
- Casing sizes and depths
- Drilling and well installation observations as described in this section
- Problems encountered and resolution
- Decontamination observations
- Weather conditions
- Inventory of materials on site.

Complete a boring log for each boring with the observations recorded in the field book. Fill out a well completion form for monitoring wells and record the data in the field book.

Draw the well installation specifics in a diagram in the field book. Include the following information in each well diagram (denoted by depth from ground surface):

- Bottom of the boring

- Surface casing depth (if intermediate casing is left in the hole)
- Borehole diameter(s)
- Screen location(s)
- Filter pack
- Bentonite seal(s)
- Cave-in locations
- Centralizers
- Height of riser without cap (above ground surface)
- Protective casing detail.

Additional documentation for well construction in the field book will include the following:

- Grout, sand, and bentonite volume calculations prior to well installation
- The quantity and composition of the grout, seals, and filter pack actually used during construction
- All measurements made to top of filter pack, seal, grout batches and other depths
- Screen slot size (in inches), slot configuration, outside diameter, inside diameter, schedule/thickness, composition, and manufacturer
- Coupling/joint design and composition
- Protective casing composition and nominal inside diameter
- Start and completion dates
- Discussion of all procedures and any problems encountered during drilling and well construction
- Surface completion information and date.

5.0 REFERENCES

American Society for Testing and Materials (ASTM) D-1586-84. Test Method for Penetration Test and Split-Barrel Sampling of Soils, *1995 Annual Book of ASTM Standards*, Vol. 04.08.

American Society for Testing and Materials (ASTM) D-5092-90. Design and Installation of Groundwater Monitoring Wells in Aquifers, *1995 Annual Book of ASTM Standards*, Vol. 04.08.

National Water Well Association (NWWA). "Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells."

Driscoll, F.G. 1986. *Groundwater and Wells*, Second Edition, H.M. Smyth Co., Inc., Johnson Division, St. Paul, Minnesota.

Prepared for
Sequoyah Fuels

STANDARD OPERATING PROCEDURE NO. 2
MONITOR WELL DEVELOPMENT

Sequoyah Fuels Site
Gore, Oklahoma

April 2001

Prepared by
Shepherd Miller, Inc.

STANDARD OPERATING PROCEDURE NO. 2

MONITORING WELL DEVELOPMENT

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1.0 PURPOSE AND SCOPE

This document defines the standard operating procedure (SOP) for developing groundwater monitoring wells and piezometers. This SOP explains the necessary equipment and procedures for developing wells in both bedrock and alluvium.

This is a generalized SOP that presents several options for procedures, equipment, and materials. Site-specific conditions must be evaluated to select the most appropriate options. When referencing this SOP, also specify the site-specific procedure, equipment, and materials that have been selected for the site.

Due to the variability of site-specific conditions, well designs, and drilling methods, a complete description of all procedures and options for development are beyond the scope of this SOP. For more detailed development procedures, refer to the National Water Well Association (NWWA) "Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells," "Groundwater and Wells" (Second Edition), and The American Society for Testing and Materials (ASTM) Design and Installation of Groundwater Monitoring Wells in Aquifers (D 5092-90).

2.0 RELATED STANDARD OPERATING PROCEDURES

This procedure is intended to be used with the following SOPs:

- SOP No. 3 Equipment Decontamination
- SOP No. 1 Groundwater Monitoring Well Installation

3.0 NECESSARY EQUIPMENT

A combination of the following items are required to properly develop groundwater-monitoring wells:

- Calculator
- Field notebook

- Waterproof pen
- Stainless steel submersible pump
- Gas-powered electric generator
- PVC hand pump
- PVC or stainless steel bailer (sized appropriately for well)
- Nylon rope or wireline (deep wells) for bailing
- Surge block (sized appropriately for well)
- PVC or stainless steel pipe for operating surge block (sized appropriately for well)
- 5-gallon bucket
- Appropriate health and safety equipment
- Liquinox soap (or equivalent).

The following equipment is necessary to measure water levels:

- Electric water level probe capable of producing measurements to a precision of 0.01 foot
- Replacement batteries for water level probe
- Field logbook, field data sheets, and black pen
- Engineers tape (10ths, 100ths feet)
- Additional stainless steel weight
- Paper cups and/or turkey baster
- Paper towels
- Liquinox soap
- Potable water
- Sprayer or laboratory wash bottle filled with deionized water

- Appropriate health and safety equipment, including at least safety glasses and latex gloves.

The following equipment may be needed to perform decontamination:

- Brushes
- Wash tubs (plastic)
- Buckets (plastic)
- Scrapers
- Steam cleaner or hot water washer
- Paper towels
- Liquinox detergent (or equivalent)
- Potable water
- Deionized water
- Garden type water sprayers
- Laboratory wash bottles
- Clean plastic sheeting and/or trash bags.

4.0 WELL DEVELOPMENT PROCEDURES

The purpose of well development is to repair damage done to the formation during drilling. Development removes well drilling fluids, solids, or other particulates that may be introduced or deposited on the borehole wall during drilling and construction activities. Development also may be performed on older or improperly developed wells that are suspected of not providing representative groundwater samples. Development thus restores the natural hydraulic conductivity and geochemical equilibrium of the aquifer material surrounding the well to near pre-well installation conditions. Properly developed monitoring wells allow groundwater samples to be collected that represent the aquifer of concern.

Develop a newly installed monitoring well only after the cement/bentonite grout has been allowed to set for at least 24 hours. Complete monitoring well development activities before collecting water samples for analytical testing. Before using development equipment and between uses at wells, decontaminate the equipment according to SOP No. 3.

The well completion method, open area and slot configuration, slot size, type of drilling fluid, filter pack size and thickness, and type of formation, will affect monitoring well development. Consider all these factors when developing wells.

4.1 Well Development Methods

Well development methods include mechanical surging, backwashing, and overpumping. Methods that involve adding water to the well or using air can potentially alter groundwater quality. Therefore, do not use jetting, airlift pumping, or air surging for developing wells.

4.1.1 Mechanical Surging

Mechanical surging forces water to flow into and out of the screen by running a plunger up and down the well. A surge block is usually used to produce the surging action. A heavy bailer may be used, but the bailer is not as effective as the surge block in creating flow reversals. A dual wiper surge block with a bypass valve is most effective in reversing flows.

Begin mechanical surging immediately below the static water level and relatively gently. Move progressively downward to prevent the tool from becoming sand locked and steadily increase the force of surging. Surging may force fine material back into the formation before the fines are removed from the well. To minimize this problem, bail fine material from the borehole as often as possible.

In formations with many clay streaks, do not use surge blocks, because they may cause the clay to plug the formation. In formations with large amounts of mica, surge gently in order to minimize mica clogging, because vigorous surging may cause the screen to clog. In low-permeability formations, vigorous surging can cause screens to collapse. The hydraulic conductivity of the formation must be capable of yielding sufficient water to keep pressure

differentials within reasonable limits. Surge silt and sandy formations with 0.010-inch or smaller slot screen only with great caution.

4.1.2 Backwashing

Backwashing is accomplished by starting the pump and, as soon as water reaches the surface, shutting off the pump to let the water flow back into the well (the check valve must be removed). This flow reversal breaks down the bridging, and the pumping then carries the fine material toward the screen and into the well. During backwashing, occasionally let the pump discharge to remove the sand that has been brought in by the surging action. As with overpumping, backwashing is most effective when the pump intake is raised and lowered throughout the saturated screen interval.

4.1.3 Overpumping

Overpumping involves purging the well at a higher rate than the well will be purged during sample collection. Although this is the easiest development method, it seldom produces complete development by itself. Overpumping will more fully develop the more-permeable zones and is less effective in the less-permeable zones. In some cases, overpumping may compact finer sediments around the borehole and thereby restrict flow into the screen. Overpumping is most effective in filter-packed wells located in competent, relatively homogenous formations because flow toward the well bore is more or less uniform. Overpumping is most effective when the pump intake is raised and lowered throughout the saturated screen interval.

Overpumping may be performed with electric submersible pumps, hand pumps, or peristaltic pumps. Do not use airlift development, unless a dual wall system with a check valve to prevent aerated water from entering the well is specified. A bailer can be used, but it can cause over-development of parts of high producing zones.

Record the maximum pumping rate that occurs during overpumping. Pumping rates during sample collection purging will be less than the maximum pumping rate recorded during overpumping.

4.2 Calculating Saturated Borehole Volume

Figure 1 presents a sample saturated borehole volume calculation and a blank form to calculate specific saturated borehole volume. The basic formula is volume equals pi times the radius squared times depth ($V=\pi r^2 d$). To calculate the saturated borehole volume, the casing and borehole radii and the height of water in the casing and filter pack must be known. Measure the water level in the field and obtain the borehole and casing radii from the well completion data.

Figure 2 presents a sample saturated borehole volume calculation, as described below:

- Equation (a) shows how to calculate the casing radius in feet by dividing the nominal-casing diameter in inches by 2 (to convert the diameter to a radius) and dividing the result by 12 (to convert inches to feet).
- Equation (b) shows how to calculate the borehole radius in feet by dividing the nominal borehole diameter in inches by 2 (to convert the diameter to a radius) and dividing the result by 12 (to convert inches to feet).
- Equation (c) shows how to calculate the casing volume, given the casing radius and height of water in the casing.
- Equation (d) shows how to calculate the annular volume, given the annular radius and the height of water in the filter pack.
- Equation (e) shows how to calculate the saturated annulus volume by subtracting the casing volume from the borehole volume and multiplying the result by the assumed effective porosity of the annulus.
- Equation (f) shows how to calculate the saturated borehole volume by adding the casing volume to the saturated annulus volume and converting cubic feet to gallons.

In confined wells and unconfined wells that are screened and filter packed below the water table, the height of water in the casing will exceed the height of water in the filter pack (i.e., $h_1 > h_2$). In these cases, calculate the height of water in the filter pack based on the top of the filter pack interval, and not the top of the screen interval. To calculate the saturated borehole volume in these cases, substitute the appropriate height of water in feet into Equations C and D.

Note that wells have variable amounts of filter pack below the bottom of the screen. The volume of water below the bottom of the screen may be a significant portion of the total saturated borehole volume if there is only a few feet of measurable water in the screen and several feet of filter pack below the bottom of the screen. The saturated borehole volume calculation presented in Figure 2 does not account for the volume of water in the borehole below the screen. For wells with only minimal amounts of water in the screen, evaluate the amount of water within the borehole below the screen and consider it when purging the well.

4.3 Field Parameter Measurement

Although development is a physical process of removing fines from the borehole, measuring water quality is a useful tool to help assess the development procedure. During overpumping, monitor water quality parameters at least every one-half saturated borehole volume. These parameters include temperature, pH, specific conductivity, and turbidity. For operational and calibration procedures of the instruments, refer to the manufacturer's operation manual. Regardless of the development method used, record final water-quality parameter measurements to provide background data for collecting water samples.

4.4 Generalized Development Procedure

A generalized monitoring well development procedure consists of surging, backwashing, and then overpumping the well, as described below:

- Before mobilization, obtain the following well construction data: well depth, screen length and type (e.g., slot size), filter pack interval, water production during drilling, description of measuring point, borehole diameter, and well casing diameter.
- Install plastic sheeting on the ground around the well to keep equipment clean.
- Decontaminate all downhole equipment as specified in SOP No. 3
- Measure the static water level and total well depth.
- Starting at the top of the water table, surge the well with either a surge block or a bailer. Surge throughout the entire screened saturated interval. Initial surging should be gentle, but surging energy should be gradually increased throughout development.

- Frequently purge the monitoring well to remove fines pulled into the well. At this stage of development, bailing the well is probably most effective due to the amount of fines and sand that will probably be present. Pumps can be damaged by sand and so pumps should probably not be used at this stage. Continue surging and bailing until sand production ceases or stabilizes.

- Install a submersible pump without a check valve. Starting at the top of the water table, backwash the well by running the pump to near surface discharge, turning the pump off, and letting the water surge back down the well. Continue backwashing the well throughout the saturated-screened interval while occasionally pumping some water to remove fine materials pulled into the well. Continue backwashing the well until sand production stabilizes or ceases.

- Gradually increase the pumping cycle as the well cleans up until the pumping eventually becomes continuous (overpumping).

- During well construction and surging, debris can be deposited on the casing above the normal water level. Rinse the inside of the well casing with clean formation water during development. Rinse the well casing early in the development procedure to ensure that debris washed down the well casing will be removed during development.

- If measurable amounts of water are added during well construction, purge approximately five times that amount of water during overpumping in addition to purging a minimum of three saturated borehole volumes.

- During development, carefully monitor well characteristics (e.g., pumping rates and recovery rates) to help develop a purging/sample collection strategy. Determine the recommended sample collection pumping rate and pump placement during development, and carefully document these values.

- Continue development until sand production ceases or stabilizes and the turbidity stabilizes. Continue development as long as water quality (e.g., pH, conductivity, and temperature) continues to change. Depending on specific well characteristics, some monitoring wells may not clean up and will only produce highly turbid water. Most wells can be developed to yield representative formation water.

4.5 Development of Low-yielding Wells

Developing low-yielding wells can be very time consuming, may take several days, and the development methods previously discussed may not be effective. In some cases, there may be no choice but to follow the procedures described in Section 4.4 (except for overpumping) and let the well recover between efforts. Do not overpump low-yielding wells because these wells

cannot produce water steadily. Surging/bailing and backwashing will develop low-yielding wells with minimal purging. After a well has been surged and backwashed, purge it dry at least three times.

In extreme cases where wells are dry or nearly dry, water of known quality may need to be added to wells during development. Add water to facilitate development only if all other procedures fail. You may also circulate clean water down to the well casing and back up through the annulus before installing the annular seal. Because of the relatively low hydraulic conductivity of such formations, a negligible amount of water will penetrate the formation. Immediately following the procedure, install the annular seal and pump the well to remove, as much as possible, the water used in the development process.

5.0 DOCUMENTATION

Document field observations and data to provide information on well development and to keep a permanent record. Record these observations and data with waterproof ink either in a bound, weatherproof field book with consecutively numbered pages or on well development forms (Attachment A).

As part of the development process, record the following information in the field book:

- Person performing the development
- Well designation
- Well location
- Date(s) and time of well development
- Decontamination procedure
- Static water level from top of well casing before and after development
- Instrument calibration record
- Volume of water in the well before development
- Total well depth

- Screen length
- Depth from top of well casing to top of sediment inside well, before and after development, if present
- Volume of water removed and time of removal
- Field measurements of pH, specific conductance, temperature, and turbidity taken during and after development
- Physical character of water removed throughout development (color, odor, and turbidity)
- Type and size/capacity of pump and/or bailer
- Description of development technique.

6.0 REFERENCES

American Society for Testing and Materials (ASTM) D-5092-90. Design and Installation of Groundwater Monitoring Wells in Aquifers, *1995 Annual Book of ASTM Standards*, Vol. 04.08.

National Water Well Association (NWWA). "Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells."

Driscoll, F.G. 1986. *Groundwater and Wells*, Second Edition, H.M. Smyth Co., Inc., Johnson Division, St. Paul, Minnesota.

Figure 1 **Saturated Borehole Volume Calculation (blank form and example)**

Project: ____________
Date: ____________
Personnel: ____________

Blank Form

Well: ________			**Nominal Casing Diameter:**	________	**inches**
Total Depth:	________	**feet**	**Nominal Borehole Diameter:**	________	**inches**
Depth to Water:	________	**feet**	**Effective Porosity (P) of Filter Pack in Annulus:** (Assume P=0.30 if no other data are available)	________	
Height of Water in Casing (h_1):	________	**feet**	**Height of Water in Filter Pack (h_2):**	________	**feet**

a. Casing Radius (r_1) =	**Casing Diameter**	________	**inches ÷ 2÷ 12=**	________	**feet = r_1**
b. Borehole Radius (r_2) =	**Borehole Diameter**	________	**inches ÷ 2÷ 12=**	________	**feet = r_2**

c. Casing Volume (V_1) = $\pi r_1^2 h_1$ =	**3.142(**	________	**^{2})(**	________	**)$ft^3 = V_2$**
d. Annulus Volume (V_2) = $\pi r_2^2 h_2$ =	**3.142(**	________	**^{2})(**	________	**)$ft^3 = V_2$**
e. Saturated Annulus Volume(V_A) = P(V_2 - V_1) =	**P(**	________	**–**	________	**)$ft^3 = V_A$**
f. Saturated Borehole Volume(V_T) = *7.48(V_1 + V_A) =	**7.48(**	________	**+**	________	**)gal = V_T**

***Convert from ft^3 to gallons by multiplying by 7.48**

Example

Well: MW-1			**Nominal Casing Diameter:**	**2**	**inches**
Total Depth:	**35**	**feet**	**Nominal Borehole Diameter:**	**6.25**	**inches**
Depth to Water:	**20**	**feet**	**Effective Porosity (P) of Filter Pack in Annulus:** (Assume P=0.30 if no other data are available)	**0.45**	
Height of Water in Casing (h_1):	**15**	**feet**	**Height of Water in Filter Pack (h_2):**	**15**	**feet**

a. Casing Radius (r_1) =	**Casing Diameter**	**2**	**inches ÷ 2÷ 12=**	**0.083**	**feet = r_1**
b. Borehole Radius (r_2) =	**Borehole Diameter**	**6.25**	**inches ÷ 2÷ 12=**	**0.260**	**feet = r_2**

c. Casing Volume (V_1) = $\pi r_1^2 h_1$ =	**3.142(**	**0.083**	**^{2})(**	**15**	**) = 0.32 $ft^3 = V_1$**
d. Annulus Volume (V_2) = $\pi r_2^2 h_2$ =	**3.142(**	**0.260**	**^{2})(**	**15**	**) = 3.18 $ft^3 = V_2$**
e. Saturated Annulus Volume(V_A) = P(V_2 - V_1) =	**0.45(**	**3.18**	**–**	**0.32**	**) = 1.287 $ft^3 = V_A$**
f. Saturated Borehole Volume(V_T) = *7.48(V_1 + V_A) =	**7.48(**	**0.32**	**+**	**1.287**	**) = 12.02 gal = V_T**

***Convert from ft^3 to gallons by multiplying by 7.48**

ATTACHMENT A

MONITORING WELL DEVELOPMENT DATA SHEET

MONITORING WELL DEVELOPMENT DATA SHEET

IDENTIFICATION

Project Number____________________

Location____ Date ________ Time _____Page__of__

Personnel ____

WEATHER CONDITIONS

Ambient Air Temperature: _____ °C ☐ °F ☐ Not Measured ☐ **Wind:** Heavy ☐ Moderate ☐ Light ☐

Precipitation: None ☐ Rain ☐ Snow ☐ Heavy ☐ Moderate ☐ Light ☐ Sunny ☐ Partly Cloudy ☐

INITIAL WELL MEASUREMENTS (Measurements in feet made from top of well casing)

Static Water Level____ Total Depth_____Top of Screen_____ Filter Pack Interval______ Borehole Diameter(inches)

Well Casing ID_____ Well Casing OD_____ Protective Casing Stickup___ Well Casing Stickup____ Feet of Water

FINAL WELL MEASUREMENTS

Static Water Level__ Total Depth___ Total Volume Purged__ Saturated Borehole Volume (gal)___ Max Pumping Rate _____

INSTRUMENT CALIBRATION

pH Meter: Meter Number______________ **Conductivity Meter:** Meter Number

Buffer___ Measured Value_____ Temp.____ °C Standard_____mS/cm Measured Value_________mS/cm Temp.___°C

Buffer___ Measured Value_____ Temp.____ °C Standard_____mS/cm Measured Value_________mS/cm Temp.___°C

Turbidity Meter:_____ Standard ____NTU Measured Value______NTU Standard ____NTU Measured Value______NTU

DEVELOPMENT PROCEDURES

Surging Procedure/Equipment____

____

Backwashing Procedure/Equipment____

____

Overpumping Procedure/Equipment____

____

Decontamination Procedure____

____

FIELD PARAMETER MEASUREMENTS DURING PURGING

Time	Volume (gallons)	pH	Cond. (µS/cm)	Temp. °C ☐ °F ☐	Turbidity Visual Est.☐ Measured☐	Comments

Notes ____

____

____

____

Prepared for
Sequoyah Fuels

STANDARD OPERATING PROCEDURE NO. 3
EQUIPMENT DECONTAMINATION

Sequoyah Fuels Site
Gore, Oklahoma

April 2001

Prepared by
Shepherd Miller, Inc.

STANDARD OPERATING PROCEDURE NO. 3

EQUIPMENT DECONTAMINATION

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1.0 PURPOSE AND SCOPE

The purpose of this document is to define the standard procedure for decontamination. The American Society for Testing and Materials (ASTM) Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites (D 5088-90) was used as a guide in preparing this Standard Operating Procedure (SOP).

The overall objective of multimedia sampling programs is to obtain samples that accurately depict the chemical, physical, and/or biological conditions at the sampling site. Extraneous contaminants can be brought onto the sampling location and/or be introduced into the medium of interest during the sampling program (e.g., by bailing or pumping ground water with equipment that was previously contaminated at another site). Trace quantities of these contaminants can thus infect a sample and lead to false positive analytical results and, ultimately, to an incorrect assessment of the contaminant conditions at the site. Decontamination of sampling equipment (e.g., bailers, pumps, tubing, and soil and sediment sampling equipment) and field support equipment (e.g., drill rigs and vehicles) is therefore required to ensure that sampling cross-contamination is prevented and that onsite contaminants are not carried off site.

2.0 EQUIPMENT NECESSARY FOR DECONTAMINATION

The following equipment may be needed to perform decontamination:

- Brushes
- Wash tubs (plastic)
- Buckets (plastic)
- Scrapers
- Steam cleaner or hot water washer
- Paper towels
- Liquinox detergent (or equivalent)
- Potable water

- Deionized water
- Garden type water sprayers
- Laboratory wash bottles
- Clean plastic sheeting and/or trash bags.

3.0 DECONTAMINATION PROCEDURES

3.1 General Decontamination Procedures for All Equipment

Decontaminate all equipment that will contact a sampled media. General procedures that apply to most specific decontamination procedures are listed below.

- Dress in suitable safety equipment to reduce personal exposure.
- Wear clean or new rubber or latex gloves during decontamination activities and when handling decontaminated equipment.
- Do not decontaminate new equipment, such as disposable filters and silicon tubing that is certified clean by the manufacturer.
- Decontaminate all wash/rinse tubs before initial use and between boreholes.
- Replace rinse and detergent waters, unless in garden sprayers, with new solutions between borings or sample locations. In some cases, new solutions may be needed between samples in the same location.
- Following decontamination, place equipment in a clean area or on clean plastic sheeting to prevent contact with contaminated soil. If the equipment will not be used immediately, cover the equipment or wrap it in plastic sheeting or heavy-duty trash bags to minimize potential airborne contamination.

3.2 Decontaminating Sampling Equipment

Decontaminate sampling equipment as follows:

- Scrape off gross contamination from equipment at the sampling or construction site.

- For equipment that water will not damage, place the equipment in a wash tub containing Liquinox and potable water or spray the equipment with a Liquinox/potable water solution contained within a garden type sprayer, and scrub the equipment with a bristle brush or similar utensil (if possible).
- In a second wash tub or using a second garden sprayer, triple rinse equipment with potable water to remove the Liquinox solution.
- Triple rinse the equipment with deionized water from a garden sprayer or laboratory wash bottles, and let the equipment air dry (if possible).

3.3 Decontaminating Submersible Pumps

Decontaminate the insides of an electric submersible pump and discharge hose (e.g., a Redi-flo2 pump) as follows:

- Before performing internal decontamination, remove the Redi-Flo2 internal pump fluid and replace it with deionized water (see the Red-Flo2 owner's manual).
- Pump Liquinox/potable water solution through the pump and hose. Be sure that the volume of solution used is not less than one volume of fluid contained in the pump and hose. (Note that a Redi-Flo2 pump with 250 feet of 0.5-inch inner-diameter hose contains 2.55 gallons of fluid.).
- Pump potable rinse water through the pump and hose. Be sure that the volume of solution used is not less than three times the volume of fluid contained in the pump and hose.
- Pump deionized rinse water through the pump and hose. Be sure that the volume of solution used is not less than three times the volume of fluid contained in the pump and hose.

Decontaminate the outside of the pump and discharge hose as follows:

- When removing the pump and hose from the well, place the hose reel 10 to 20 feet away from the well to allow the hose to be decontaminated before placing it on the reel. Do not let decontamination fluids enter the well.
- While removing the pump from the well, wash the outside of the pump and hose with Liquinox/potable water solution and triple rinse it with potable water.
- Triple rinse the hose with deionized water before placing the hose on the reel and/or triple rinse the hose with deionized water while lowering the pump into the

next well. If the pump and hose are exposed to airborne contaminants (e.g., dust and mud), rinse the pump and hose while lowering the pump down the next well.

3.4 Decontaminating Water Level Probes

Decontaminate water level probes by using the general decontamination procedures for sampling equipment (Section 4.2) or by wiping them successively with paper towels wetted with Liquinox solution, potable water, and deionized water. Rinse the water level probe with deionized water before use. Store the water level probe in a plastic bag after decontamination.

3.5 Decontaminating Delicate Equipment

Carefully wipe clean equipment that water will damage successively with paper towels wetted with Liquinox solution, potable water, and deionized water. Be sure to avoid damaging the equipment.

3.6 Decontaminating Drilling and Heavy Equipment

Decontaminate drilling and heavy equipment as follows:

- Dress in suitable safety equipment to reduce personal exposure.
- With a flat-bladed scraper, scrape gross contamination or drill cuttings off equipment at the sampling or construction site.
- Spray equipment, such as drill rigs, augers, drill bits, and shovels, with a Liquinox/potable water solution using a hot water washer. Be sure to adequately clean the insides of the hollow-stem augers and backhoe buckets.
- Rinse the equipment with potable water.
- Place drilling equipment on the clean drill rig and move it to a clean area. If the equipment will not be re-used immediately, store it in a designated clean area.

3.7 Disposing of Decontamination Solution

Dispose of used wash and rinse solutions at a location that will not bias subsequent samples.

4.0 DOCUMENTATION

Be sure to document the decontamination of sampling and drilling equipment. Record the documentation with black waterproof ink in the sampler's field notebook with consecutively numbered pages. This documentation should include the following:

- The personnel who performed the decontamination
- Date
- Decontamination procedures and observations
- Rinsate sample collection procedure (if collected).

5.0 REFERENCES

American Society for Testing and Materials (ASTM) D-5088-84. Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites, *1995 Annual Book of ASTM Standards*, Vol. 04.08.

HEALTH AND SAFETY PLAN

Prepared For:
Sequoyah Fuels Company
Gore, Oklahoma

Prepared By:
Shepherd Miller, Inc.
3801 Automation Way, Suite 100
Fort Collins, Colorado 80525

May 2001

SHEPHERD MILLER

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HEALTH AND SAFETY PLAN

Shepherd Miller Inc.

ATTACHMENT

1.0 INTRODUCTION

This Appendix discusses health and safety concerns related to the well drilling, installation and testing planned by Shepherd Miller Inc. (SMI) at the Sequoyah Fuels site. This Appendix serves as a supplement to the Site Health and Safety (H&S) Plan.

Any health and safety concerns which are not directly addressed by this Appendix should be directed to Craig Harlin, the Site Radiation Safety Officer (RSO). The Site RSO has authority to suspend, postpone, or modify any work activity that is potentially hazardous to workers or is a violation of NRC rules, license conditions or Hazardous Work Permit (HWP) activity.

SMI employees for these activities include Joe Reed, Ed Muller, Paul Sorek, and Toby Wright, Project Manager. Phone numbers for these managers are listed in Section E.7.

SMI field work will be directed by the SMI Field Supervisor at the site.

2.0 HAZARDS

Hazards at the site include industrial and physical hazards encountered in drilling and construction operations in rough terrain, plus potential chemical and radiological hazards. Industrial and physical hazards include the following:

- Drilling rigs and other potentially hazardous equipment operating nearby
- Underground utilities or buried materials
- Dust and noise generated by activities on site
- Steep slopes and natural tripping hazards
- Plants and particulate matter creating eye injury hazards
- Insect and snake bites
- Heat or cold stress or other weather-related hazards

Chemical and radioactive hazards associated with the site are listed in the Site H&S Plan. The maximum concentration of uranium measured near proposed drilling locations is 7940 ug/g soil at Proposed Core Location 7, less than 5 ug/g soil at Proposed Core Location 8, and 650 ug/g soil at Proposed Core Location 10.

Acid water - Low-pH water may be present in some wells at the site and can present a hazard to the skin, eyes, and lungs through contact with the skin or eyes or if it is inhaled or ingested. Acute symptoms may include skin burns, eye and sinus irritation and nausea. If acute symptoms are detected, work is to stop and workers are to withdraw and rinse their eyes and skin. Workers will return to the location only after approval by the site RSO.

Uranium - A primary emphasis of this Health and Safety Plan is minimizing potential hazards from uranium. Inhalation of uranium dust will be the most likely hazard associated with drilling where uranium contamination is present. Uranium can be taken into the body by ingestion, wound contamination or skin absorption. If sufficiently large quantities are involved, chemical poisoning and radiation exposure can occur. With soluble compounds of uranium, the primary hazard is chemical poisoning of the kidney. For all insoluble uranium compounds, the primary hazard is alpha radiation exposure of the lungs.

Radioactivity – The external radiation dose form uranium at the site is expected to be very low and therefore a minor radiation concern. The principal radiation hazard form uranium comes form breathing and swallowing dust. Inhaled dust containing uranium may deposit directly on the surface of the lung tissue. This would cause a radiation dose to the lungs because the alpha and beta particles would be able to interact directly with the lung tissue. In addition, soluble compounds of uranium may cross through the lung tissue, enter the bloodstream, be filtered out by the kidneys and gradually excreted in the urine. The radiation dose to the kidneys is not as hazardous as the chemical action of the uranium on the kidney tissue.

In addition, well drilling, installation and testing activities planned at the site, including the use of Reverse Air techniques, may involve working around or near hazardous materials such as inorganic acids or bases (used for sample preservation), and fuel and oil for portable equipment.

The Site Safety Officer maintains the required material safety data sheets (MSDS) on file and available for all individuals to review prior to working with any such materials.

3.0 MONITORING

Radiological contamination surveys and radiological monitoring will be performed by SFC except for personal contamination monitoring which shall be performed by the workers themselves.

External radiation exposure monitoring will be performed through the use of thermoluminescent dosimeters (TLD) and exposure rate surveys. Internal radiation exposure will monitored through air sampling and bioassay programs.

SMI and employees must monitor themselves prior to leaving the restricted area. Written instructions will be posted near the monitor and all workers will be instructed by the RSO in the proper use of the instrument. If radioactivity exceeds the posted action level, the instrument will sound a preset alarm, indicating that the worker must wash and notify the RSO.

4.0 PERSONAL PROTECTIVE EQUIPMENT

Workers on the site must wear appropriate work clothing and personal protective equipment (PPE), including the following:

- Safety glasses or goggles
- Steel-toed boots
- Hard hat in permit area and for all drilling operations
- Orange safety vest
- Work clothes or coveralls
- Gloves, including chemical-resistant gloves for working with acid water and heavy work gloves for operating equipment
- Respirators with appropriate cartridges if required by the Site RSO

- Hearing protection as required (when working near drilling operations, etc.)

5.0 DECONTAMINATION

The Site RSO will designate a support area and a decontamination area. All equipment coming into contact with potential contamination shall be cleaned, surveyed and found free of contamination before removal from the restricted area or use at a non-contaminated drilling location on-site. Decontamination should be completed in accordance with SFC procedure G-158, Contamination Control. Copies of this procedure are available from the Site RSO.

Additional guidelines for decontamination of equipment during well drilling, installation, and testing are contained in the SMI Hydrogeology Task Work Plan and Standard Operating Procedures (SOPs).

6.0 GENERAL HEALTH AND SAFETY WORK RULES

Workers must wear appropriate work clothing and personal protective equipment (PPE) in the work area.

Workers must conduct required personal monitoring and comply with other health and safety requirements of the Site RSO and SMI supervisor.

Visitors to the site must obtain permission from the Site RSO and must follow health and safety requirements, including wearing required PPE and participating in radiation safety training.

Because ingestion of contaminated particles (soil) is a potential hazard at the site, eating, drinking, smoking, and chewing gum or tobacco are allowed only outside the active work area. Likewise, workers should wash their hands and faces before eating or drinking.

Working on or near drilling rigs presents many safety hazards. Workers should read and follow the guidelines in the "Drilling Safety Guide," reprinted in this H&S Plan.

The SMI Field Supervisor is responsible for obtaining clearance (for safety, potential presence of underground utilities or buried materials, etc.) from the Site RSO or Site Manager for proposed drilling sites. For off-site locations, the SMI Field Supervisor must scout the area for signs warning of buried utilities and clear the proposed drilling site with the appropriate utility.

The SMI Field Supervisor and workers at the drilling site must watch for overhead power or utility lines when moving the drill rig and raising or lowering the mast. The minimum distance from any part of the drill rig to the overhead line must be 20 feet or more.

Construction equipment always has the right-of-way over regular vehicles.

Equipment operators shall watch for workers on the ground who may be in their path and provide warning to these workers before moving.

Motor vehicle operators shall obey all posted traffic signs, signals, and speed limits and wear seat belts when vehicles are in motion.

Workers must report all job-related injuries and illnesses to their supervisor promptly. This includes minor or slight injuries.

Whenever possible, workers shall perform their job assignments according to the "buddy" system. The buddy provides his or her partner with assistance; monitors the partner for signs of chemical, heat or cold stress; and notifies the supervisor if emergency help is needed.

During fall and winter months, adverse weather conditions including cold, wind and snow are likely. Workers should be prepared for possible adverse weather with layered and/or insulated clothing. The SMI Field Supervisor should be especially alert to the possibility of frostbite or hypothermia for workers who are sampling, logging core or carrying out other activities which may increase exposure to cold or wet conditions.

The supervisor is responsible for suspending operations in case of extreme adverse weather. Drilling operations shall be suspended during electrical or lightning storms.

Field crews should arrange for mobile communications. Two-way radios are recommended for work on or near the site and within the range of the site base station, and cellular phones for road travel to and from the site.

To prevent snakebite, in warm weather when snakes may be active, workers should avoid placing hands or feet into obscure areas (i.e., beneath rocks, well pads, brush piles) and should wear protective clothing and footwear in areas likely to be inhabited by snakes.

Workers should use insect repellant and wear protective clothing when working in insect infested areas. Workers who are allergic to insect stings or bites must notify their supervisor and arrange to have appropriate medication available on site.

Contact the Site RSO immediately to help coordinate emergency response. If the RSO is not immediately available, contact the Resident Manager. If the Resident Manager is not available, emergency response will be coordinated by the SMI Field Supervisor or the SMI health and safety coordinator designated by the Field Supervisor.

7.0 EMERGENCY RESPONSE

The following is provided as a format for the information which the SMI Field Supervisor is responsible for providing to the Site RSO regarding emergency procedures:

To Locate Buried Telephone Cable, Call: Charlie Mooneyham, 489-5511, ext. 23

Nearest Telephone or Mobile Radio: Administration Building

Emergency Telephone Numbers:

Fire Department: 489-5963

Ambulance Service: 1-800-372-8008

Police Office (also can dispatch ambulance): 489-5963

Types of Emergency Transportation Systems:

Nearest hospital (for transport by private vehicle): 918-774-1100 (Sequoyah Memorial Hospital, Sallisaw, OK)

Nearest Medical Center: 501-441-4000 (Sparks Regional Medical Center, Fort Smith, AR)

Directions to Sequoyah Memorial Hospital:

I-40 East to Hwy 59 Exit, Sallisaw.
Hwy 59 North to Cherokee Ave.
Cherokee Ave. East to Wheeler
North on Wheeler to Redwood.
West on Redwood to Hospital

SMI Project Contacts:

Joe Reed, Ed Muller, Paul Sorek (Phone number):

Toby Wright, Project Manager, 970 223 9600

8.0 TRAINING

All workers and visitors must participate in radiation safety training conducted by the Site RSO. At the completion of training, workers take a written test. Results of the testing will be maintained in each worker's file. In addition, workers will be trained regarding specific hazards identified when Radiation Work Permits are issued for individual projects.

ATTACHMENT 1

DRILLING SAFETY GUIDE

DRILLING SAFETY GUIDE

The Drilling Safety Guide has been prepared through the volunteer efforts of member delegations of the Diamond Core Drill Manufacturers Association (DCDMA) and the National Drilling Contractors Association (NDCA) and is published by the National Drilling Federation for the benefit of the drilling industries.

This guide contains suggested safety procedures. It is not intended to nor does it set forth any standard industry procedures or requirements, nor does it contain any procedures or requirements mandated by law. It is to be used as a guideline for the safe operation of drilling equipment. NDF, DCDMA and NDCA and their officers and members deny any liability for any injury to persons or property which may occur even if these procedures are properly followed. Further, neither the NDF, DCDMA nor the NDCA or their officers or members accept responsibility for the completeness of the guide or the applicability of the statements or procedures to the use of all drilling machines and tools in all environments. Many aspects of drilling safety cannot be expressed in detail and cannot be met by mechanical means, but can only be accomplished with the exercise of intelligence, care and common sense.

DRILLING SAFETY GUIDE

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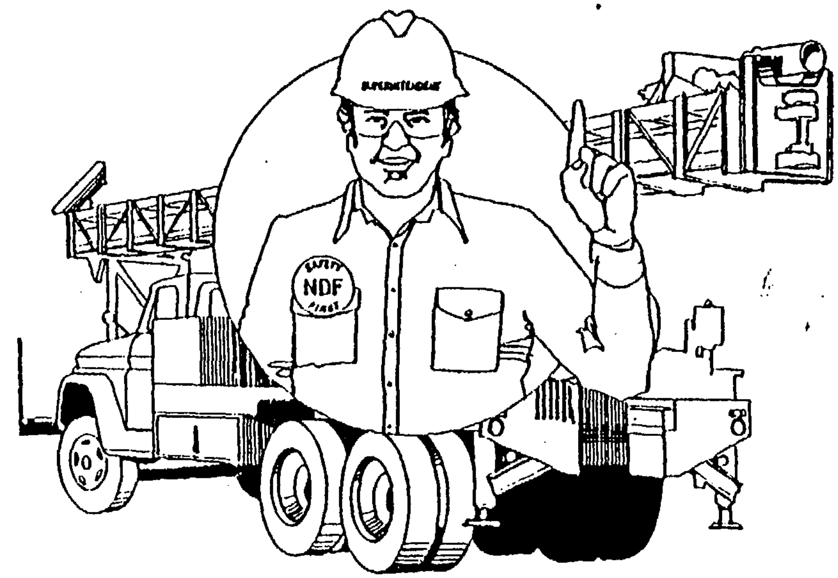
DRILLING SAFETY GUIDE

I. An Introduction To Drilling Safety

The organization where you work is interested in your safety, not only when you are working on or around a drill rig, but also when you are traveling to and from a drilling site, moving the drill rig and tools from location to location on a site or providing maintenance on a drill rig or drilling tools. This safety guide is for your benefit.



Every drill crew should have a designated safety supervisor. The safety supervisor should have the authority to enforce safety on the drilling site. A rig worker's first safety responsibility is to listen to the safety directions of the safety supervisor.

Governmental Regulations

All local, state and federal regulations or restrictions, currently in effect or effected in the future, take precedence over the recommendations and suggestions which follow. Government regulations will vary from country to country and from state to state.

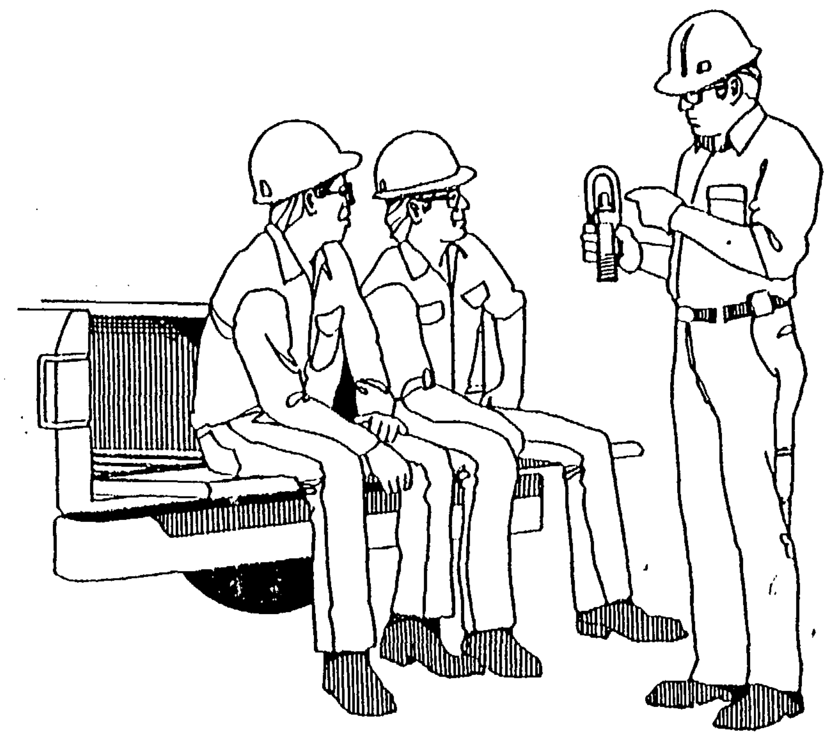
3. The Safety Supervisor

The safety supervisor for the drill crew will in most cases be the drill rig operator.

- The safety supervisor should consider the "responsibility" for safety and the "authority" to enforce safety to be a matter of first importance.
- The safety supervisor should be the leader in using proper personal safety gear and set an example in following the rules that are being enforced on others.
- The safety supervisor should enforce the use of proper personal protective safety equipment and take appropriate corrective action when proper personal protective safety equipment is not being used.
- The safety supervisor should understand that proper maintenance of tools and equipment and general "housekeeping" on the drill rig will provide the environment to promote and enforce safety.
- Before drilling is started with a particular drill, the safety supervisor must be assured that the operator (who may be the safety supervisor) has had adequate training and is thoroughly familiar with the drill rig, its controls and its capabilities.
- The safety supervisor should inspect the drill rig at least daily for structural damage, loose bolts and nuts, proper tension in chain drives, loose or missing guards or protective covers, fluid leaks, damaged hoses and/or damaged pressure gauges and pressure relief valves.
- The safety supervisor should check and test all safety devices such as emergency shut-down switches at least daily and preferably at the start of a drilling shift. Drilling should not be permitted until all emergency shut-down and warning systems are working correctly. Do not wire around, bypass or remove an emergency device.
- The safety supervisor should check that all gauges, warning

lights and control levers are functioning properly [illegible]sten for unusual sounds on each starting of an engine.

- The safety supervisor should assure that all new drill rig workers are informed of safe operating practices on and around the drill rig and should provide each new drill rig worker with a copy of the organization's drilling operations safety manual, and when appropriate the drill rig manufacturer's operations and maintenance manual. The safety supervisor should assure that each new employee reads and understands the safety manual.



- The safety supervisor should carefully instruct a new worker in drilling safety and observe the new worker's progress towards understanding safe operating practices.
- The safety supervisor should observe the mental, emotional and physical capability of each worker to perform the assigned work in a proper and safe manner. The safety supervisor should dismiss any worker from the drill site whose mental and physical capabilities might cause injury to the worker or coworkers.

...e safety supervisor should assure that there is a first-aid k... on each drill rig and a fire extinguisher on each drill rig and on each additional vehicle and assure that they are properly maintained.

- The *safety supervisor* (and as many crew members as possible) should be well trained and capable of using first-aid kits, fire extinguishers and all other safety devices and equipment.
- The safety supervisor should maintain a list of addresses and telephone numbers of emergency assistance units (ambulance services, police, hospitals, etc.) and inform other members of the drill crew of the existance and location of the list.

4. Individual Protective Equipment

For most geotechnical, mineral and/or groundwater drilling projects, individual protective equipment should include a safety hat, safety shoes, safety glasses and close fitting gloves and clothing. The clothing of the individual drill rig worker is not generally considered protective equipment; however, your clothing should be close fitting but comfortable, without loose ends, straps, draw strings or belts or otherwise unfastened parts that might catch on some rotating or translating component of the drill rig. Rings and jewelry should not be worn during a work shift.

- Safety Head Gear. Safety hats (hard hats) should be worn by everyone working or visiting at or near a drilling site. All safety hats should meet the requirements of ANSI Z89.1. All safety hats should be kept clean and in good repair with the headband and crown straps properly adjusted for the individual drill rig worker or visitor.
- Safety Shoes or Boots. Safety shoes or boots should be worn by all drilling personnel and all visitors to the drill site that observe drilling operations within close proximity of the drill rig. All safety shoes or boots should meet the requirements of ANSI Z41.1
- Gloves. All drilling personnel should wear gloves for protection against cuts and abrasion which could occur while handling wire rope or cable and from contact with sharp edges and burrs on drill rods and other drilling or sampling tools. All gloves should be close fitting and not have large cuffs or loose ties which can catch on rotating or translating components of the drill rig.

- Safety Glasses. All drilling personnel should w... ...ety glasses. All safety glasses should meet the requirements of ANSI Z87.1.

- Other Protective Equipment. For some drilling operations, the environment or regulations may dictate that other protective equipment be used. The requirement for such equipment must be determined jointly by the management of the drilling organization and the safety supervisor. Such equipment might include face or ear protection or reflective clothing. Each drill rig worker should wear noise reducing ear protectors when appropriate. When drilling is performed in chemically or radiologically contaminated ground, special protective equipment and clothing may and probably will be required. The design and composition of the protective equipment and clothing should be determined as a joint effort of management and the client who requests the drilling services.

5. Housekeeping On And Around The Drill Rig

The first requirement for safe field operations is that the safety supervisor understands and fulfills the responsibility for maintenance and "housekeeping" on and around the drill rig.

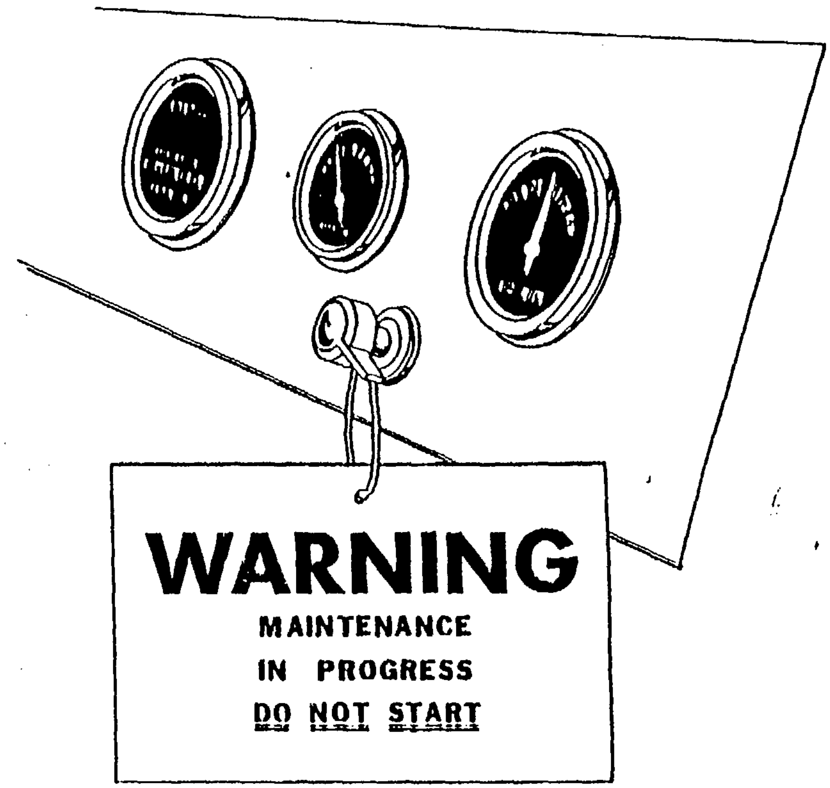
- Suitable storage locations should be provided for all tools, materials and supplies so that tools, materials and supplies can be conveniently and safely handled without hitting or falling on a member of the drill crew or a visitor.
- Avoid storing or transporting tools, materials or supplies within or on the mast (derrick) of the drill rig.
- Pipe, drill rods, casing, augers and similar drilling tools should be orderly stacked on racks or sills to prevent spreading, rolling or sliding.
- Penetration or other driving hammers should be placed at a safe location on the ground or be secured to prevent movement when not in use.
- Work areas, platforms, walkways, scaffolding and other accessways should be kept free of materials, debris and obstructions and substances such as ice, grease or oil that could cause a surface to become slick or otherwise hazardous.
- Keep all controls, control linkages, warning and operation lights and lenses free of oil, grease and/or ice.
- Do not store gasoline in any portable container other than a non-sparking, red container with a flame arrester in the fill spout and having the word "gasoline" easily visible.

6. Maintenance Safety

Good maintenance will make drilling operations safer. Also, maintenance should be performed safely.

- Wear safety glasses when performing maintenance on a drill rig or on drilling tools.
- Shut down the drill rig engine to make repairs or adjustments to a drill rig or to lubricate fittings (except repairs or adjustments that can only be made with the engine running). Take precautions to prevent accidental starting of an engine during maintenance by removing or tagging the ignition key.

- Always block the wheels or lower the leveling j[illegible] both and set hand brakes before working under a drill rig.
- When possible and appropriate, release all pressure on the hydraulic systems, the drilling fluid system and the air pressure systems of the drill rig prior to performing maintenance. In other words, reduce the drill rig and operating systems to a "zero energy state" before performing maintenance. Use extreme caution when opening drain plugs and radiator caps and other pressurized plugs and caps.
- Do not touch an engine or the exhaust system of an engine following its operation until the engine and exhaust system have had adequate time to cool.



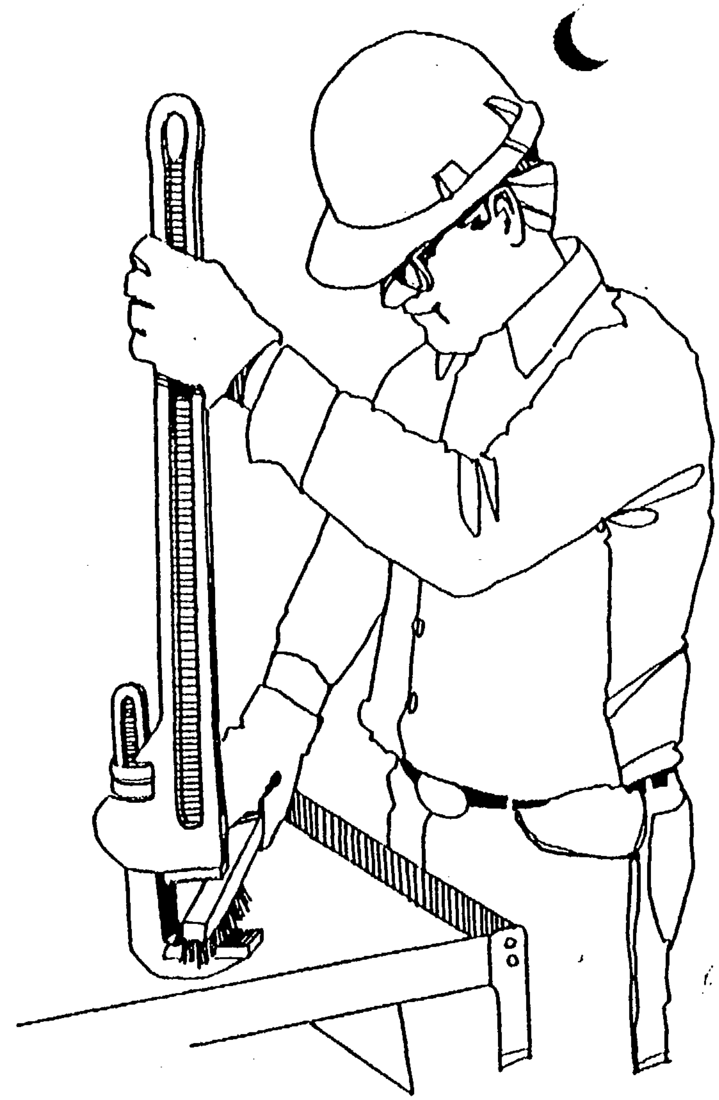
- Never weld or cut on or near a fuel tank.
- Do not use gasoline or other volatile or flammable liquids as a cleaning agent on or around a drill rig.
- Follow the manufacturer's recommendations for applying the proper quantity and quality of lubricants, hydraulic oils and/or coolants.

Replace all caps, filler plugs, protective guards or panels high pressure hose clamps and chains or cables that have been removed for maintenance before returning the drill rig to service.

7. Safe Use Of Hand Tools

There are almost an infinite number of hand tools that can be used on or around a drill rig and in repair shops and more than an equal number of instructions for proper use. "Use the tool for its intended purpose" is the most important rule. The following are a few specific and some general suggestions which apply to safe use of several hand tools that are often used on and around drill rigs.

- When a tool becomes damaged, either repair it before using it again or get rid of it.
- When using a hammer, any kind of hammer for any purpose, wear safety glasses and require all others around you to wear safety glasses.
- When using a chisel, any kind of chisel, for any purpose, wear safety glasses and require all others around you to wear safety glasses.
- Keep all tools cleaned and orderly stored when not in use.
- Use wrenches on nuts – don't use pliers on nuts.
- Use screwdrivers with blades that fit the screw slot.
- When using a wrench on a tight nut – first use some penetrating oil, use the largest wrench available that fits the nut, when possible pull on the wrench handle rather than pushing, and apply force to the wrench with both hands when possible and with both feet firmly placed. Don't push or pull with one or both feet on the drill rig or the side of a mud pit or some other blocking-off device. Always assume that you may lose your footing – check the place where you may fall for sharp objects.
- Keep all pipe wrenches clean and in good repair. The jaws of pipe wrenches should be wire brushed frequently to prevent an accumulation of dirt and grease which would otherwise build up and cause wrenches to slip.
- Never use pipe wrenches in place of a rod holding device.
- Replace hook and heel jaws when they become visibly worn.



- When breaking tool joints on the ground or on a drilling platform, position your hands so that your fingers will not be smashed between the wrench handle and the ground or the platform, should the wrench slip or the joint suddenly let go.

8. Clearing The Work Area

Prior to drilling, adequate site clearing and leveling should be performed to accommodate the drill rig and supplies and provide a

sa[illegible]rking area. Drilling should not be commenced when tree limbs, unstable ground or site obstructions cause unsafe tool handling conditions.

9. Start Up

- All drill rig personnel and visitors should be instructed to "stand clear" of the drill rig immediately prior to and during starting of an engine.
- Make sure all gear boxes are in neutral, all hoist levers are disengaged, all hydraulic levers are in the correct nonactuating positions and the cathead rope is not on the cathead before starting a drill rig engine.
- Start all engines according to the manufacturer's manual.

10. Safety During Drilling Operations

Safety requires the attention and cooperation of every worker and site visitor.

- Do not drive the drill rig from hole to hole with the mast (derrick) in the raised position.
- Before raising the mast (derrick) look up to check for overhead obstructions. (Refer to Section 11 on Overhead and Buried Utilities.)
- Before raising the mast (derrick), all drill rig personnel (with exception of the operator) and visitors should be cleared from the areas immediately to the rear and the sides of the mast. All drill rig personnel and visitors should be informed that the mast is being raised prior to raising it.
- Before the mast (derrick) of a drill rig is raised and drilling is commenced, the drill rig must be first leveled and stabilized with leveling jacks and/or solid cribbing. The drill rig should be releveled if it settles after initial set up. Lower the mast (derrick) only when the leveling jacks are down and do not raise the leveling jack pads until the mast (derrick) is lowered completely.
- Before starting drilling operations, secure and/or lock the mast (derrick) if required according to the drill manufacturer's recommendations.

- The operator of a drill rig should only operate a dr[illegible]g from the position of the controls. If the operator of the drill rig must leave the area of the controls, the operator should shift the transmission controlling the rotary drive into neutral and place the feed control lever in neutral. The operator should shut down the drill engine before leaving the vicinity of the drill.
- Throwing or dropping tools should not be permitted. All tools should be carefully passed by hand between personnel or a hoist line should be used.
- Do not consume alcoholic beverages or other depressants or chemical stimulants prior to starting work on a drill rig or while on the job.
- If it is necessary to drill within an enclosed area, make certain that exhaust fumes are conducted out of the area. Exhaust fumes can be toxic and some cannot be detected by smell.
- Clean mud and grease from your boots before mounting a drill platform and use hand holds and railings. Watch for slippery ground when dismounting from the platform.
- During freezing weather, do not touch any metal parts of the drill rig with exposed flesh. Freezing of moist skin to metal can occur almost instantaneously.
- All air and water lines and pumps should be drained when not in use if freezing weather is expected.
- All unattended boreholes must be adequately covered or otherwise protected to prevent drill rig personnel, site visitors or animals from stepping or falling into the hole. All open boreholes should be covered, protected or backfilled adequately and according to local or state regulations on completion of the drilling project.
- "Horsing around" within the vicinity of the drill rig and tool and supply storage areas should never be allowed, even when the drill rig is shut down.
- When using a ladder on a drill rig, face the ladder and grasp either the side rails or the rungs with both hands while ascending or descending. Do not attempt to use one or both hands to carry a tool while on a ladder. Use a hoist line and a tool "bucket" or a safety hook to raise or lower hand tools.

An elevated derrick platform should be used with the following precautions:

● When working on a derrick platform, use a safety belt and a lifeline. The safety belt should be at least 4 in. (100 mm) wide and should fit snugly but comfortably. The lifeline, when attached to the derrick, should be less than 6 ft. (2 m) long. The safety belt and lifeline should be strong enough to withstand the dynamic force of a 250 lb. (115 kg) weight (contained within the belt) falling 6 ft. (2 m).

● When climbing to a derrick platform that is higher than 20 ft. (6 m), a safety climbing device should be used.

● When a rig worker is on a derrick platform, the lifeline should be fastened to the derrick just above the derrick platform and to a structural member that is not attached to the platform or to other lines or cables supporting the platform.

● When a rig worker first arrives at a derrick platform, the platform should immediately be inspected for broken members, loose connections and loose tools or other loose materials.

● Tools should be securely attached to the platform with safety lines. Do not attach a tool to a line attached to your wrist or any other part of your body.

● When you are working on a derrick platform, do not guide drill rods or pipe into racks or other supports by taking hold of a moving hoist line or a traveling block.

● Loose tools and similar items should not be left on the derrick platform or on structural members of the derrick.

● A derrick platform over 4 ft. (1.2 m) above ground surface should have toe boards and safety railing that are in good condition.

● Workers on the ground or the drilling floor should avoid being under rig workers on elevated platforms, whenever possible.

Be careful when lifting heavy objects:

● Before lifting any object without using a hoist, make sure that the load is within your personal lifting capacity. If it is too heavy, ask for assistance.

● Before lifting a relatively heavy object, approach the object by bending at the knees, keeping your back vertical and unarched while obtaining a firm footing. Grasp the object firmly with both hands and stand slowly and squarely while keeping your back vertical and unarched. In other words, perform the lifting with the muscles in your legs, not with the muscles in your lower back.

● If a heavy object must be moved some distance without the aid of machinery, keep your back straight and unarched. Change directions by moving your feet, not by twisting your body.

● Move heavy objects with the aid of hand carts whenever possible.

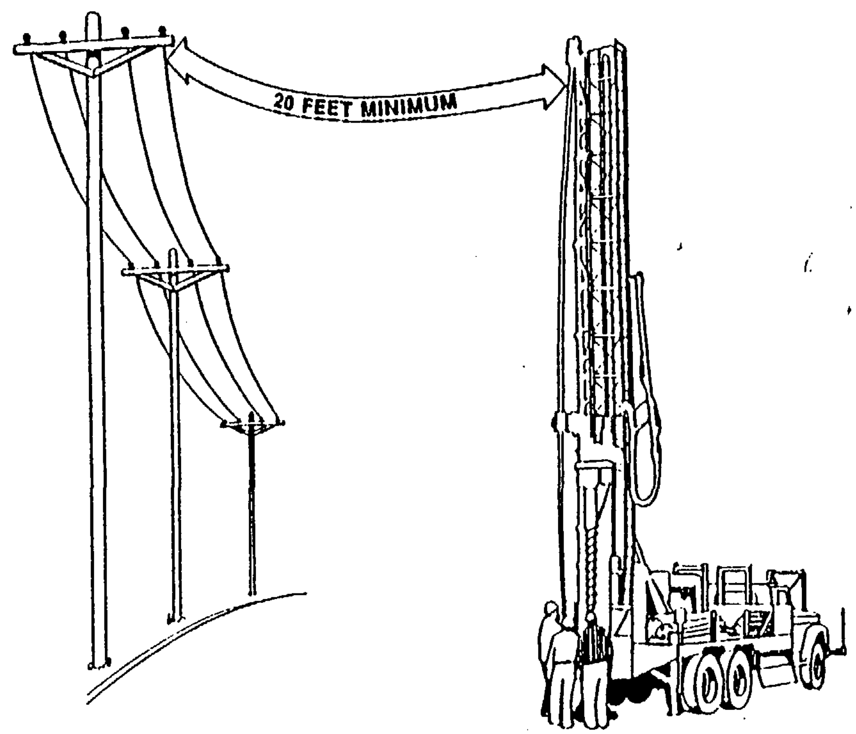
Drilling operations should be terminated during an electrical storm and the complete crew should move away from the drill rig.

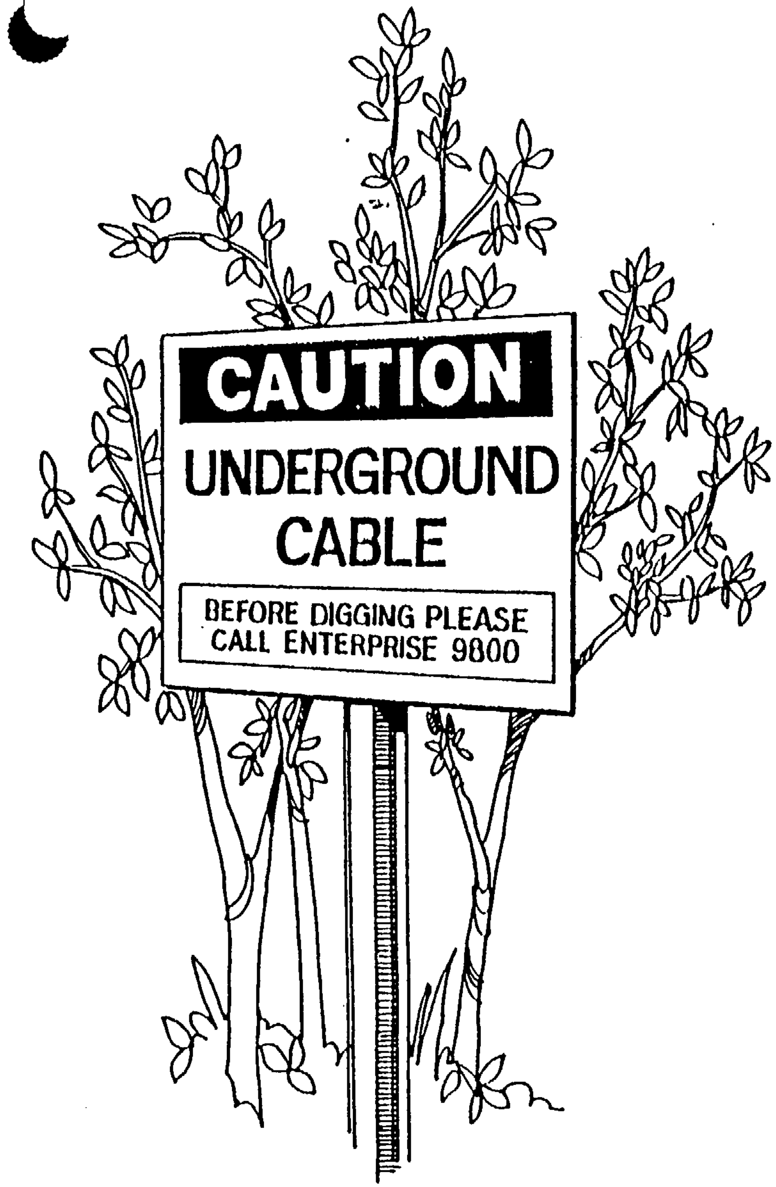
11. Overhead And Buried Utilities

The use of a drill rig on a site or project within the vicinity of electrical power lines and other utilities requires that special precautions be taken by both supervisors and members of the exploration crew. Electricity can shock, it can burn and it can cause death.

● Overhead and buried utilities should be located, noted and emphasized on all boring location plans and boring assignment sheets.

● When overhead electrical power lines exist at or near a drilling site or project, consider all wires to be alive and dangerous.





• Watch for sagging power lines before entering a site. Do not lift power lines to gain entrance. Call the utility and ask them to lift or raise the lines or deenergize (turn off) the power.

• Before raising the drill rig mast (derrick) on a site in the vicinity of power lines, walk completely around the drill rig. Determine what the minimum distance from any point on the drill rig to the nearest

power line will be when the mast is raised and/or be raised. Do not raise the mast or operate the drill rig if this distance is less than 20 ft. (6 m), or if known, the minimum clearance stipulated by federal, state and local regulations.

• Keep in mind that both hoist lines and overhead power lines can be moved toward each other by the wind.

• In order to avoid contact with power lines, only move the drill rig with the mast (derrick) down.

• If there are any questions whatever concerning the safety of drilling on sites in the vicinity of overhead power lines, call the power company. The power company will provide expert advice at the drilling site as a public service and at no cost.

Underground electricity is as dangerous as overhead electricity. Be aware and always suspect the existance of underground utilities such as electrical power, gas, petroleum, telephone, sewer and water. Ask for assistance:

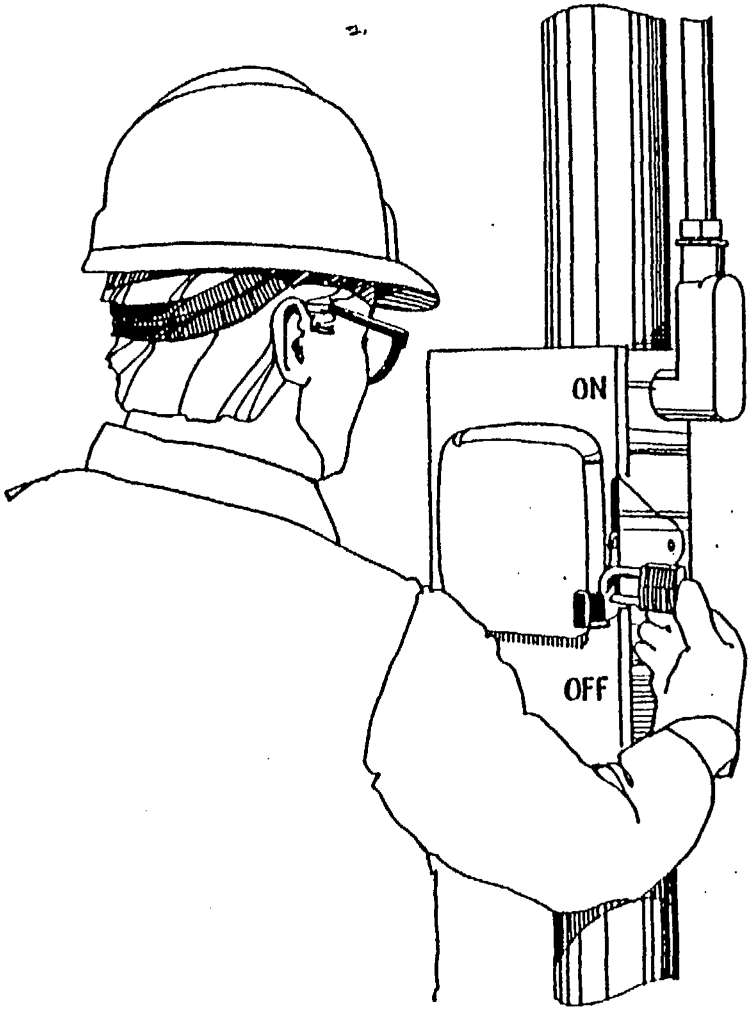
• If a sign warning of underground utilities is located on a site boundary, do not assume that underground utilities are located on or near the boundary or property line under the sign: call the utility and check it out. The underground utilities may be a considerable distance away from the warning sign.

• Always contact the owners of utility lines or the nearest underground utility location service before drilling. Determine jointly with utility personnel the precise location of underground utility lines, mark and flag the locations and determine jointly with utility personnel what specific precautions must be taken to assure safety.

12. Safe Use Of Electricity

Drilling projects sometimes require around-the-clock operations and, therefore, require temporary electrical lighting. In general, all wiring and fixtures used to provide electricity for drilling operations should be installed by qualified personnel in accordance with the National Electrical Code (NFPA70–1984) with consideration of the American Petroleum Institute's recommended practices for electrical installations for production facilities (API–RP–500B). Lights should be installed and positioned to assure that the work area and operating

po... are well lit without shadows or blind spots. The following specific recommendations emphasize the safe use of electricity during land-based drilling operations:



• Before working on an electrical power or lighting system, lock-out the main panel box with your own lock and keep the key on your person at all times.

• All wiring should be installed using high quality connections, fixtures and wire, insulated and protected with consideration of the

drilling environment. Makeshift wiring and equipmen...uld not be permitted.

• All lights positioned directly above working areas should be enclosed in cages or similar enclosures to prevent loose or detached lamps or vaportight enclosures from falling on workers.

• Lights should be installed to produce the least possible glare or "blind spots" on tools, ladders, walkways, platforms and the complete working area.

• Electrical cables should be guarded and located to prevent damage by drilling operations or by the movement of personnel, tools or supplies.

• All plug receptacles should be the three-prong, U-blade, grounded type and have adequate current carrying capacity for the electrical tools that may be used.

• All electric tools should have three-prong, U-blade, ground wire plugs and cords.

• *Do not use electrical tools with lock-on devices.*

• All electrical welders, generators, control panels and similar devices should be adequately grounded.

• Control panels, fuse boxes, transformers and similar equipment should have a secure, protective enclosure.

• *Avoid attaching electrical lighting cables to the derrick or other* components of the drill rig. If this must be done, use only approved fasteners. Do not "string" wire through the derrick.

• Poles used to hold wiring and lights should not be used for any other purpose.

• Power should be turned off before changing fuses or light bulbs.

• When a drilling area is illuminated with electrical lighting, all workers should wear safety head gear that protects the worker's head, not only against falling or flying objects, but also against limited electrical shock and burn according to ANSI Z89.1 and Z89.2.

• Electrical equipment should only be operated by trained, designated personnel.

• If you are not qualified to work on electrical devices or on elec*tric lines, do not go near them.*

13. React To Contact With Electricity

If a drill rig makes contact with electrical wires, it may or may not be insulated from the ground by the tires of the carrier. Under either circumstance the human body, if it simultaneously comes in contact with the drill rig and the ground, will provide a conductor of the electricity to the ground. Death or serious injury can be the result. If a drill rig or a drill rig carrier makes contact with overhead or underground electrical lines:

- Under most circumstances, the operator and other personnel on the seat of the vehicle should remain seated and not leave the vehicle. Do not move or touch any part, particularly a metallic part, of the vehicle or the drill rig.
- If it is determined that the drill rig should be vacated, then all personnel should jump clear and as far as possible from the drill. Do not step off – jump off, and do not hang on to the vehicle or any part of the drill when jumping clear.
- If you are on the ground, stay away from the vehicle and the drill rig, do not let others get near the vehicle and the drill rig and seek assistance from local emergency personnel such as the police or a fire department.
- When an individual is injured and in contact with the drill rig or with power lines, attempt rescue with extreme caution. If a rescue is attempted, use a long, dry, unpainted piece of wood or a long, dry, clean rope. Keep as far away from the victim as possible and do not touch the victim until the victim is completely clear of the drill rig or electrical lines.
- When the victim is completely clear of the electrical source and is unconscious and a heart beat (pulse) cannot be detected, begin cardiopulmonary resuscitation (CPR) immediately.

14. Safe Use Of Wire Line Hoists, Wire Rope And Hoisting Hardware

The use of wire line hoists, wire rope and hoisting hardware should be as stipulated by the American Iron and Steel Institute Wire Rope Users Manual.

- All wire ropes and fittings should be visually inspected during use and thoroughly inspected at least once a week for: abrasion, broken wires, wear, reduction in rope diameter, reduction in wire diameter, fatique, corrosion, damage from heat, improper reeving, jamming, crushing, bird caging, kinking, core protrusion and damage to lifting hardware. Wire ropes should be replaced when inspection indicates excessive damage according to the Wire Rope Users Manual. All wire ropes which have not been used for a period of a month or more should be thoroughly inspected before being returned to service.
- End fittings and connections consist of spliced eyes and various manufactured devices. All manufactured end fittings and connections should be installed according to the manufacturer's instructions and loaded according to the manufacturer's specifications.
- If a ball-bearing type hoisting swivel is used to hoist drill rods, swivel bearings should be inspected and lubricated daily to assure that the swivel freely rotates under load.
- If a rod slipping device is used to hoist drill rods, do not drill through or rotate drill rods through the slipping device, do not hoist more than 1 ft. (0.3 m) of the drill rod column above the top of the mast (derrick), do not hoist a rod column with loose tool joints and do not make up, tighten or loosen tool joints while the rod column is being supported by a rod slipping device. If drill rods should slip back into the borehole, do not attempt to brake the fall of the rods with your hands or by tensioning the slipping device.
- Most sheaves on exploration drill rigs are stationary with a single part line. The number of parts of line should not ever be increased without first consulting with the manufacturer of the drill rig.
- Wire ropes must be properly matched with each sheave – if the rope is too large, the sheave will pinch the wire rope – if the rope is too small, it will groove the sheave. Once the sheave is grooved, it will severely pinch and damage larger sized wire ropes.

The following procedures and precautions must be understood and implemented for safe use of wire ropes and rigging hardware.

- Use tool handling hoists only for vertical lifting of tools (except when angle hole drilling). Do not use tool handling hoists to pull on objects away from the drill rig; however, drills may be moved using the main hoist if the wire rope is spooled through proper

..es according to the manufacturer's recommendations.

- When stuck tools or similar loads cannot be raised with a hoist, disconnect the hoist line and connect the stuck tools directly to the feed mechanism of the drill. Do not use hydraulic leveling jacks for added pull to the hoist line or the feed mechanism of the drill.
- When attempting to pull out a mired down vehicle or drill rig carrier, only use a winch on the front or rear of the vehicle and stay as far as possible away from the wire rope. Do not attempt to use tool hoists to pull out a mired down vehicle or drill rig carrier.
- Minimize shock loading of a wire rope – apply loads smoothly and steadily.
- Avoid sudden loading in cold weather.
- Never use frozen ropes.
- Protect wire rope from sharp corners or edges.
- Replace faulty guides and rollers.
- Replace worn sheaves or worn sheave bearings.
- Replace damaged safety latches on safety hooks before using.
- Know the safe working load of the equipment and tackle being used. Never exceed this limit.
- Clutches and brakes of hoists should be periodically inspected and tested.
- Know and do not exceed the rated capacity of hooks, rings, links, swivels, shackles and other lifting aids.
- Always wear gloves when handling wire ropes.
- Do not guide wire rope on hoist drums with your hands.
- Following the installation of a new wire rope, first lift a light load to allow the wire rope to adjust.
- Never carry out any hoisting operations when the weather conditions are such that hazards to personnel, the public or property are created.
- Never leave a load suspended in the air when the hoist is unattended.
- Keep your hands away from hoists, wire rope, hoisting hooks, sheaves and pinch points as slack is being taken up and when the load is being hoisted.
- Never hoist the load over the head, body or feet of any personnel.

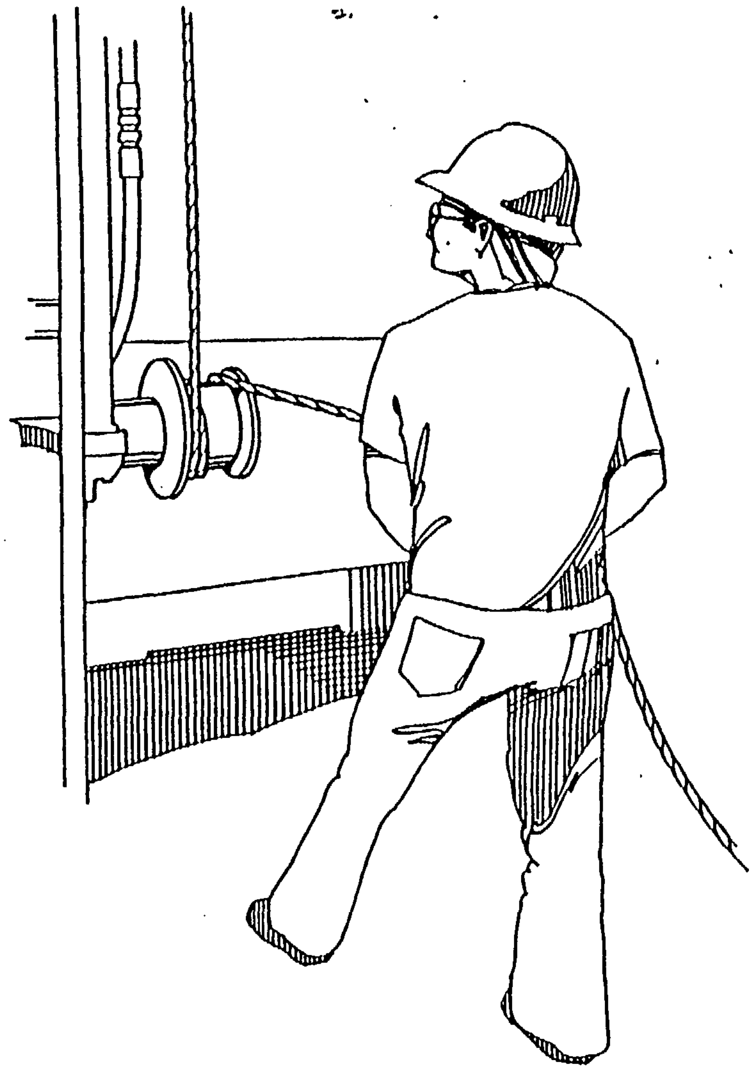
- Never use a hoist line to "ride" up the mast (de... of a drill rig.
- Replacement wire ropes should conform to the drill rig manufacturer's specifications.

15. Safe Use Of Cathead And Rope Hoists

The following safety procedures should be employed when using a cathead hoist.

- Keep the cathead clean and free of rust and oil and/or grease. The cathead should be cleaned with a wire brush if it becomes rusty.
- Check the cathead periodically, when the engine is not running, for rope wear grooves. If a rope groove forms to a depth greater than 1/8 in. (3 mm), the cathead should be replaced.
- Always use a clean, dry, sound rope. A wet or oily rope may "grab" the cathead and cause drill tools or other items to be rapidly hoisted to the top of the mast.
- Should the rope "grab" the cathead or otherwise become tangled in the drum, release the rope and sound an appropriate alarm for all personnel to rapidly back away and stay clear. The operator should also back away and stay clear. If the rope "grabs" the cathead, and tools are hoisted to the sheaves at the top of the mast, the rope will often break, releasing the tools. If the rope does not break, stay clear of the drill rig until the operator cautiously returns to turn off the drill rig engine and appropriate action is taken to release the tools. The operator should keep careful watch on the suspended tools and should quickly back away after turning off the engine.
- The rope should always be protected from contact with all chemicals. Chemicals can cause deterioration of the rope that may not be visibly detectable.
- Never wrap the rope from the cathead (or any other rope, wire rope or cable on the drill rig) around a hand, wrist, arm, foot, ankle, leg or any other part of your body.
- Always maintain a minimum of 18 inches of clearance between the operating hand and the cathead drum when driving samplers, casing or other tools with the cathead and rope method. Be aware that the rope advances toward the cathead with each hammer blow as the sampler or other drilling tool advances into the ground.

Never operate a cathead (or perform any other task around a drill rig) with loose unbuttoned or otherwise unfastened clothing or when wearing gloves with large cuffs or loose straps or lacings.



- Do not use a rope that is any longer than necessary. A rope that is too long can form a ground loop or otherwise become entangled with the operator's legs.

- Do not use more rope wraps than are required to [illegible] load.
- Do not leave a cathead unattended with the rope wrapped on the drum.
- Position all other hoist lines to prevent contact with the operating cathead rope.
- When using the cathead and rope for driving or back-driving, make sure that all threaded connections are tight and stay as far away as possible from the hammer impact point.
- The cathead operator must be able to operate the cathead standing on a level surface with good, firm footing conditions without distraction or disturbance.

16. Safe Use Of Augers

The following general procedures should be used when starting a boring with continuous flight or hollow-stem augers:

- Prepare to start an auger boring with the drill rig level, the clutch or hydraulic rotation control disengaged, the transmission in low gear and the engine running at low RPM.
- Apply an adequate amount of down pressure prior to rotation to seat the auger head below the ground surface.
- Look at the auger head while slowly engaging the clutch or rotation control and starting rotation. Stay clear of the auger.
- Slowly rotate the auger and auger head while continuing to apply down pressure. Keep one hand on the clutch or the rotation control at all times until the auger has penetrated about one foot or more below ground surface.
- If the auger head slides out of alignment, disengage the clutch or hydraulic rotation control and repeat the hole starting process.
- An auger guide can facilitate the starting of a straight hole through hard ground or a pavement.

The operator and tool handler should establish a system of responsibility for the series of various activities required for auger drilling, such as connecting and disconnecting auger sections, and inserting and removing the auger fork. The operator must assure that the tool handler is well away from the auger column and that the auger fork is removed before starting rotation.

Only use the manufacturer's recommended method of securing the auger to the power coupling. Do not touch the coupling or the auger with your hands, a wrench or any other tools during rotation.

- Whenever possible, use tool hoists to handle auger sections.
- Never place hands or fingers under the bottom of an auger section when hoisting the auger over the top of the auger section in the ground or other hard surfaces such as the drill rig platform.
- Never allow feet to get under the auger section that is being hoisted.
- When rotating augers, stay clear of the rotating auger and other rotating components of the drill rig. Never reach behind or around a rotating auger for any reason whatever.
- Use a long-handled shovel to move auger cuttings away from the auger. Never use your hands or feet to move cuttings away from the auger.
- Do not attempt to remove earth from rotating augers. Augers should be cleaned only when the drill rig is in neutral and the augers are stopped from rotating.

17. Safety During Rotary And Core Drilling

Rotary drilling tools should be safety checked prior to drilling:

- Water swivels and hoisting plugs should be lubricated and checked for "frozen" bearings before use.
- Drill rod chuck jaws should be checked periodically and replaced when necessary.
- The capacities of hoists and sheaves should be checked against the anticipated weight to the drill rod string plus other expected hoisting loads.

Special precautions that should be taken for safe rotary or core drilling involve chucking, joint break, hoisting and lowering of drill rods:

- Only the operator of the drill rig should brake or set a manual chuck so that rotation of the chuck will not occur prior to removing the wrench from the chuck.
- Drill rods should not be braked during lowering into the hole with drill rod chuck jaws.

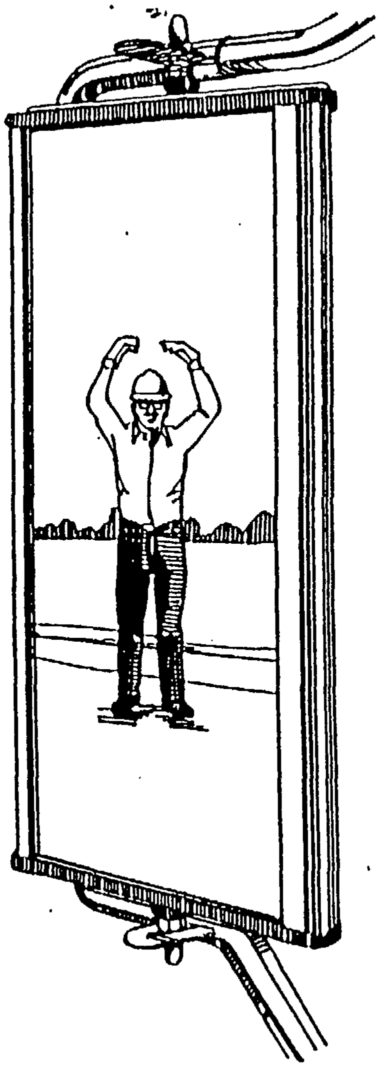
- Drill rods should not be held or lowered into the hole with pipe wrenches.
- If a string of drill rods are accidentally or inadvertently released into the hole, do not attempt to grab the falling rods with your hands or a wrench.
- In the event of a plugged bit or other circulation blockage, the high pressure in the piping and hose between the pump and the obstruction should be relieved or bled down before breaking the first tool joint.
- When drill rods are hoisted from the hole, they should be cleaned for safe handling with a rubber or other suitable rod wiper. Do not use your hands to clean drilling fluids from drill rods.
- If work must progress over a portable drilling fluid (mud) pit, do not attempt to stand on narrow sides or cross members. The mud pit should be equipped with rough surfaced, fitted cover panels of adequate strength to hold drill rig personnel.
- Drill rods should not be lifted and leaned unsecured against the mast. Either provide some method of securing the upper ends of the drill rod sections for safe vertical storage or lay the rods down.

18. Safety During Travel

The individual who transports a drill rig on and off a drilling site should:

- Be properly licensed and should only operate the vehicle according to federal, state and local regulations.
- Know the traveling height (overhead clearance), width, length and weight of the drill rig with carrier and know highway and bridge load, width and overhead limits, making sure these limits are not exceeded with an adequate margin.
- Never move a drill rig unless the vehicle brakes are in sound working order.
- Allow for most overhang when cornering or approaching other vehicles or structures.
- Be aware that the canopies of service stations and motels are often too low for a drill rig mast to clear with the mast in the travel position.

Watch for low hanging electrical lines, particularly at the entrances to drilling sites or restaurants, motels or other commercial sites.



- Never travel on a street, road or highway with the mast (derrick) of the drill rig in the raised or partially raised position.
- Remove all ignition keys when a drill rig is left unattended.

19. Loading And Unloading

When loading or unloading a drill rig on a trailer or a truck:

- Use ramps of adequate design that are solid and substantial enough to bear the weight of the drill rig with carrier – including tooling.
- Load and unload on level ground.
- Use the assistance of someone on the ground as a guide.
- Check the brakes on the drill rig carrier before approaching loading ramps.
- Distribute the weight of the drill rig, carrier and tools on the trailer so that the center of weight is approximately on the center-line of the trailer and so that some of the trailer load is transferred to the hitch of the pulling vehicle. Refer to the trailer manufacturer's weight distribution recommendations.
- The drill rig and tools should be secured to the hauling vehicle with ties, chains and/or load binders of adequate capacity.

20. Off-Road Movement

The following safety suggestions relate to off-road movement:

- Before moving a drill rig, first walk the route of travel, inspecting for depressions, stumps, gulleys, ruts and similar obstacles.
- Always check the brakes of a drill rig carrier before traveling, particularly on rough, uneven or hilly ground.
- Check the complete drive train of a carrier at least weekly for loose or damaged bolts, nuts, studs, shafts and mountings.
- Discharge all passengers before moving a drill rig on rough or hilly terrain.
- Engage the front axle (for 4 x 4, 6 x 6, etc. vehicles or carriers) when traveling off highway on hilly terrain.
- Use caution when traveling side-hill. Conservatively evaluate side-hill capability of drill rigs, because the arbitrary addition of drilling tools may raise the center of mass. When possible, travel directly uphill or downhill. Increase tire pressures before traveling in hilly terrain (do not exceed rated tire pressure).
- Attempt to cross obstacles such as small logs and small erosion

channels or ditches squarely, not at an angle.

- Use the assistance of someone on the ground as a guide when lateral or overhead clearance is close.
- After the drill has been moved to a new drilling site, set all brakes and/or locks. When grades are steep, block the wheels.
- Never travel off-road with the mast (derrick) of the drill rig in the raised or partially raised position.

21. Tires, Batteries And Fuel

Tires on the drill rig must be checked daily for safety and during extended travel for loss of air and they must be maintained and/or repaired in a safe manner. If tires are deflated to reduce ground pressure for movement on soft ground, the tires should be reinflated to normal pressures before movement on firm or hilly ground or on streets, roads and highways. Under inflated tires are not as stable on firm ground as properly inflated tires. Air pressures should be maintained for travel on streets, roads and highways according to the manufacturer's recommendations. During air pressure checks, inspect for:

- Missing or loose wheel lugs.
- Objects wedged between duals or embedded in the tire casing.
- Damaged or poorly fitting rims or rim flanges.
- Abnormal or uneven wear and cuts, breaks or tears in the casing.

The repair of truck and off-highway tires should only be made with required special tools and following the recommendations of a tire manufacturer's repair manual.

Batteries contain strong acid. Use extreme caution when servicing batteries.

- Batteries should only be serviced in a ventilated area while wearing safety glasses.
- When a battery is removed from a vehicle or service unit, disconnect the battery ground clamp first.
- When installing a battery, connect the battery ground clamp last.
- When charging a battery with a battery charger, turn off the power source to the battery before either connecting or disconnecting charger leads to the battery posts. Cell caps should be loosened prior to charging to permit the escape of gas.

- Spilled battery acid can burn your skin and damage your eyes. Spilled battery acid should be immediately flushed off of your skin with lots of water. Should battery acid get into someone's eyes, flush immediately with large amounts of water and see a medical physician at once.
- To avoid battery explosions, keep the cells filled with electrolyte, use a flashlight (not an open flame) to check electrolyte levels and avoid creating sparks around the battery by shorting across a battery terminal. Keep lighted smoking materials and flames away from batteries.

Special precautions must be taken for handling fuel and refueling the drill rig or carrier.

- Only use the type and quality of fuel recommended by the engine manufacturer.
- Refuel in a well-ventilated area.
- Do not fill fuel tanks while the engine is running. Turn off all electrical switches.
- Do not spill fuel on hot surfaces. Clean any spillage before starting an engine.
- Wipe up spilled fuel with cotton rags or cloths – do not use wool or metallic cloth.
- Keep open lights, lighted smoking materials and flames or sparking equipment well away from the fueling area.
- Turn off heaters in carrier cabs when refueling the carrier or the drill rig.
- Do not fill portable fuel containers completely full to allow expansion of the fuel during temperature changes.
- Keep the fuel nozzle in contact with the tank being filled to prevent static sparks from igniting the fuel.
- Do not transport portable fuel containers in the vehicle or carrier cab with personnel.
- Fuel containers and hoses should remain in contact with a metal surface during travel to prevent the buildup of static charge.

First Aid

At least one member of the drill crew, and if only one, preferably the drilling and safety supervisor, should be trained to perform first aid. First aid is taught on a person-to-person basis, not by providing or reading a manual. Manuals should only provide continuing reminders and be used for reference. It is suggested that courses provided or sponsored by the American Red Cross or a similar organization would best satisfy the requirements of first aid training for drill crews.

For drilling operations it is particularly important that the individual responsible for first aid should be able to recognize the symptoms and be able to provide first aid for electrical shock, heart attack, stroke, broken bones, eye injury, snake bite and cuts or abrasions to the skin. Again, first aid for these situations is best taught to drill crew members by instructors qualified by an agency such as the American Red Cross.

A first aid kit should be available and well maintained on each drill site.

23. Drill Rig Utilization

Do not attempt to exceed manufacturers' ratings of speed, force, torque, pressure, flow, etc. Only use the drill rig and tools for the purposes which they are intended and designed.

24. Drill Rig Alterations

Alterations to a drill rig or drilling tools should only be made by qualified personnel and only after consultation with the manufacturer.

APPENDIX B

SUPPLEMENTAL DATA COLLECTION TRIP REPORT

SUPPLEMENTAL DATA COLLECTION TRIP REPORT

Prepared For:
Sequoyah Fuels Corporation
I-40 & Highway 10
Gore, Oklahoma 74435

Prepared By:
Shepherd Miller
3801 Automation Way, Suite 100
Fort Collins, Colorado 80525

April 2002

SHEPHERD MILLER

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1.0 INTRODUCTION

Sequoyah Fuels Corporation (SFC) recently submitted new groundwater characterization and modeling data (Shepherd Miller, 2001) to support decommissioning and reclamation of its Gore, Oklahoma facility. As a result of discussions with the Nuclear Regulatory Commission (NRC) regarding these submittals, several issues regarding site conditions characterization and the groundwater modeling have been identified that need further study. These issues include:

- Increasing arsenic concentrations in well MW095A not predicted by, and inconsistent with, the groundwater modeling;
- Anomalous uranium and arsenic water quality values in 005 Drainage not predicted by, and inconsistent with, the groundwater modeling; and
- Concerns with delineation and characterization of the hydrogeologic and geochemical conditions associated with the subsurface Swale near well MW010.

As a result of these issues, SFC initiated a supplemental data collection effort. This effort was performed February 7 through February 13, 2002. The scope and findings of this effort are presented herein, although results of analytical testing (partitioning coefficient testing on terrace, fill and colluvium) and model revisions are pending. This report discusses the field efforts for each of the three areas described above and concludes with recommendations for additional studies for characterization and evaluation of potential groundwater mitigation efforts. Relevant tables, figures and photographs are included.

2.0 WELL MW095A ARSENIC ANOMALY

The objective of the field effort associated with well MW095A (Figure 1) was to better understand the basis for the arsenic anomaly at this location. Partitioning coefficient (K_d) testing for arsenic and transport modeling did not predict the measured concentrations and increasing arsenic concentration trend at this location (Figure 2). Potential controls of arsenic mobility are thought to include local hydrologic conditions that are not representative of the rest of the site and possible chemical complexation of the arsenic with organic compounds found in Pond 2, the probable past local source for arsenic flowing toward well MW095A.

The investigation approach included hydraulic conductivity tests on wells MW095A, MW097A, MW097, MW093A, MW059A (Figure 1), as well as analysis of water samples from selected wells for evidence of arsenic complexation with organic compounds. Based on these data, additional transport modeling will be performed to identify what K_d or hydraulic conductivity conditions might be required to account for the observed anomaly at well MW095A. The following sections discuss the specific field efforts and available preliminary findings.

2.1 Hydraulic Conductivity Testing

Slug tests were performed to see if anomalously high hydraulic conductivity conditions, which could cause locally faster constituent transport rates, were present in this area. The wells tested for hydraulic conductivity include MW095A, MW097A, MW097, MW093A, MW059A (Figure 1), which are proximal to or downgradient from Pond 2, and are near the predicted flow path from Pond 2 to well MW095A. Three of these wells, MW093A, MW95A, and MW97A, are completed in Shale Unit 4. MW059A is completed in both Shale Unit 3 and Shale Unit 4. MW097 is completed in the unconsolidated colluvial material.

The slug tests were performed and analyzed in exactly the same manner as described in SMI, 2001. Table 1 summarizes the calculated hydraulic conductivity for these wells.

Slug test data analyses for this investigation are presented in Attachment A. Prior to this investigation, the hydraulic conductivity of the colluvium was assumed to be 5 feet per day

(ft/day), although no test on this material had been performed. MW097 slug test results indicate that the colluvial deposits have a hydraulic conductivity of 39 ft/day, which exceeds the 5 ft/day value used in the model by a factor of eight. The slug test results for the Shale Unit 4 wells indicate a hydraulic conductivity of between 0.93 ft/day and 4.73 ft/day. These values vary from good agreement with the previously modeled value of 0.5 ft/day to an order of magnitude greater than the previously modeled value. The measured hydraulic conductivity for MW059A, 21.38 ft/day, was higher than previously measured formations for either Shale Unit 3 or Shale Unit 4 by one to two orders of magnitude.

The aquifer testing program indicates that some of the hydraulic conductivity values used in the 2001 groundwater model may have been underestimated. The consequence of underestimating the hydraulic conductivity is reduced contaminant transport velocity, all other parameters held equal. However, the underestimation of hydraulic conductivity is likely not sufficient, on its own, to account for the apparent early arrival of arsenic at well MW095A (Figure 2). Changes to the revised groundwater model, which is currently under development, will be implemented to reflect recently acquired data.

2.2 Arsenic Speciation Testing

Materials deposited in the Pond 2 (Unit 18) area included raffinate and sludge by-products, contaminated rock, yellowcake drums, soda ash, anode blades, drum liners, electrolyte sludge and laboratory wastes (SFC, 1998). In addition, SFC personnel have indicated that significant amounts of the organic compounds tributylphosphate ($C_{12}H_{27}PO_4$) and hexane (C_6H_{14}), which were associated with the solvent extraction process, were also deposited in Pond 2. This has led to speculation that the arsenic in Pond 2 may have formed organic-arsenic complexes or possibly ammonium-arsenic complexes that could migrate at a less retarded rate than the un-complexed arsenic. Therefore, analytical testing of water samples for arsenic speciation (As III, As V, mononmethylarsonic acid [MMAs], dimethylarsinic acid [DMAs], thioarsenates, and other organoarsenicals) was undertaken.

Raw water samples were collected from wells in areas thought to be impacted by Pond 2 seepage and associated organic compounds (MW095A, MW057A, MW059A [Figure 1]) and from wells

not likely impacted by Pond 2 seepage and associated organic compounds (MW064A, MW035A, MW042A, MW071A [Figure 1]) in an attempt to identify differences in arsenic speciation and transport mobility. The water samples were sent to Frontier Laboratories in Seattle, Washington for analysis.

2.3 Analytical Results

Samples sent to Frontier Geosciences (FG) for arsenic speciation were initially analyzed by ion-chromatography inductively coupled plasma mass-spectrometry (IC-ICP-MS). Using this analytical method, the As species As(III), As(V), MMAs, and DMAs, as well as other unknown As-species are separated by anion-chromatography using a hydroxide eluent. After separation/speciation, the eluent stream is injected into the plasma flame of the ICP-MS and As in the various fractions is quantified by detection of mass/charge75. Total As is then determined by direct introduction of the filtered sample to ICP-MS after acidification with 1 percent HNO_3.

The results of these analyses are presented in Table 2. Interference was observed during As speciation with IC-ICP-MS, peaks were broadened and retention times were shifted with respect to standards (Figure 3). Peaks were observed at retention times unspecific for known As-species. As(V) matrix spikes were not recovered intact, the signal was shifted more than 2 minutes and the approximate recovery is about 180 percent. Due to the peak shifting, it is not possible to determine which species are present with any certainty, and therefore the approximate concentrations are listed by their retention times (Table 2). Dilution did not overcome the interference, and the reason for the strong interference remains unknown. Common interferents (anions and Fe) are not present at concentrations that would explain these results. Therefore, the analyses for As speciation using the IC-ICP-MS analyses are inconclusive and analysis of these waters for individual As species using this analytical method does not appear to achieve reliable results.

Total arsenic (TAs), as determined by IC-ICP-MS (i.e. by addition of all As-species), suggests that As levels ranges from 0.4 µg/L to 5,180 µg/L. Total arsenic levels determined by direct ICP-MS range from 0.58 to 3,940 µg/L, but there is very poor sample-to-sample agreement for As concentrations determined by the two methods. A comparison of the results from these

analyses is presented in Table 2. It should be noted that at the conclusion of the IC-ICP-MS analysis the anion exchange column on the IC needed to be recharged. This suggests that an unidentified As species was present and was irreversibly or very tightly bound to the resin, thereby necessitating column regeneration. It is of interest to note that, if present, the interferent was present in all samples and not just those samples thought to be impacted by organic solvents. Given the discrepancies in results and the atypical chromatograms, a second analytical method was used to investigate As speciation.

The second investigative analytical methodology used consisted of hydride generation cryotrapping gas chromatography atomic absorption spectrometry (HG-CT-GC-AAS). The "cryo" method is similar to EPA method 1632. The overall quality of the HG-CT-GC-AAS and ICP-MS data look good; no analytical issues were encountered and all QA measurements were within established control limits (Tables 3 through 6). Sample MW059A exhibited some peak broadening during the As(III) and total inorganic arsenic (TIA) analysis by HG-CT-GC-AAS which might have lead to an overestimation of the As levels in this sample (Figure 4). However, comparing total As determined by ICP-MS to the TIAs detected by HG-CT-GC-AAS (Table 2), it is obvious that the majority of the As is not accounted for in the sum of the inorganic species. TIAs levels determined by HG-CT-GC-AAS ranged from 0.034 to 0.668 μg/L compared to total As levels that ranged from 0.58 to 3940 μg/L via ICP-MS, a difference of almost four orders of magnitude. Thus, either much of the As in the samples were present as non-hydride forming As species and therefore not detected by the cryo-method or total ICP-MS results are biased high due to the presence of an unknown interference. The presence of a non-hydride forming organic As-species cannot be ruled out.

In summary, results from the As speciation analysis are inconclusive. The possibility exists that the total As data obtained by ICP-MS is biased high due to an unknown interference. It is also possible that there are unknown As species present at comparable concentrations that are not amenable to hydride generation and therefore were not detected by the Cryo method, and were not eluted efficiently from the IC column during analysis with IC-ICP-MS, yielding uncertain results. However, total As numbers determined by ICP-MS are in reasonably good agreement with historical sampling values determined by ICP (Figure 3). Because both of these methods

are considered very reliable for determination of total As and employ different detection methods it is unlikely that both would error high with a comparable magnitude. Therefore, it seems prudent to assume that the total As numbers that have been determined by ICP-MS and ICP are accurate and represent actual arsenic levels at the site. Because it was not possible to isolate and identify the unknown As species, the geochemical reactivity of these complexes cannot be determined. It is therefore also not reasonable to assume that partition coefficients (K_ds) determined experimentally using and inorganic arsenic species (As(V)) are representative the K_ds of these potentially present unknown species.

As a result of the analytical complexities encountered while investigating As speciation, two actions will be taken to more accurately model As transport. First, the revised ground water flow model will incorporate the recent hydraulic conductivity tests data to more accurately represent measured flow conditions. Second, the transport model will include calibration of As K_d to accurately reproduce the trends of As arrival at well MW095A, as well as As trends in other site wells.

3.0 005 DRAINAGE ANOMALY

Recent sampling of the 005 Drainage surface waters (Figures 5 and 6) indicate elevated levels of uranium and nitrate that were not predicted by, and are inconsistent with, the most recent groundwater modeling. As a result of these new data, monthly sampling of site drainages has been implemented. Due to limited flows during the low rainfall periods, only a few sample locations are amenable to regular and consistent sampling. Figures 5 and 6 illustrate and Table 7 summarizes the recent surface water samples collected for the 005 Drainage, Figure 7 illustrates the 005 Drainage trenching and soil sampling locations of this investigation. It is suspected that when the 005 Sump pump failed, the groundwater flowing above the bedrock through the backfill materials at the head of the drainage migrated past the French drain collection system and into the 005 Drainage surface waters. These waters are typically collected through a French drain system located in the backfill and pumped from the 005 Sump to the Emergency Basin (Figure 5). It is also possible that the French drain collection and pump back system is not intercepting all of the groundwater flow from the backfill materials. Regardless of their source, the current site model did not predict the occurrence of the constituents in the drainage or in the 005 Sump.

The objectives of the field efforts for the 005 Drainage area were to:

- Better characterize the hydrogeologic conditions in the backfill at the head of the 005 Drainage,
- Determine if the measured concentrations in the drainage are caused by impacted groundwater flowing from the backfill area, and
- Determine geochemical properties (e.g., K_d) of native soils and fill materials.

The technical approach for the 005 Drainage study included two components. The first component consisted of excavating a trench in the fill materials at the head of the 005 Drainage between the emergency basin and the existing 005 Sump, south of Fluoride Holding Basin No. 2 (Figure 7); this trench is referred to as 005 Drainage Trench 1. The second component consisted of sampling soils and water from small excavations in the banks of the 005 Drainage at various points along its alignment (Figure 7).

Soil samples were collected from each trench or pit excavated during the investigation. Soil samples were collected with a stainless steel spoon the day after excavation activities concluded. To obtain a fresh sample, six inches of soil were removed prior to sampling. In some instances, hard soils and shale bedrock samples were first broken into smaller sizes using a rock hammer. Composite samples were collected from materials of similar character at three to four separate locations within each pit or trench. Soils were placed into clean 250-mL glass jars for shipment to the laboratory for geochemical analysis and testing. Soil samples were split and subsampled at the lab. One subsample was dried at 38 ^{O}C for percent moisture determinations and digested according to EPA Method 3050 and analyzed for total As, F and U. The other splits were used for adsorption or desorption batch tests designed to provide additional information on contaminant partitioning within these solid materials.

Water samples were collected within 48 hours, once sufficient waters had collected in the respective trenches. No precipitation fell within this period and the samples are considered to be representative of groundwater water quality conditions. Water samples were collected using a Geotech peristaltic pump with an inline 0.45-micron filter. Tubing was replaced or cleaned with deionized water between sampling events. Decontamination of sampling tubing was performed by pumping trench water through the tubing for five minutes prior to sampling. Three samples were collected at each location. One of these samples was left unpreserved, while the other samples were preserved with either trace metal grade nitric acid or phosphoric acid. The samples were analyzed for fluoride, uranium and arsenic, and dissolved organic carbon (DOC) respectively.

3.1 005 Drainage Trench 1: Top of Drainage

The trench located in the fill material near the head of the drainage (005 Drainage Trench 1) was advanced to characterize the hydrogeologic conditions associated with the buried drainage channel and to collect soil and water samples for analysis.

A track hoe was used to excavate down to competent bedrock (Photo 1). The excavation stratigraphy was documented and visually logged by a professional geologist from the top of the trench wall, and digital photographs were taken of the excavation. The end points of the trench

were recorded with a hand-held GPS unit. Table 8 summarizes the GPS coordinates of the trench and Table 7 summarizes the samples collected from the trench. Depths of geologic contacts were visually estimated due to the hazards associated with instability of the trench sidewalls. The cross section illustrated in Figure 8 was developed from these field observations.

The buried channel bottom was encountered at approximately six to eight feet deep. Stratigraphy observed in the trench consisted of a hard sandstone unit overlain by one to two feet of clay (Figure 8). Based on its elevation and lateral occurrence, the sandstone is believed to be Sandstone Unit 3 and the overlying clay is interpreted to be weathered remnants of Shale Unit 3. Overlying the clay/weathered shale unit is a one-foot thick layer of gravel with clay. This unit is interpreted to be the basal gravel on which fill or gravelly fill material was placed in the old 005 Drainage bottom. The unit was observed to be producing water in the trench sidewall, although it was not possible to estimate the rate of water production. Visual estimates of the clayey gravel hydraulic conductivity are approximately 30 feet per day based on particle size distribution and professional judgement. Water and soil samples collected from the pit are summarized in Table 7.

The sandstone bedrock unit was observed to gradually rise in the southern portion of the trench, with the clayey gravel unit thinning to the south. The bedrock abruptly rose in the northern portion of the trench due to what is interpreted to be the buried outcrop on the north side of the buried drainage (Figure 8).

The clayey gravel unit was covered with roughly five to six feet of fill material consisting of clay with gravel and sand (Photo 2). The fill material is believed to be re-worked terrace deposits cut from higher portions of the site during facility construction. A layer of 10-mil black plastic was observed below the upper one to two feet of fill. This liner was apparently placed to reduce infiltration into the fill. The one to two feet of fill above the plastic liner was observed to be reddish brown clay that contained a trace of gravel.

SFC personnel indicate that a French drain system was installed within the fill to collect seepage in the buried drainage. Although there are no known drawings of this drain system, it is believed to consist of perforated plastic pipe with a surrounding gravel pack that collects the seepage from

the upper portions of the filled drainage and drains it to the 005 Sump, where it is pumped back to the Emergency Basin.

Two portions of the French drain system were exposed during excavation of the trench; one portion near the center of the trench above the deepest section of the buried channel, and one portion near the southern end of the trench (Figure 8 and Photograph 2). The pipes and associated gravel pack were located approximately one to two feet above the clayey gravel unit. The pipe in the southern portion of the trench was observed to produce roughly 0.25 gpm of relatively clear water. Little water was observed from the pipe and gravel pack in the northern portion of the trench.

Waters pooling in the trench were differentiated by color. The northern portion of the trench contained cloudy water, while the southern portion of the trench contained clearer water that may have originated primarily from the pipe and associated gravel pack. The center of the trench appeared to contain a mixture of these two waters. Soil and water samples were collected from the northern and southern portions of the trench (Figure 8). Soil Sample 005-S-01-01 was a composite sample collected from the clay with gravel fill at the northern portion of the trench (Figure 8). Soil Sample 005-S-01-02 was collected from the gravel with clay material on top of the weathered shale near the base of the trench. This sample was collected below the previously discussed sample. Water Sample 005-2 was taken in the bottom of the trench at his location.

Soil Sample 005-S-02-01 was collected from the southern portion of the trench (Figure 8) from the gravely clay fill material. The sample was composited from the excavated spoils pile. Soil Sample 005-S-02-02 was collected from near the bottom of the trench in the gravel material. Water Sample 005-2 was collected slightly north of where the soil samples were collected.

3.2 005 Drainage Test Pits: Drainage Alignment

Small pits were excavated down to sandstone bedrock along the margins of the 005 Drainage using a backhoe (Figure 8). The pits were advanced to evaluate whether or not the uranium and nitrate detected in surface water samples could potentially be coming from the native aquifer materials adjacent to the stream. Soil and groundwater samples were collected, with the

groundwater samples collected from the pit excavations after sitting over night to allow sufficient water to accumulate. Pit nomenclature and sampling was based upon three trench lines; each of the three trench lines (3, 4 and 5) consists of a pit N, north of the drainage, a M pit near the middle of the drainage, and a pit S, located south of the drainage. Samples were collected from the colluvial materials and the underlying shale bedrock, where present. If the colluvium was underlain by sandstone, no bedrock sample was collected. Sample designation 1 refers to the colluvial soil sample and a designation of 2 indicates a shale bedrock sample. For example, sample 005-4M-2 was collected in the medial pit of trench line 4 in the bedrock shale. Water samples were collected from all pits except the most downstream northern pit (Pit 005-5N) because no water was present after 48 hours. Table 7 summarizes the samples collected and sample matrix from each trench and pit location. Table 9 summarizes the lithologic characteristics of the material encountered at each trench.

3.3 Sample Analysis

A complete list of solid samples (soil fill or bedrock shale) collected from the 005 Drainage are listed in Table 10 along with the analyses and tests conducted on each sample. Whole rock analysis was done on all samples to provide information on the total concentrations of As, U, and F in the solid matrix. Selected samples were used in absorption and/or batch desorption tests. These tests were undertaken to enhance our understanding of contaminant transport within the fill, colluvium and adjacent bedrock shale. Previous investigations had used batch desorption tests to establish partition coefficients (K_d) as described in SMI 2001. There are numerous methods commonly used for establishing a K_d, each of which is associated with certain advantages and disadvantages. The current transport model under-predicts uranium contamination in the drainage. Low K_d values in the transport model were suspected because the previously established K_d values may not have accurately predicted apparent uranium mobility. Therefore, absorption tests were performed to arrive at K_d values using alternate methods. In addition, batch desorption tests were initiated on colluvium and bedrock samples to provide K_d values that could be compared to those obtained in the previous site investigation. Preliminary results from this analysis are presented in the following section. Adsorption isotherm and batch desorption tests are still in progress.

3.4 Analytical Results and Conclusions

Conceptually, if groundwater contaminant concentrations are determined to be equal or higher in the banks than the stream, the source of the contamination would be inferred to be derived from the bedrock aquifers. Conversely, if concentrations were higher in the stream, the 005 Sump overflow would be considered as the source of contaminants in the drainage. The same concept would be valid for bedrock and unconsolidated sediment uranium concentrations. Analytical results of the groundwater samples are summarized in Figures 9 through 13 and Tables 11 and 12. Groundwater analyses indicate that all constituents are higher in the waters collected in the center pits with one notable exception, fluoride in trench 005-4S is slightly higher (0.8 mg/L) than in trench 005-4M (0.4 mg/L) (see Figure 11). Uranium and arsenic concentrations in all trench lines are greatest in the M or middle pit, indicating the source of the contamination to the drainage is not from the bedrock. Additionally, concentrations of all constituents diminish in a downstream direction indicating a source near the head of the stream.

Analytical results for the bedrock and soil samples are presented in Table 13 and Figures 14 through 18. In general, constituent concentrations for 005 Drainage test pit samples were higher in bedrock than the overlying colluvial soils. The one exception is fluoride in pit 005-4M. Fluoride concentrations were 3.3 mg/kg in bedrock and 3.8 mg/kg in the soils. Laboratory analyses of the unconsolidated material indicate that uranium concentrations increase in a downstream direction. Uranium concentrations increase from 14.5 mg/kg in 005 Drainage Trench 1 to 564 mg/kg in trench 005-5M. Uranium concentrations in shale bedrock generally decrease downstream. Analytical data for Trench 005-3N indicate uranium concentration of 4.69 mg/kg in bedrock whereas 005-5S contained 2.1 mg/kg.

Interpretation of the laboratory results indicate that the groundwater uranium concentrations are greatest in the 005 Drainage Trench 1, especially in the gravel deposit beneath the French drain lines. It is likely that some of the impacted groundwater in the gravel is not being intercepted by the French drain system and ultimately flows down gradient, either within the unconsolidated sediments or as surface water. The unconsolidated sediments appear to contain more uranium than would be suggested by the groundwater uranium concentrations and are likely due to past spills or contaminated solids washed from the site being transported downstream prior to

construction of the storm water intercept trench in 1990. Fluoride was below drinking water standards in all water analysis.

4.0 MW010 SWALE AREA

An additional objective of the field investigation was to evaluate the swale suspected near monitoring well MW010A (Figure 19). This swale is essentially a small surface drainage channel that was covered with local fill materials at the time of facility construction and is suspected of being a subsurface feature that significantly influences local groundwater flow. The technical approach to this field effort consisted of excavating a trench and several test pits. Each pit or trench was excavated until sandstone bedrock was encountered with the exception of trench 5, where sandstone was deeper than the maximum possible excavation depth. Geologic mapping of the material encountered in each pit was conducted. In particular, a lens of well-rounded, well-sorted river gravel was encountered just above sandstone bedrock. Soil samples were collected from the gravel and the overlying fill.

A trench (MW010 Trench 1) approximately 130 feet long was excavated perpendicular to the expected slope of the swale in an attempt to establish the extent of the fill material. The excavation stratigraphy was documented and visually logged by a professional geologist from the top of the trench wall, and digital photographs of the excavation were taken. The pit sidewalls were prone to collapse. Therefore only visual estimates of depths were recorded. The end points of the trench were recorded with a hand-held GPS unit. Table 8 summarizes the GPS coordinates of the trench and summarizes the samples collected from the trench. Depths of geologic contacts were visually estimated. The cross section illustrated in Figure 20 was developed from these field observations.

Depth to bedrock (weathered shale or sandstone) was approximately 15 feet. The excavated area was found to be predominantly compacted fill material to bedrock. The fill consisted of basal gravel varying from one to three feet thick. The gravel consisted of well sorted (washed) well rounded, coarse gravels. The presence of this basal gravel caused the excavated trench to be unstable, and sloughing was common. An additional gravel layer was intermittently present at a depth of approximately seven feet. The balance of the fill material consists of clay with varying amounts of gravel.

The trench was excavated eastward until the basal gravel pinched out. Both gravel layers produced water in varying amounts. Figure 20 is a cross-sectional schematic that illustrates lithology and sample locations. Soil and water samples were collected for analysis. Soil and water samples were collected and preserved in the same manner as samples collected for the 005 Drainage sampling.

Four additional smaller pits (MW010 Trench 2, MW010 Trench 3, MW010 Trench 4 and MW010 Trench 5) were excavated to further investigate the gravel fill and to evaluate its extent, if possible (Figure 19). Each pit was excavated to sandstone bedrock and each encountered the gravel fill to some extent. Overall, the depth to bedrock diminished down slope and the gravel layer thinned and contained more fine-grained material. Table 9 summarizes the geologic conditions identified in these smaller trenches.

Groundwater was observed entering MW010 Trench 2, MW010 Trench 3 and MW010 Trench 4 from the south, the direction of the Decorative Pond. A lesser amount of groundwater was observed entering from up slope. After two days, the water levels in the pits and the trench were surveyed to establish the approximate groundwater elevation. Groundwater entering the western-most trench (MW010 Trench 4) was discolored and appeared yellowish, with light foam of a darker yellow color. The color of the trench water changed from yellow to reddish yellow and finally to a reddish brown during the three days the excavation was open. Subsequent laboratory analyses indicate that the water sampled from the trench contained low uranium concentrations (see Table 12).

The MW010A swale appears to be a much broader feature than was originally estimated. The presence of laterally extensive gravels at the base of the fill materials appears to provide a preferential path for groundwater flow. Groundwater elevations collected in surrounding wells and within the trenches indicate that there is a groundwater mound associated with the Decorative Pond, deflecting groundwater flow to the southwest from the southward dip of the swale. Furthermore, the gravel appears to thin in every direction except northward. The northern direction was not investigated because of the proximity to buildings and the weigh station. Future evaluation of pre-operational topographic information will aid in further

delineation of the swale and potential distribution of the gravel fill. Results of these evaluations will be documented and incorporated in the revised modeling that is currently being performed.

Gravels encountered during excavation appeared to be washed river gravel that was probably imported to the site during the initial phase of site construction. Hydraulic conductivity was visually estimated to be on the order of 50 feet per day, based on the observed inflow of water into the trenches. The gravel contained few fines and chemical retardation is anticipated to be low. Because of the nature of the fill placement, the gravel is interpreted to thin toward the edges. Clays in the fill appear to cause confining conditions, as observed in the gravel in pits excavated between the trench and the Decorative Pond. Confined conditions are suspected because the surveyed trench water levels and groundwater elevations in surrounding wells indicate a water level above the top of the basal gravel though no water was observed to flow from the overlying clayey fill. Furthermore, the bedrock well MW030A, located nearest to the Decorative Pond and completed in the shallow bedrock system, exhibits confined conditions evidenced by water levels above the ground surface, preventing downward contaminant migration. Water levels in unconsolidated fill materials encountered in the pits, trench and Decorative Pond indicate groundwater flowing in these deposits flow from up slope and from the Decorative Pond. The lowest groundwater elevations were encountered in the pits. Diminished flow velocities are expected as groundwater encounters colluvial deposits and the gravel fill pinches out. Hydrologic data from this evaluation will be incorporated into the revised groundwater model and documented in the associated report.

Soil samples were collected from the excavated spoils pile for analysis. Sample locations and sample matrix are described in Table 8. Samples analyses, as described in Section 3.3 and Tables 12 and 13, will aid in determination of in-situ K_d value to be used in the updated groundwater transport model. Additional adsorption tests will be conducted on selected samples. The sample selection will be based on analytical results.

4.1 Hydraulic Conductivity Testing

Slug tests were performed to see if anomalously high hydraulic conductivity conditions, which could cause locally faster constituent transport rates, were present in this area. The tests were

performed and analyzed in exactly the same manner as described in Shepherd Miller (2001). The raw data and analysis of these tests is provided in the Attachment A to this report. Table 1 summarizes the calculated hydraulic conductivity for these wells.

Previous to this investigation, the hydraulic conductivity of the terrace soils in this area was assumed to be 5 ft/day, which is similar to Shale Unit 1. A slug test performed on well MW010 yielded a calculated hydraulic conductivity of 72.6 ft/day, assuming a saturated thickness of approximately 3 feet, based on visual inspections of the MW010 Trench 1 located 15 feet away from MW010. In the trench it was observed that only the basal three feet of gravel fill material was saturated, the balance of the overlying material in the screened interval was a relatively low permeability gravelly clay that did not appear to be producing water indicating semi-confined conditions. Therefore, it was considered appropriate and conservative to calculate the hydraulic conductivity of well MW010 using the 3-foot producing zone as the saturated thickness. With this assumption, the calculated hydraulic conductivity at this well represents an order of magnitude increase in hydraulic conductivity over the current model configuration for this area.

MW010A is completed in Shale Unit 2 and Shale Unit 3. The average hydraulic conductivity used for Shale Unit 2 and Shale Unit 3 in the groundwater model was 1.2 ft/day and 0.1, respectively. The hydraulic conductivity that was established by the MW010A slug test was 1.5 ft/day, which is consistent with the previously modeled value.

The aquifer testing program indicates that the hydraulic conductivity values used in the groundwater model for layers 1 and 2 (Terrace and Shale Unit 1) in the areas investigated may have been underestimated. The consequence of underestimating the hydraulic conductivity is reduced contaminant transport velocity, all other parameters held equal. Changes to the groundwater model to reflect the recently acquired data will be implemented in the future.

4.2 Analytical Results and Conclusions

Groundwater was sampled in MW010 Trench 1, MW010 Trench 2, MW010 Trench 4 and MW010 Trench 5. The analytical results were used in conjunction with nearby monitoring wells in the unconsolidated deposits. Analytical results are presented in Table 12 and the resulting

uranium contour map is presented in Figure 21. The results indicate that the contaminant migration is limited to the gravel deposits of the backfilled swale. The localized hydraulic gradient reversal due to the water level in the decorative pond prevents southward migration of the uranium plume.

Uranium analyses for the current MW010 swale investigations combined with the most recent monitoring well analytical results are depicted in Figure 21. Uranium migration in the unconsolidated sediments appears to be limited in extent to the gravel deposits. Uranium groundwater concentrations appear to diminish where more fines are present in the distal edges of the fill material. Further analysis will be performed in the swale area. The interpreted nature and extent of the gravel fill will be incorporated in the groundwater flow and transport model and will presented in the final modeling report.

5.0 TERRACE BACKGROUND SAMPLING

Two pits were excavated into un-impacted terrace materials east of Highway 10 (Background Trench E-1 and Background Trench E-2; Figure 1). Soil and water samples from these locations will be used to develop K_d values for the terrace materials using batch tests. The trenches were excavated to bedrock and the soil and groundwater samples were collected, stored and shipped in the same manner as the samples collected for the 005 and MW010 swale investigations. Twelve liters of water were collected from the southern pit (Background Trench E-2) to use in batch testing. This trench was selected because there was more water available for sampling than in pit E-1. Both soil and groundwater samples were analyzed for U, F, and As. These results are summarized in Tables 12 and 13.

6.0 RECOMMENDATIONS FOR ADDITIONAL STUDY AND FIELD EFFORTS

The recent supplemental field data collection activities are anticipated to resolve many of the outstanding site characterization issues, although some additional studies may be of value to enhance the site characterization and help support potential future groundwater mitigation efforts. A comprehensive list of potential study topics cannot be assembled at this time because all the recent field data results are not yet available. The following presents a brief discussion of potential areas of additional study or effort.

6.1 All Site Drainages

The potential exists for transport of impacted site groundwater along portions of the drainages covered with fill. Monthly surface water sampling of the site drainages has been initiated. Based on the results of this sampling, additional trenching could be considered for those drainages where anomalous water quality is identified.

6.2 005 Drainage Alternatives

Recent surface water sampling data and excavation of fill at the head of the 005 Drainage indicate that the French drain/005 Sump system may not be intercepting all the subsurface waters from the upper portions of the buried 005 Drainage. The following sections present designs for field scale pilot tests of mitigation alternatives. Two alternatives were evaluated. The first approach consists of a hydraulic containment and pump back system. The second approach employs a passive permeable reactive barrier using zero valant iron or similar reductant. SFC has selected the containment/pumpback approach for the 005 Drainage. Installation will be completed in calendar year 2002

6.3 Well MW010/Swale Area

Some questions remain regarding the distribution of basal gravel and fill materials in the Swale and regarding the hydrologic/hydraulic relationship of the Decorative Pond to local groundwater flow. Stratigraphic and hydrologic mapping of the Swale currently being performed will shed light on these issues. However, additional trenching around the Decorative Pond, especially to

the southwest and southeast, may be of value to better delineate the extent of gravel, the groundwater quality and flow path, and the influence of the Decorative Pond head. This trenching is planned for later in 2002.

Based on the existing site information, it appears that installing a hydraulic containment and pumpback system (similar to the system described for the 005 Drainage above), could provide an effective way to intercept and treat a significant amount of terrace groundwater potentially flowing from this area. However, revision of the site flow model is best completed before conceptual or detailed design is undertaken.

6.3.1 Hydraulic Collection and Pumpback System

Design of a hydraulic collection and pumpback system is described below. Details and specifications are presented on Figure 22. The existing trench excavated to the top of the uppermost sandstone unit (Sandstone Unit 3, approximately 8 feet deep) would be expanded to have 2H:1V side slopes and a minimum three-foot bottom width over a 100-foot long alignment spanning the deepest portions of the buried drainage. The side slope lay-back is intended to provide sufficient worker safety and trench wall stability during construction. The trench bottom would be cleaned of residual sediment and materials.

A 60-mil HDPE membrane or similar material liner placed between geofabric protection layers would be installed on the down gradient side of the trench and sealed to the sandstone using site clay. A perforated 4-inch to 6-inch drainage collection pipe would be installed on the sandstone outcrop upgradient of the membrane liner and covered with well graded gravel to slightly above the zone producing water or a minimum thickness of at least two feet. The excavation side walls would be brought in to approximate a vertical wall as the gravel and liner are installed.

A 12-inch to 16-inch, standpipe would be placed vertically in the deepest portion of the excavation as a sump into which the perforated drainage collection pipe will drain. The natural slope of the sandstone to the lowest portion of the trench will allow the drainage pipe to convey water to the sump. A submersible pump with automatic controls would be installed in the sump. The pump would be piped to the site water treatment facility. The liner material would be placed

over the top surface of the gravel and cover with random fill placed to the elevation of the ground surface. Alternatively, a filter sand layer with a minimum thickness of one foot could be placed on top of the gravel layer and then covered by native fill materials to the ground surface.

The French drain pipes that currently daylight into the existing trench would remain in place. The upgradient pipe ends would be trimmed and remain open to transmit flow. The gravel backfill would be placed to a minimum elevation of one-foot above the invert of the French drain pipes. Pipe ends on the downgradient side would be trimmed, capped and covered by the plastic membrane liner installed on the downgradient side of the trench.

Two 2-inch PVC monitoring wells points would be installed approximately 10 feet and 20 feet downgradient of the collection trench in the deepest portion of the buried drainage to provide performance monitoring. In addition, surface water sampling throughout the 005 Drainage should be performed monthly until it is verified that the uranium-bearing water has been successfully intercepted.

6.3.2 Permeable Reaction Barrier (PRB)

A conceptual design of a PRB using zero valent iron (ZVI or FeO) is described below. Figure 23 illustrates the conceptual design of this alternative. This second alternative could be installed as a field scale pilot test of this approach, following bench scale tests, for long-term passive mitigation of groundwater impacts.

A new trench could be excavated upgradient of the collection trench described above. Similar to the collection trench, the ZVI trench would be excavated to the top of the uppermost sandstone unit approximately 8 feet deep) with 2H:1V side slopes and a minimum five-foot bottom width over a 100-foot long alignment spanning the deepest portions of the buried drainage. The side slope lay back is intended to provide sufficient worker safety and trench wall stability during construction. The trench bottom would be cleaned of residual sediment and materials.

A funnel and gate type system would be installed in the trench, utilizing a low permeability material at the ends of the trench and ZVI in the center of the trench, as shown on Figure 23.

The low permeability material could be a slurry wall, compacted clay or HDPE membrane as described in the collection trench alternative. Conceptually, a 300-foot trench would be excavated, with a 100-foot wide ZVI section flanked by two 45-foot wide low permeability sections. The actual width of each portion of the trench would be dictated by subsurface flow analysis and bench scale permeability testing of the ZVI to ensure adequate flow through the reactive portion of the trench.

The ZVI portion of the trench would be filled in uniform with ZVI using a backhoe bucket and hand shovels to a maximum height of 5 feet. The excavation side walls would be brought in to approximate a vertical wall as the ZVI is installed. If the French drain pipes are intercepted during excavation, the ZVI would be installed up to one foot above the pipe ends in the upgradient side of the trench wall to provide treatment of any flows from these pipes. Pipe ends on the downgradient side would be trimmed, plugged and covered by the low permeability liner installed on the down gradient side of the trench. A one-foot thick layer of filter sand would also be installed on the upgradient side of the ZVI, as well as above the ZVI with clean native fill materials filling the remained of the excavation. Figure 23 presents conceptual details of the ZVI trench.

Two 2-inch PVC monitoring wells points would be installed approximately 10 feet and 20 feet downgradient of the PRB in the deepest portion of the buried drainage to provide performance monitoring. In addition, surface water monitoring throughout the 005 Drainage would be performed monthly.

6.3.2.1 Summary

The hydraulic collection and pumpback system is the most proven and immediate alternative to mitigate impacted groundwater discharge to the 005 drainage. However, testing of a PRB is suggested to provide efficient passive mitigation in the long-term.

7.0 REFERENCES

Shepherd Miller, Inc. (SMI), 2001. Hydrogeological and Geochemical Site Characterization Report. October.

Sequoyah Fuels Corporation (SFC), 1998. "Site Characterization Report."

TABLES

Table 1 Calculated Hydraulic Conductivity Tests

Well Location	Hydrologic Unit	Hydrologic Condition	Borehole Diameter (ft)	Screen Length (ft)	Saturated Thickness (ft)	Hydraulic Conductivity (ft/day)	Storage Coefficient	Analysis Method
MW010	Gravel Backfill	Confined	0.615	~3	~3	72.63	na	Bouwer and Rice (1976)
MW010A	2SH/3SH	Confined	0.500	13.50	14.00	1.52	6.25E-03	Cooper, et. al. (1967)
MW059A	3SH/4SH	Unconfined	0.500	4.71	5.43	21.38	na	Bouwer and Rice (1976)
MW093A	4SH	Unconfined	0.615	16.57	17.09	2.51	na	Bouwer and Rice (1976)
MW095A	4SH	Confined	0.615	5.50	5.50	4.73	na	Bouwer and Rice (1976)
MW097	Colluvium	Unconfined	0.615	0.90	1.55	39.00	na	Bouwer and Rice (1976)
MW097A	4SH	Confined	0.615	17.00	17.00	0.93	na	Bouwer and Rice (1976)

na – data not derived from this test

Hydrologic Unit	Previous Slug Tests (ft/day)				Modeled Value (ft/day)
	no. tests	log mean	max	min	
Alluvium	2	0.334	5.01	0.0223	50.0
shale 1	13	0.0246	0.261	0.00416	0.800
shale 2	4	0.138	1.35	0.0118	1.200
shale 3	3	0.0478	0.488	0.0103	0.100
shale 4	5	0.0314	1.3	0.00466	0.500

Table 2 Results from Arsenic Speciation Analysis

HG-CT-GC-AAS Results						COMPARISON		
Sample ID	As (III)	TIA	*As(V)	TA by ICP-MS		TIA by HG-CT-GC-AAS	TA by ICP-MS	Sum of As Species by IC-ICP-MS
MW071A	0.015	0.275	0.260	0.58		0.275	0.58	558
MW042A	0.250	0.191	ND	670		0.191	670	20
MW064A	2.814	0.668	ND	3940		0.668	3940	1200
MW035A (1:1 diluted)	0.014	0.034	0.020	3		0.034	3	0.7
MW059A	0.988	0.603	ND	1420		0.603	1420	5180
MW095A	0.018	0.089	0.071	52.7		0.089	52.7	0.4
MW057A	0.134	0.258	0.124	3310		0.258	3310	5.0
IC-ICP-MS Results								
	As(III)	As(V)	US-1	US-2	US-3	US-4	US-5	Sum of
Sample ID	(3.7 min)	(14.20 min)	(15.80 min)	(16.80 min)	(17.50 min)	(18.40 min)	(19.50 min)	As Species
MW071A	<1	<1	0.0	<1	557.7	<1	<1	558
MW042A	<1	<1	0.0	<1	<1	19.7	<1	20
MW064A	<10	<10	0.0	<10	1202	<10	<10	1200
MW035A (1:1 diluted)	<0.1	<0.1	0.1	<0.1	0.3	<0.1	<0.1	0.7
MW059A	16	<10	0.0	<10	5183	<10	<10	5180
MW095A	<0.1	<0.1	0.0	<0.1	0.3	<0.1	<0.1	0.4
MW057A	<10	<10	0.0	<10	0.0	<10	<10	5.0
**MW042A MD	<1	<1	0.0	<1	452.6	<1	<1	453
**MW042A MS+500 ppb	354	<1	872.6	<1	<1	<1	<1	873
**MW042A MSD+500 ppb	364	<1	946.7	<1	<1	<1	<1	947

All results in µg/L
TIA = Total Inorganic Arsenic, essentially all As(III) and As(V)
TA = Total Arsenic, regardless of species
ND = not detected
US – Unidentified Species
* Arsenate is calculated by difference: As(V)=TIAs-As(III)
** Matrix Duplicate (MD), Matrix spike (MS) and matrix spike duplicate (MSD) using 500 ppb As(III)
IC-ICP-MS = ion-chromatography inductively coupled plasma mass-spectrometry
ICP-MS = Inductively coupled plasma mass Spectrometry
HG-CT-GC-AAS = hydride generation cryotrapping gas chromatography atomic absorption spectrometry

Table 3 Quality Control Data - Duplicate Report

Analyte (µg/L)	Sample QC'd	Rep. 1	Rep. 2	Mean	RPD
As(III)	SC3-UUI-201	0.207	0.196	0.201	5.3
TIAs	SB-A2	0.850	0.812	0.831	4.6
Tas	MW071A	0.58	0.59	0.58	1.4

Table 4 Quality Control Data - Matrix Spike / Matrix Spike Duplicate Report

Analyte (µg/L)	Sample QC'd	Sample conc.	Spike Level	MS	% Rec.	MSD	% Rec.	RPD
As(III)	SC3-UUI-201	0.207	0.400	0.586	94.7	0.621	103.5	5.8
TIAs	SB-A2	0.850	1.000	1.829	97.9	1.872	102.2	2.3
TAs	MW071A	0.58	20.00	21.43	104.3	19.94	96.8	7.2

MS = matrix spike
MSD = matrix spike duplicate
RPD = relative percent difference

Table 5 Quality Control Data - Preparation Blank Report

Analyte (µg/L)	IBW1	IBW2	IBW3	IBW4	Mean	Std Dev	Est. MDL
As(III) HG-CT-GC-AAS	0.000	0.002	0.000	0.001	0.001	0.0007	0.003
TIAs HG-CT-GC-AAS	0.006	0.002	0.003	0.003	0.003	0.0015	0.005
Tas	-0.03	-0.04	-0.03	0.00	-0.02	0.017	0.060

Std Dev = Standard deviation
Est. MDL = Estimated method detection limit

Table 6 Quality Control Data - Standard Reference Material Report

Analyte (µg/L)	SRM Identity	Cert. Value	Obs. Value	% Rec.
As(III) HG-CT-GC-AAS	not available			
TIAs HG-CT-GC-AAS	NIST1640	26.67	23.83	89.4
Tas	NIST1640	26.67	26.28	98.5

SRM Identity = Standard reference material identity
Obs. Value = Experimental result
Cert. Value = Certified value
% Rec. = Percent recovery

Table 7 Recent Sampling for the 005 Drainage

Trench Line	Sample ID	Matrix	Location
005 Drainage Trench 1	005-1	Water	North end of trench
	005-2	Water	South end of trench
	005-S-01-01	Soil	clay and gravel fill at north end of trench @2.5'
	005-S-01-02	Soil	gravel with clay fill at north end of trench @ 6'
	005-S-02-01	Soil	clay and gravel fill at south end of trench @ 4'
	005-S-02-02	Soil	gravel with clay fill a south end of trench @5.5
005 Drainage Trench 3	005-03N	Water	
	005-03M	Water	
	005-03S	Water	
	005-03N-1	Soil	composite sample
	005-03N-2	Shale	composite sample
	005-03M-1	Soil	composite sample
	005-03S-1	Soil	composite sample
	005-03S-2	Shale	composite sample
005 Drainage Trench 4	005-04N	Water	
	005-04M	Water	
	005-04S	Water	
	005-04N-1	Soil	composite sample
	005-04N-2	Shale	composite sample
	005-04M-1	Soil	composite sample
	005-04M-2	Shale	composite sample
	005-04S-1	Soil	composite sample
	005-04S-2	Shale	composite sample
005 Drainage Trench 5	005-05M	Water	
	005-05S	Water	
	005-05N-1	Soil	composite sample
	005-05M-1	Soil	composite sample
	005-05S-1	Soil	composite sample
MW010 Trench 1	MW010-1	Gravel	Basal gravel @ 12'
	MW010-2	Shale	Weathered shale @ 14'
	MW010-3	Soil	Composite above 12'
	MW010-1W	Water	Collected near exposed pipe
MW010 Trench 2	MW010-2-1	Soil	Composite clay/gravelly clay
	MW010-2-2	Gravel	Basal gravel @ 8'
	MW010-2	Water	
MW010 Trench 4	MW010-4-1	Soil	Composite clay/gravelly clay
	MW010-4-2	Gravel	Basal Gravel @ 6'
	MW010-4	Water	
MW010 Trench 5	MW010-5-1	Soil	Composite clay/gravelly clay
	MW010-5	Water	
Background Trench E1	E1-1	Soil	Terrace Material
	E1	Water	
Background Trench E2	E2-1	Soil	Terrace/Colluvial Material
	E2	Water	
	E2 - background	Water	12 liters for batch tests

Table 8 Summary of GPS Coordinates for the Trenches and Trench Sampling

Waypoint	Northing	Easting	Location
Wpt 001*	196439	2836121	005 10' N of North End of Trench 1
Wpt 002*	196374	2836107	005 West Bank at Bend in Trench 1
Wpt 003*	196337	2836119	005 South End of Trench 1
Wpt 004*	196399	2836055	MW037 Location Check
Wpt 005*	196409	2836117	005 Trench 1 Drainage Bottom - Approx.
Wpt 006*	196412	2836028	005 Trench 3 South Excavation
Wpt 007*	196439	2836022	005 Trench 3 Middle Excavation
Wpt 008*	196449	2836024	005 Trench 3 North Excavation
Wpt 009*	196396	2835849	005 Trench 4 South Excavation
Wpt 010*	196412	2835864	005 Trench 4 Middle Excavation
Wpt 011*	196444	2835858	005 Trench 4 North Excavation
Wpt 012*	196594	2835580	005 Trench 5 South Excavation
Wpt 013*	196631	2835568	005 Trench 5 Middle Excavation
Wpt 014*	196649	2835548	005 Trench 5 North Excavation
Wpt 015*	196667	2835534	MW100B Location Check
Wpt 016*	195492	2837148	MW010 Trench 1 East End
Wpt 017*	195488	2837014	MW010 Trench 1 West End
Wpt 018*	195432	2837034	MW010 Trench 2 Center on South Bank
Wpt 019*	195433	2837056	MW010 Trench 3 Center on South Bank
Wpt 020*	195396	2836979	MW010 Trench 4 Center on South Bank
Wpt 021*	195473	2836974	MW010 Trench 5 Center on South Bank
Wpt 022*	195488	2837035	MW010 Trench 1 Water Sample Location
Wpt 023*	195047	2838179	East of Hwy 10 South Trench (Trench E2)
Wpt 024*	195937	2838356	East of Hwy 10 North Trench (Trench E1)
Wpt 025*	198380	2836248	Drainage North of Plant N of Salt Branch
Wpt 026*	195883	2841887	Outcrop at NE Corner of Old Pond Dam

Table 9 Trench Lithologic Description

Trench	Depth (ft)	Lithology
MW010 Trench 1 (West Side)	0-1	Fill, Topsoil, dark grayish brown, loose moist
	1-2.5	Fill, Gravel, clayey, reddish brown, moist, gravel ~20%, firm
	2.5-3	Fill, Clay, gravelly, tans to light brown, firm, moist, gravel ~20%
	3-6	Fill, Clay, gravelly, dark reddish brown to black, moist, wet in places, gravel ~20%
	6-9	Fill, clay, sandy, trace gravel, some gravel lenes, Reddish brown to black, moist, wt in places, especially in gravel lenses
	9-12	Fill, Gravel, some clay~30%, reddish brown, wet, loose, rounded, gravel moderately well sorted, 1-3 inches, makes good water
	12-15	Clay, weathered shale, light brown to buff, wet, soft, plastic
MW010 Trench 2	0-8	Fill, Interbeds of gravelly clay and clayey gravel, moist moderate brown to yellowish brown, gravel <10%
	8-8.5	Fill, Gravel, wet, rounded river rock, water entering pit predominantly from pond side
	8.5-9.5	Clay, weather shale, light brown, stiff, saturated, plastic
	9.5	Sandstone
MW010 Trench 3	0-6	Fill, Interbeds of clayey gravel and gravelly clay, moist, becomes very gravelly near base
	6-8.5	Clay, weathered shale light brown, stiff, saturated, plastic
	8.5	Sandstone
MW010 Trench 4	0-5	Fill, Interbeds of clayey gravel and gravelly clay, moist, becomes very gravelly near base
	5-6	Gravel, sparse clay, loose, saturated, rounded river rock
	6-8	Clay, weathered shale light brown, stiff, saturated, plastic
	8	Sandstone
MW010 Trench 5	0-1	Topsoil
	1-2	Gravelly clay, light brown to buff, moist
	2-16	gravel with clay and sand. Poorly sorted, Seeps at 6', 8', 12', and 15'
005 Drainage Trench 1	See Figure 8 for approximate depths	Fill, Clay, silty, reddish brown, moist to wet, underlain by 6 mil black plastic
		Clay, with gravel and sand, dark reddish brown to black, poorly sorted, clay~50% gravel 30%, sand 20%, moist to very moist. Contains two French drain pipes that were broken during excavation. Southern pipe flows <5 gpm
		Gravel with clay, reddish brown, very moist to wet. gravel 55%, clay 45%, soft
		Weathered shale, clay, dark brown, wet plastic, firm
		Sandstone, hard well cemented, laminated, dark gray
005 Drainage Trench 3N	0-8	Clay, some sand and gravel, reddish brown
	8-12	sandstone, hard, well cemented, very shaley
005 Drainage Trench 3M	0-3	Sandy, silty, gravelly clay, moist to saturated, moderate brown
	3	Sandstone
005 Drainage Trench 3S	0-3	Overburden, gravelly, sandy clay, reddish brown, moist becomes saturated near bottom
	3-6	sandstone, shaley, wet near top
005 Drainage Trench 3S	0-3	Overburden, gravelly, sandy clay, reddish brown, moist becomes saturated near bottom
	3-6	sandstone, shaley, wet near top

Table 9 Trench Lithologic Description (continued)

Trench	Depth (ft)	Lithology
005 Drainage Trench 3S	0-3	Overburden, gravelly, sandy clay, reddish brown, moist becomes saturated near bottom
	3-6	sandstone, shaley, wet near top
005 Drainage Trench 4N	0-3	Clay, reddish brown
	3-5	shale, saprolitic, black to dark gray with abundant iron stains
	5-8	Same as above but less weathered
005 Drainage Trench 4M	0-1	Sandy clay, moderate brown, moist to wet
	1-6	shale, gray with iron stains
005 Drainage Trench 4S	0-3	clay, reddish brown, soft, moist
	3-8	Clay, weathered shale, dark gray to black, soft moist
	8-12	sandstone, hard, well cemented, 1.5-3" interbeds
005 Drainage Trench 5N	0-2	clay, reddish brown to brown wet, plastic, soft
	2	Sandstone
005 Drainage Trench 5M	0-0.75	Clay, sandy, silty
	0.75	Sandstone
005 Drainage Trench 5S	0-4.5	clay, yellowish brown, saturated at 4'
	4.5	Sandstone
E-2	0-0.75	silty loam, dark brown, moist, soft
	0.75-2	clay, moderate brown to buff
	2	Sandstone
E-1	0-0.5	silty loam, moderate brown, moist
	0.5-4.5	clay, some gravel, moist, saturated at 2.0'
	4.5	Sandstone

Table 10 List of Samples Collected at Sequoyah Fuels Site during February 2002 and a List of Analytical Procedures Performed on Each Sample

Sample ID	Whole Rock 3050	Adsorption Test	Element(s)	Desorption Test	Element(s)
005-03M-1	X				
005-03N-1	X	X	U		
005-03N-2	X	X	U		
005-03S-1	X				
005-03S-2	X				
005-04M-1	X	X	U		
005-04M-2	X				
005-04N-1	X				
005-04N-2	X	X	U, As	X	U, As
005-04S-1	X	X	U, As	X	U, As
005-04S-2	X	X	U, As	X	U, As
005-05M-1	X			X	U, As
005-05N-1	X				
005-05S-1	X				
005-S-01-01	X			X	U, As
005-S-01-02	X			X	U, As
005-S-02-01	X	X	As		
005-S-02-02	X	X	As		
E1-1	X	X	U		
E2-1	X	X	U		
MW-10-1	X				
MW-10-2	X				
MW-10-3	X				
MW010-2-1	X				
MW010-2-2	X				
MW010-4-1	X	X	U		
MW010-4-2	X	X	U		
MW010-5-1	X				

Table 11 Drainage Surface Water Sampling Results

Location	Date	Uranium µg/l	Nitrate mg/l	Arsenic mg/l
2241	1/4/02	60.2	12.4	< 0.009
	2/22/02	40.0	5.0	< 0.009
	3/6/02	35.3	11.9	< 0.009
2242	1/4/02	46.8	15.8	< 0.009
	2/22/02	40.1	8.0	< 0.009
	3/6/02	30.4	262	< 0.009
2243	1/4/02	2.92	1.2	< 0.009
	2/22/02	1.07	< 1	< 0.009
	3/6/02	5.16	< 1	< 0.009
2244	1/4/02	< 1	70.0	0.021
	2/22/02	< 1	39.8	< 0.009
	3/6/02	1.03	38.4	< 0.009
2245	1/4/02	< 1	388	0.027
	2/22/02	< 1	13.9	0.015
	3/6/02	< 1	97.3	< 0.009
2246	1/4/02	34.6	13.0	< 0.009
	2/22/02	4.52	8.7	< 0.009
	3/6/02	4.00	4.9	< 0.009
Drainage 005 Trench 2	12/3/01	49.8	31.8	
Drainage 005 Trench 3	12/3/01	69	34.8	
Drainage 005 Trench 4	12/3/01	66.5	37.4	
Drainage 005 Trench 5	12/3/01	30	46.2	
Drainage 005 Trench 6	12/3/01	58	82.6	
Drainage 005 Trench 7	12/3/01	210	82.6	
Drainage 005 Trench 8	12/3/01	275	310	
005 Sump (2224)	12/3/01	274	309	

Location	Northing	Easting	Description
2241	196799	2835306	005 Drainage ~25' East of COE Boundary Fence
2242	196641	2835501	005 Drainage - Pool near MW100B
2243	197492	2835812	007 Drainage North of North Fluoride Holding Basin Area
2244	195726	2834825	004 Drainage - Pool ~20' East of COE Boundary Fence
2245	195151	2834303	Seep North of Port Road Bridge
2246	195204	2834191	001 Drainage North of Port Road Bridge

Table 12 2002 Trench Aqueous Sampling Data

Station	Date Sampled	Matrix	Organic Carbon, Dissolved (DOC) (mg/L)	Arsenic (mg/L)	Fluoride (mg/L)	Uranium (mg/L)
005-03M (3)	2/9/02	Aqueous	5.31	0.0044	0.5	0.13
005-03N (3)	2/9/02	Aqueous	4.14	0.002	0.1	0.0007
005-03S (3)	2/9/02	Aqueous	6.07	0.0011	0.2	0.002
005-04M	2/9/02	Aqueous	4.29	0.0029	0.4	0.143
005-04N	2/9/02	Aqueous	5.16	0.001	0.1	0.0077
005-04S	2/9/02	Aqueous	2.41	0.0011	0.8	0.0035
005-05M	2/9/02	Aqueous	4.44	0.001	0.2	0.0317
005-05S	2/9/02	Aqueous	3.96	0.001	0.2	0.0004
005-1	2/9/02	Aqueous	7.84	0.0223	0.6	0.626
005-2	2/9/02	Aqueous	8.32	0.0346	0.3	0.121
E1	2/12/02	Aqueous	19.47	0.0375	0.2	0.0016
E2	2/12/02	Aqueous	7.55	0.0032	0.1	0.0003
MW010-1W (3)	2/9/02	Aqueous	7.81	0.0143	0.3	0.0863
MW010-2 (3)	2/9/02	Aqueous	10.74	0.0121	0.2	0.0085
MW010-4 (3)	2/9/02	Aqueous	22.64	0.0618	0.4	0.0307
MW010-5 (3)	2/9/02	Aqueous	5.34	0.006	0.5	0.108

Table 13 2002 Soil Sampling Data

Station	Date Sampled	Matrix	Moisture %	Arsenic (mg/kg)	Fluoride (mg/kg)	Uranium (mg/kg)
005-03M-1	2/9/02	Soil	14.1	26.3	6.6	66.7
005-03N-1	2/9/02	Soil	14.1	9.74	1.4	9.55
005-03N-2	2/9/02	Soil	4.43	8.52	1.4	4.69
005-03S-1	2/9/02	Soil	15.7	12.6	0.83	7.56
005-03S-2	2/9/02	Soil	4.07	11.4	1.4	1.08
005-04M-1	2/9/02	Soil	20.2	8.25	3.8	396
005-04M-2	2/9/02	Soil	12	4.7	3.3	2.56
005-04N-1	2/9/02	Soil	19.1	37.5	1.4	1.09
005-04N-2	2/9/02	Soil	14.9	6	2.8	1.2
005-04S-1	2/9/02	Soil	19.7	64.5	0.84	1.76
005-04S-2	2/9/02	Soil	11.3	7.12	1.9	1.22
005-05M-1	2/9/02	Soil	36.3	12.7	3.3	564
005-05N-1	2/9/02	Soil	21.6	11	1.9	1.19
005-05S-1	2/9/02	Soil	14.1	10.1	0.73	2.1
005-S-01-01	2/9/02	Soil	18.5	12.5	9.1	18.9
005-S-01-02	2/9/02	Soil	12.6	19.7	7.2	14.5
005-S-02-01	2/9/02	Soil	18.3	8.77	7.9	11
005-S-02-02	2/9/02	Soil	11.1	14	4.6	144
E1-1	2/10/02	Soil	14.3	26	1.7	1.93
E2-2	2/10/02	Soil	18	4.33	1.3	1.39
MW-10-1	2/8/02	Soil	14.6	8.91	3.8	92.4
MW-10-2	2/8/02	Soil	20.3	8.7	3.5	6.15
MW-10-3	2/8/02	Soil	16.2	7.61	2.8	2.14
MW010-2-1	2/9/02	Soil	26.5	14.3	1.7	3.91
MW010-2-2	2/9/02	Soil	12.1	7.02	2.5	1.82
MW010-4-1	2/9/02	Soil	17.4	16.6	12	0.892
MW010-4-2	2/9/02	Soil	15.9	6.11	2.7	3.84
MW010-5-1	2/9/02	Soil	14.5	8.64	3.8	13.6

FIGURES

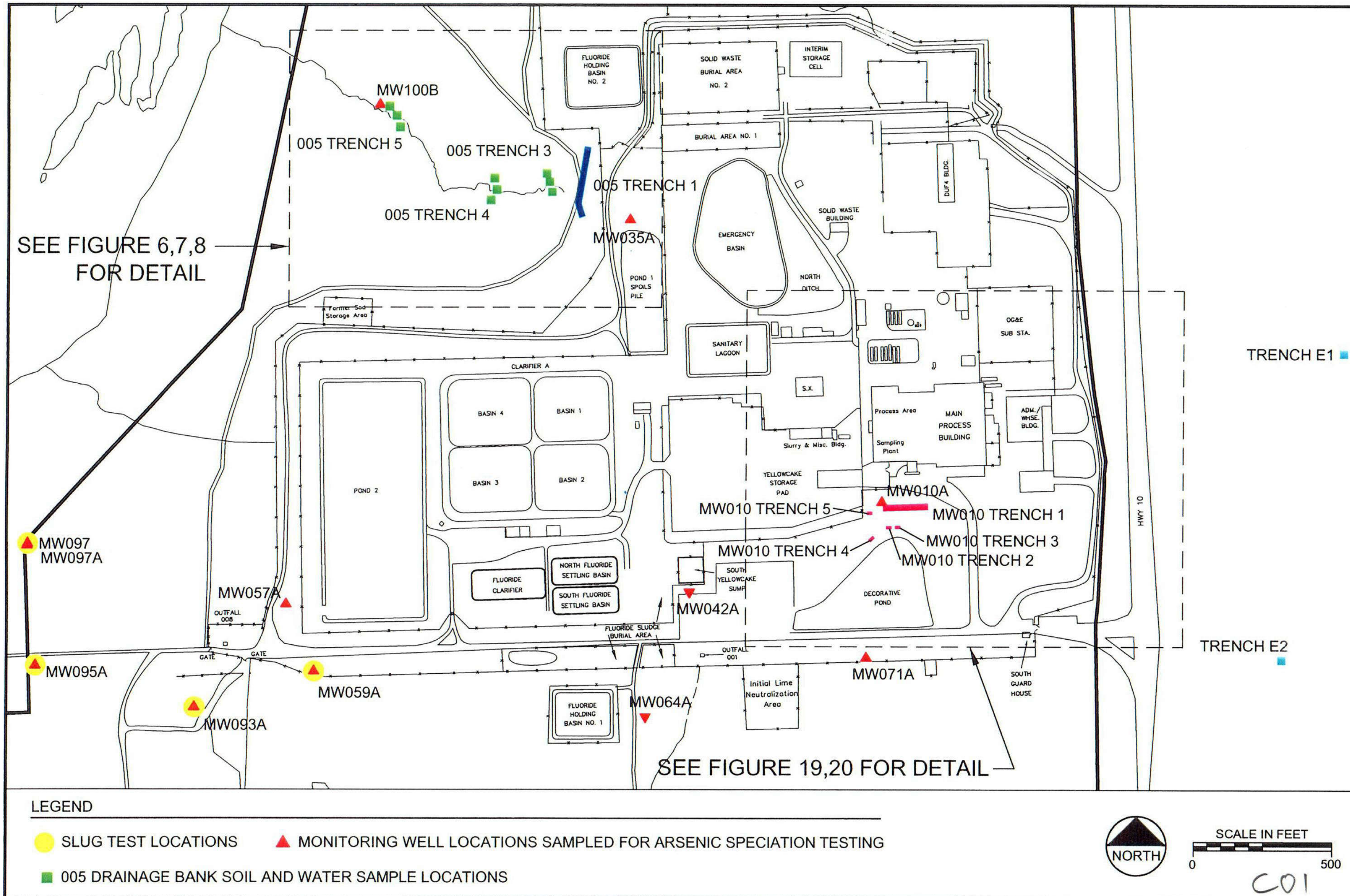

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FIGURE 1
SUPPLEMENTAL DATA COLLECTION LOCATIONS

Date:	APRIL 2002
Project:	100734
File:	TRENCH-01.DWG

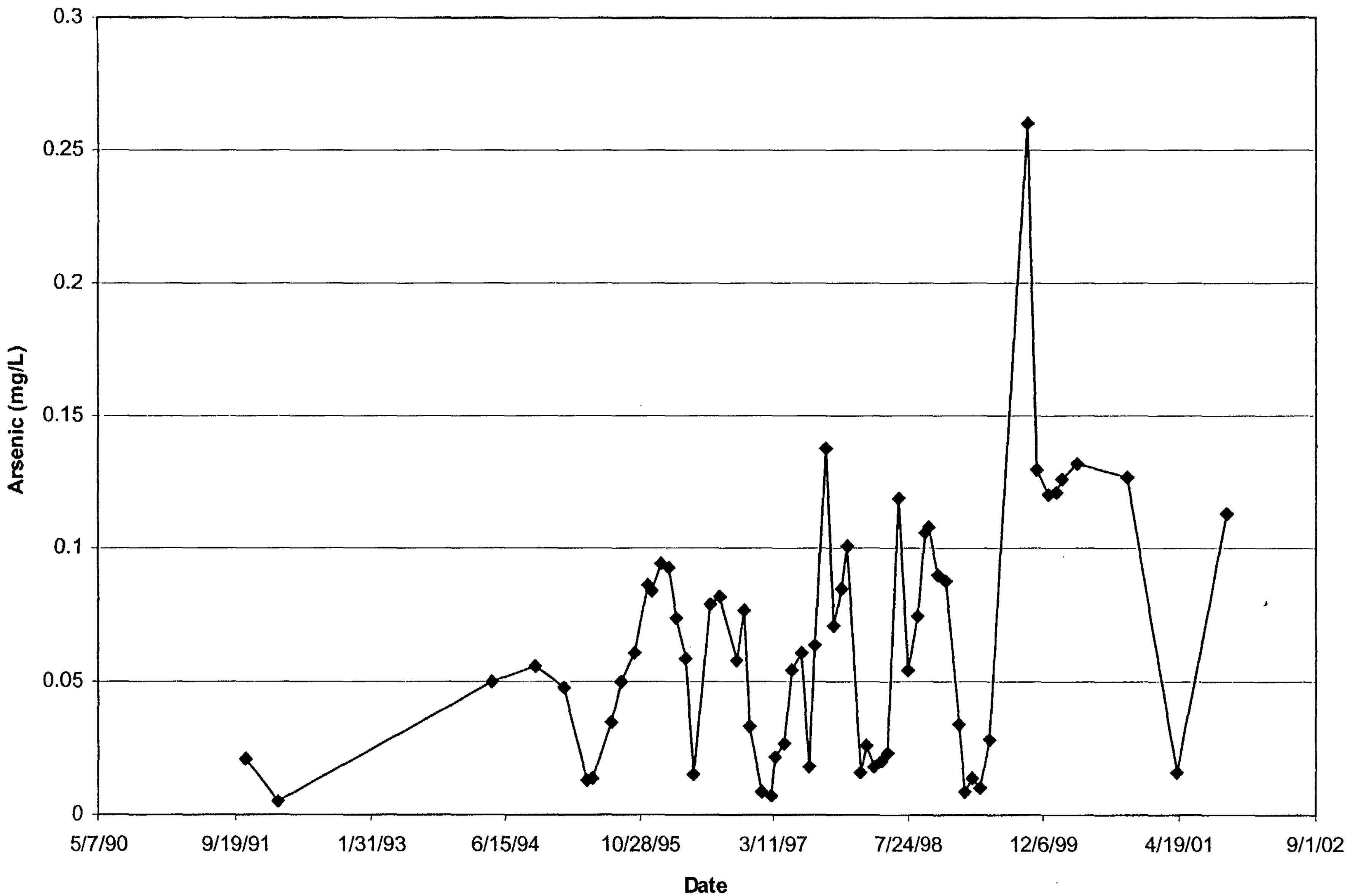

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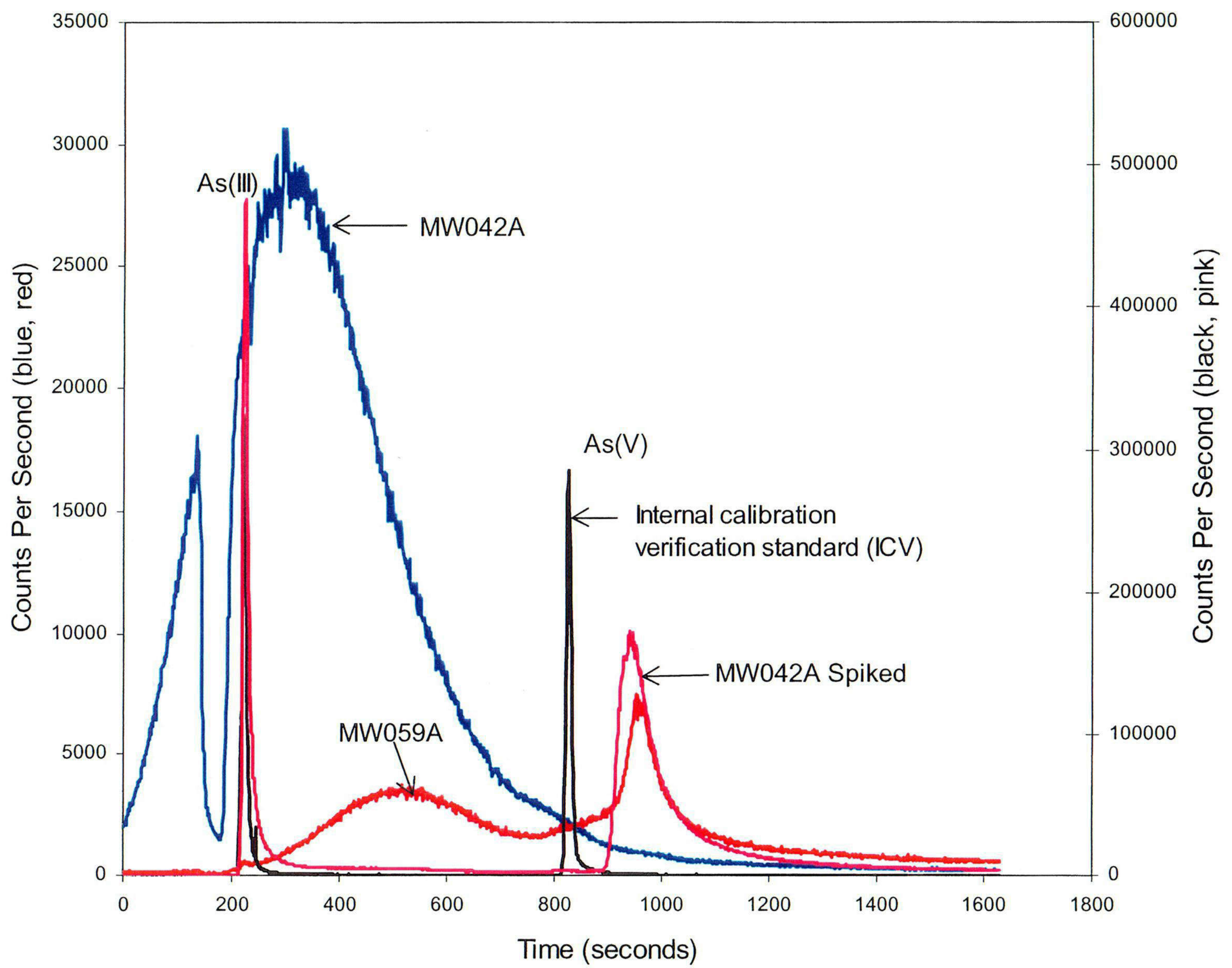
FIGURE 2
WELL MW095A ARSENIC CONCENTRATIONS

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt



C02

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FIGURE 3
ANALYTICAL RESULTS OF ARSENIC SPECIATION: IC-ICP-MS CHROMATOGRAM

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

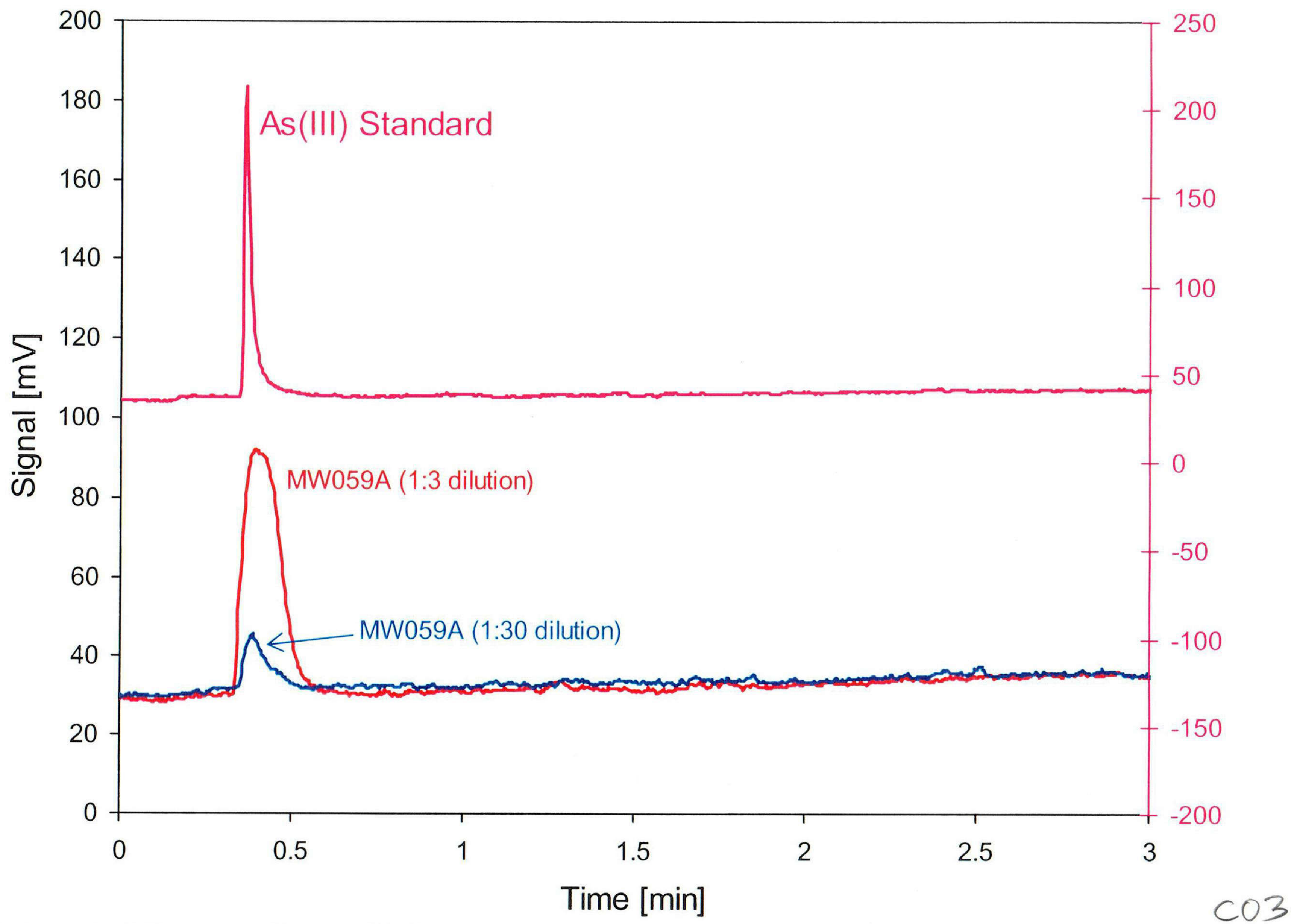

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FIGURE 4
CHROMATOGRAM OBTAINED OF SAMPLE MW059A DURING HG-CT-GC-AAS SPECIATION OF ARSENIC

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

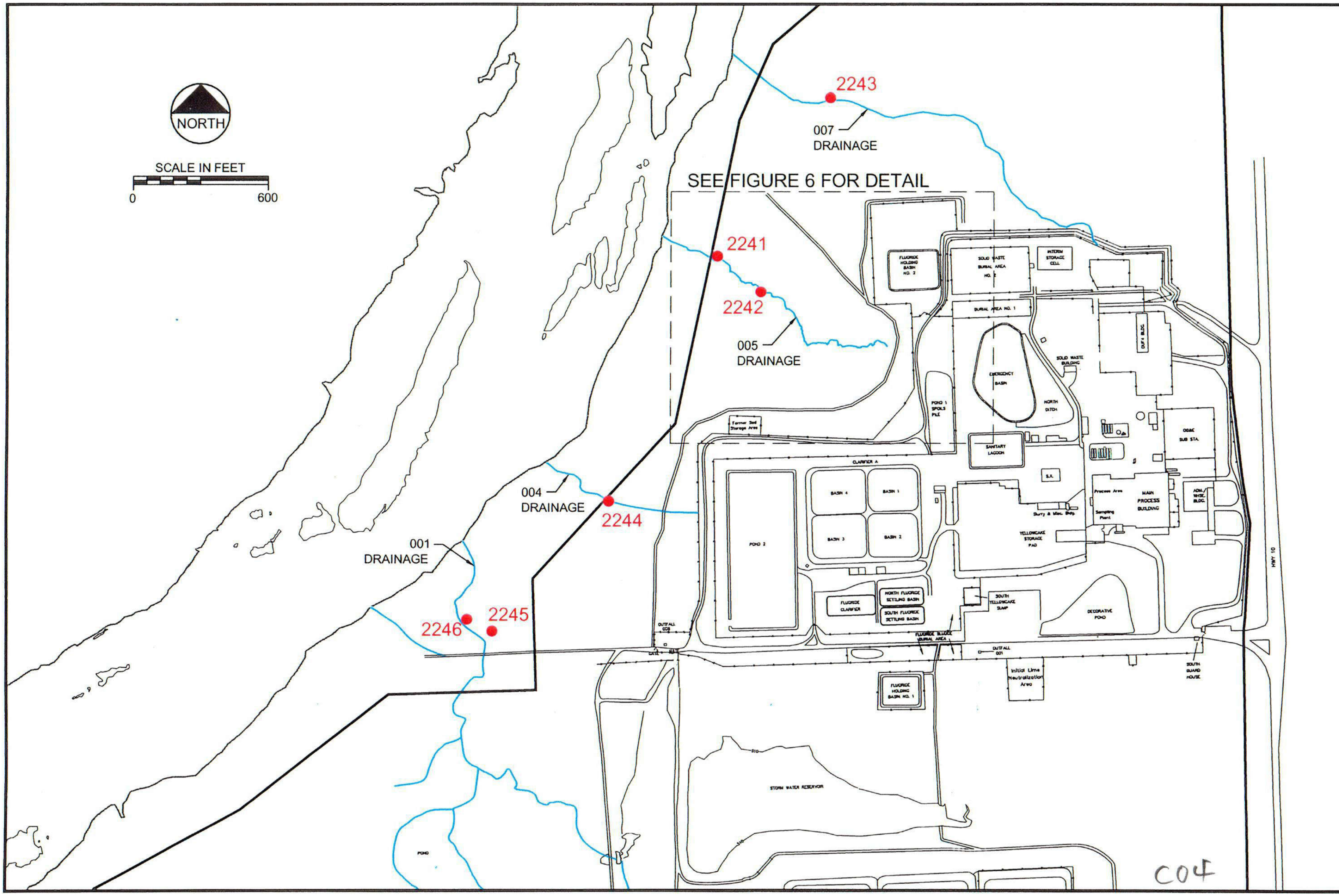

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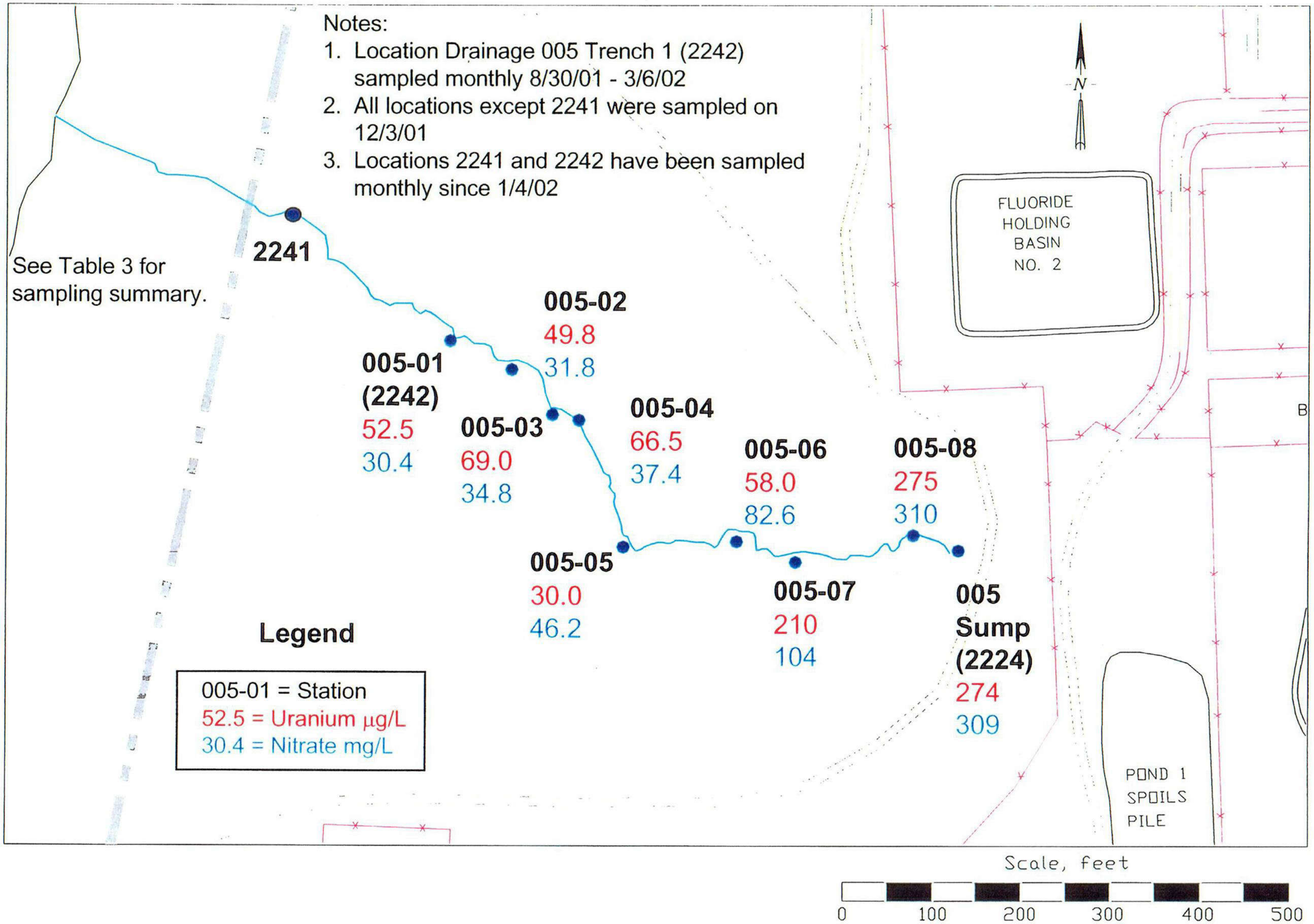
FIGURE 5
SITE DRAINAGES AND SURFACE WATER
SAMPLING LOCATIONS

Date:	APRIL 2002
Project:	100734
File:	DRAINAGESAM....-01



C05

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FIGURE 6
005 DRAINAGE SURFACE
WATER SAMPLING LOCATIONS

Date:	MARCH 2002
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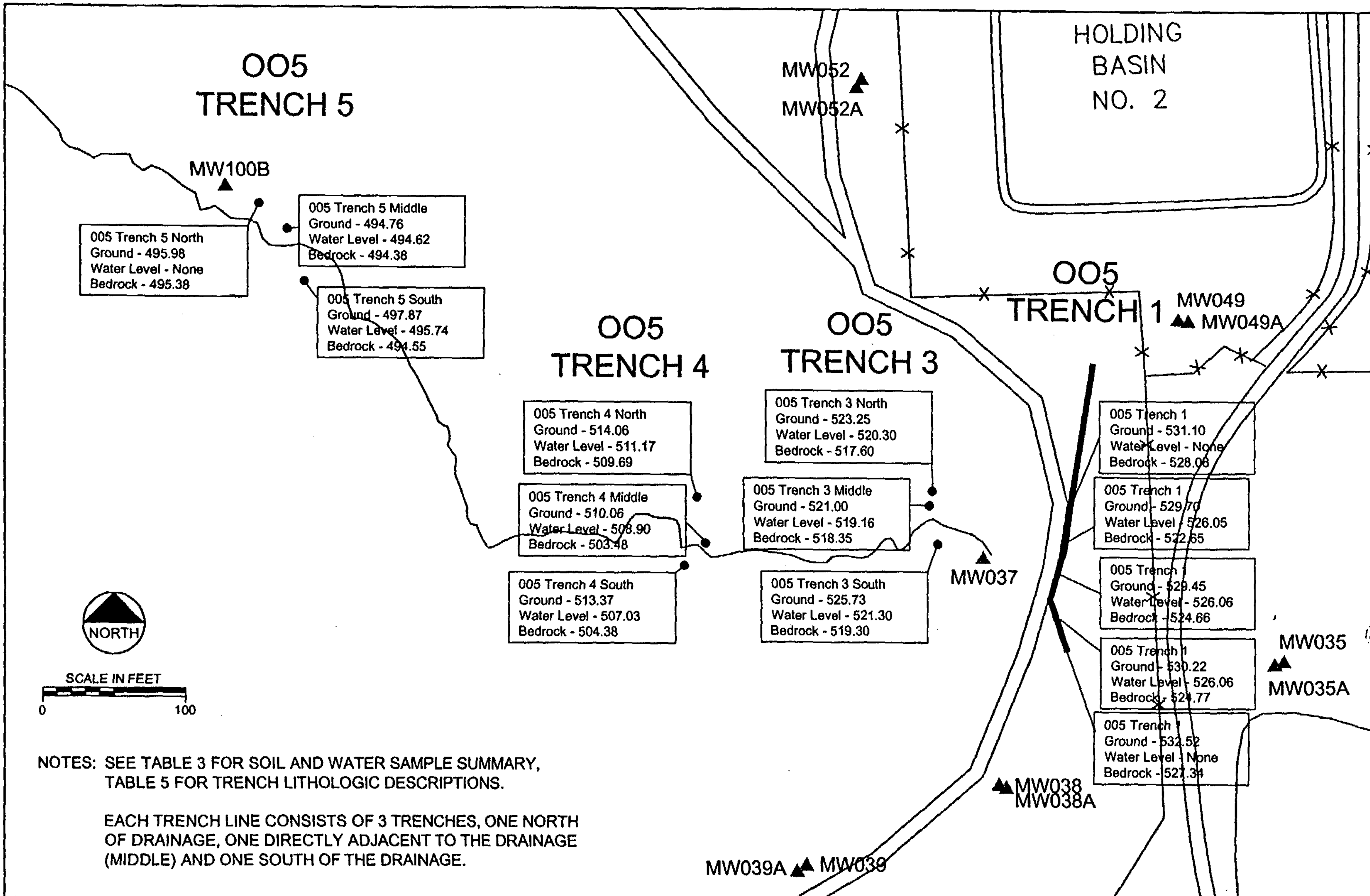
File:	TRIPFIGS.ppt



NOTES: SEE TABLE 3 FOR SOIL AND WATER SAMPLE SUMMARY, TABLE 5 FOR TRENCH LITHOLOGIC DESCRIPTIONS.

EACH TRENCH LINE CONSISTS OF 3 TRENCHES, ONE NORTH OF DRAINAGE, ONE DIRECTLY ADJACENT TO THE DRAINAGE (MIDDLE) AND ONE SOUTH OF THE DRAINAGE.

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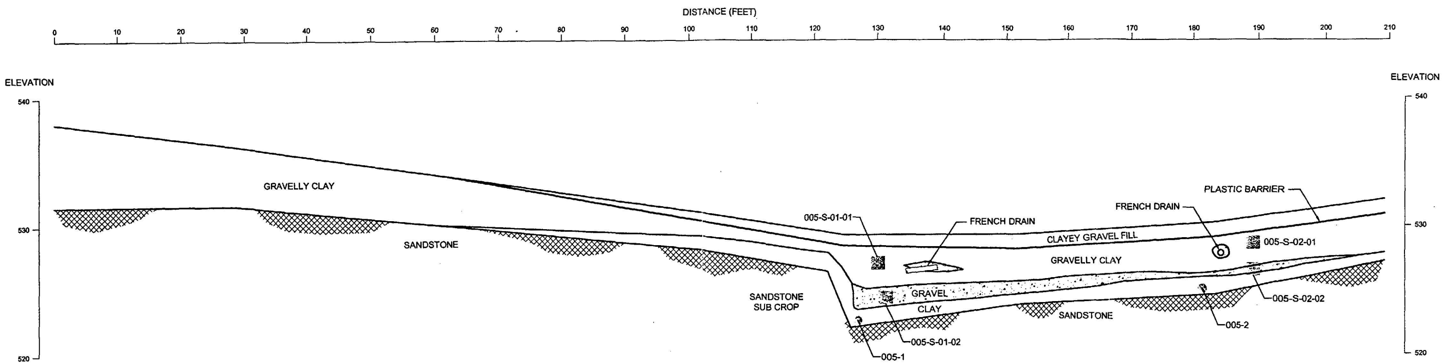
FIGURE 7
005 DRAINAGE TRENCHING AND SOIL/WATER SAMPLING LOCATIONS

Date:	APRIL 2002
Project:	100734
File:	TRENCH-FIGS



LEGEND

- SOIL SAMPLE LOCATIONS AND ASSOCIATED SAMPLE NUMBER
- WATER SAMPLE LOCATIONS AND ASSOCIATED SAMPLE NUMBER

SEE TABLE 3 FOR SOIL AND WATER SAMPLE SUMMARY

FIGURE 8
CROSS SECTION VIEW OF 005 DRAINAGE TRENCH 1

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Date:	APRIL 2002
Project:	100734
File:	PROFILES-01.DWG

Filename: E:\100734\profiles-01.dwg
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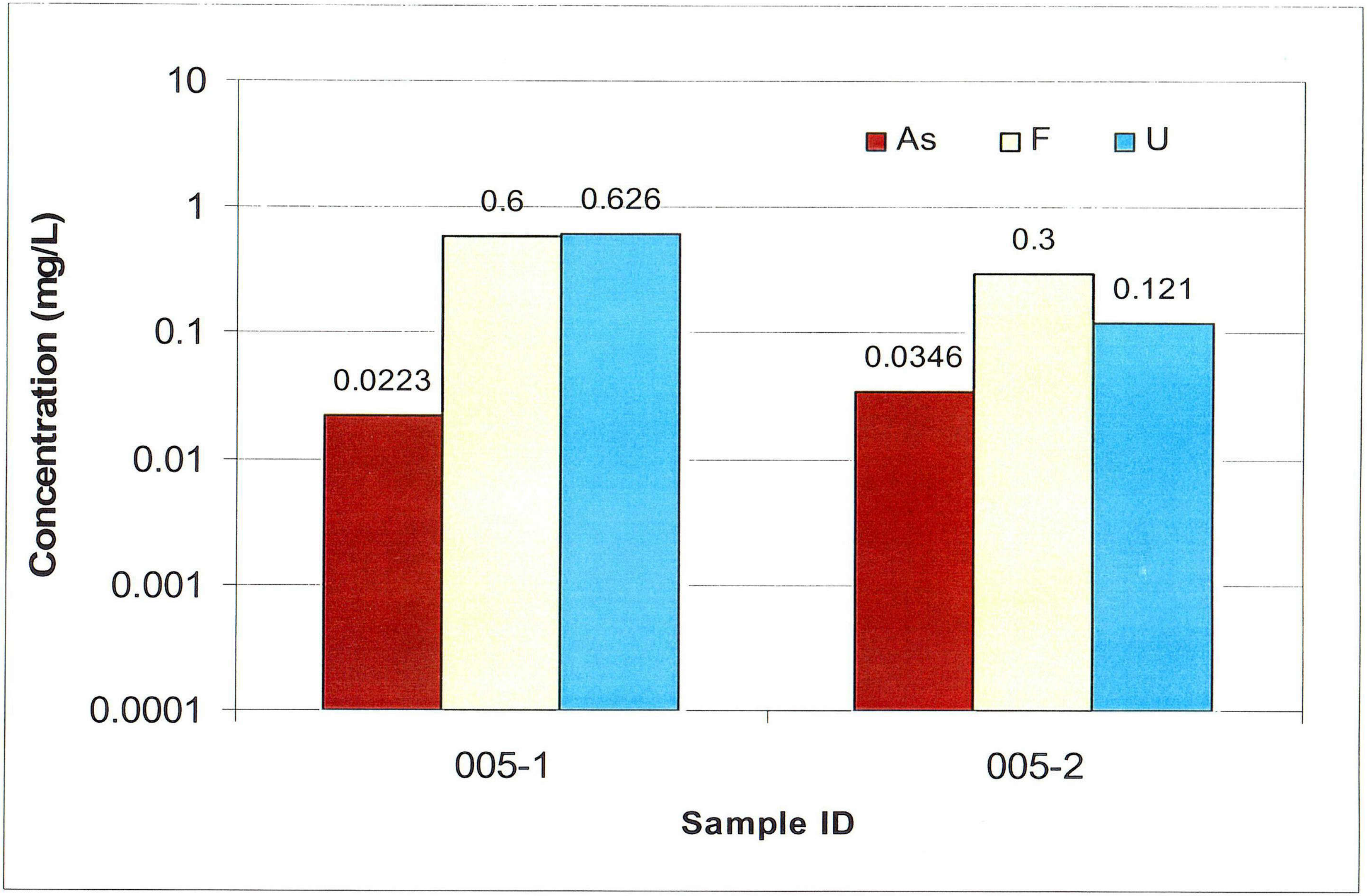

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FIGURE 9
AQUEOUS ANALYTICAL RESULTS FOR 005 DRAINAGE TRENCH 1

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

C06

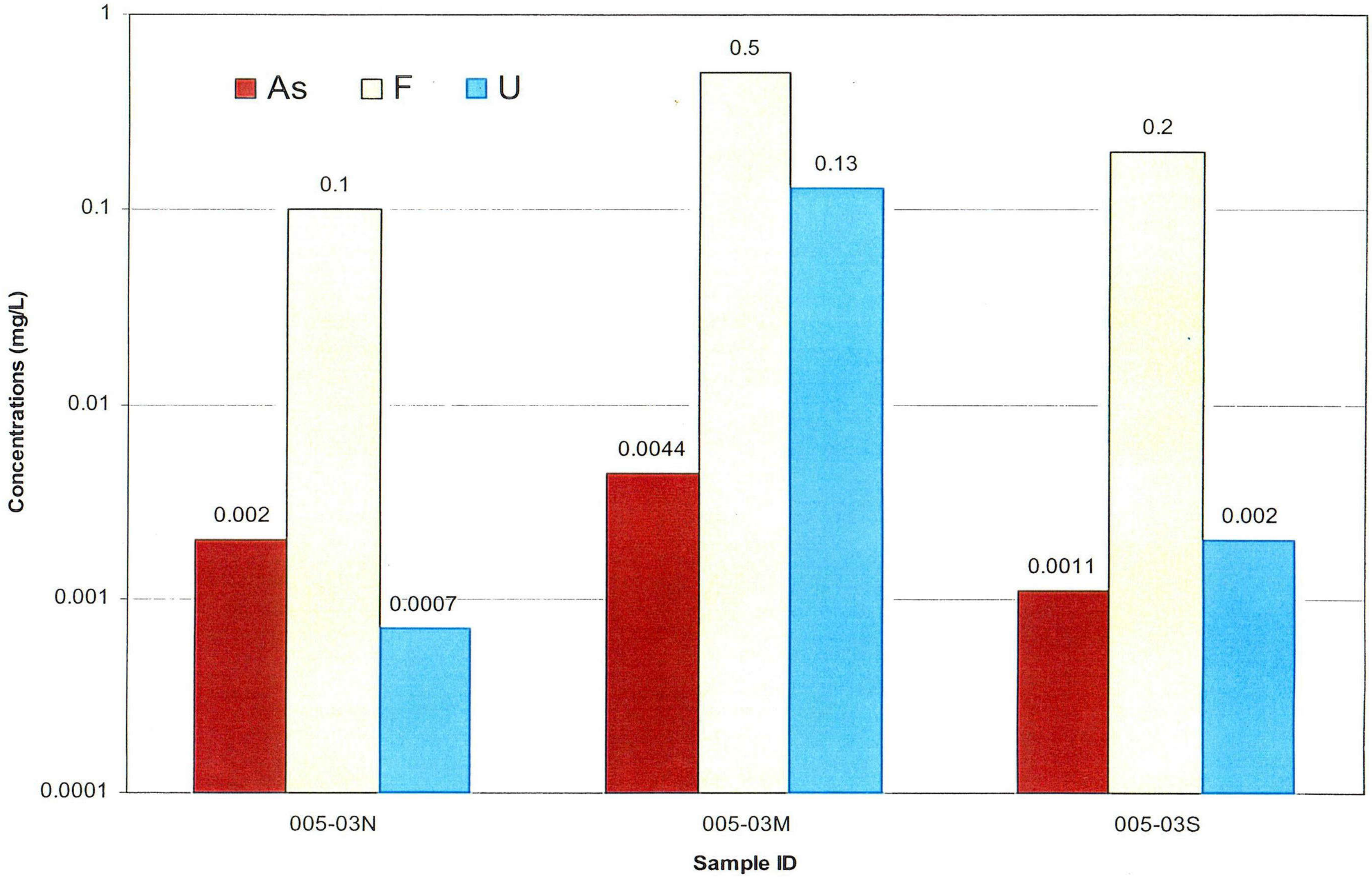

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FIGURE 10
AQUEOUS ANALYTICAL RESULTS FOR 005 DRAINAGE TRENCH 3

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

C07

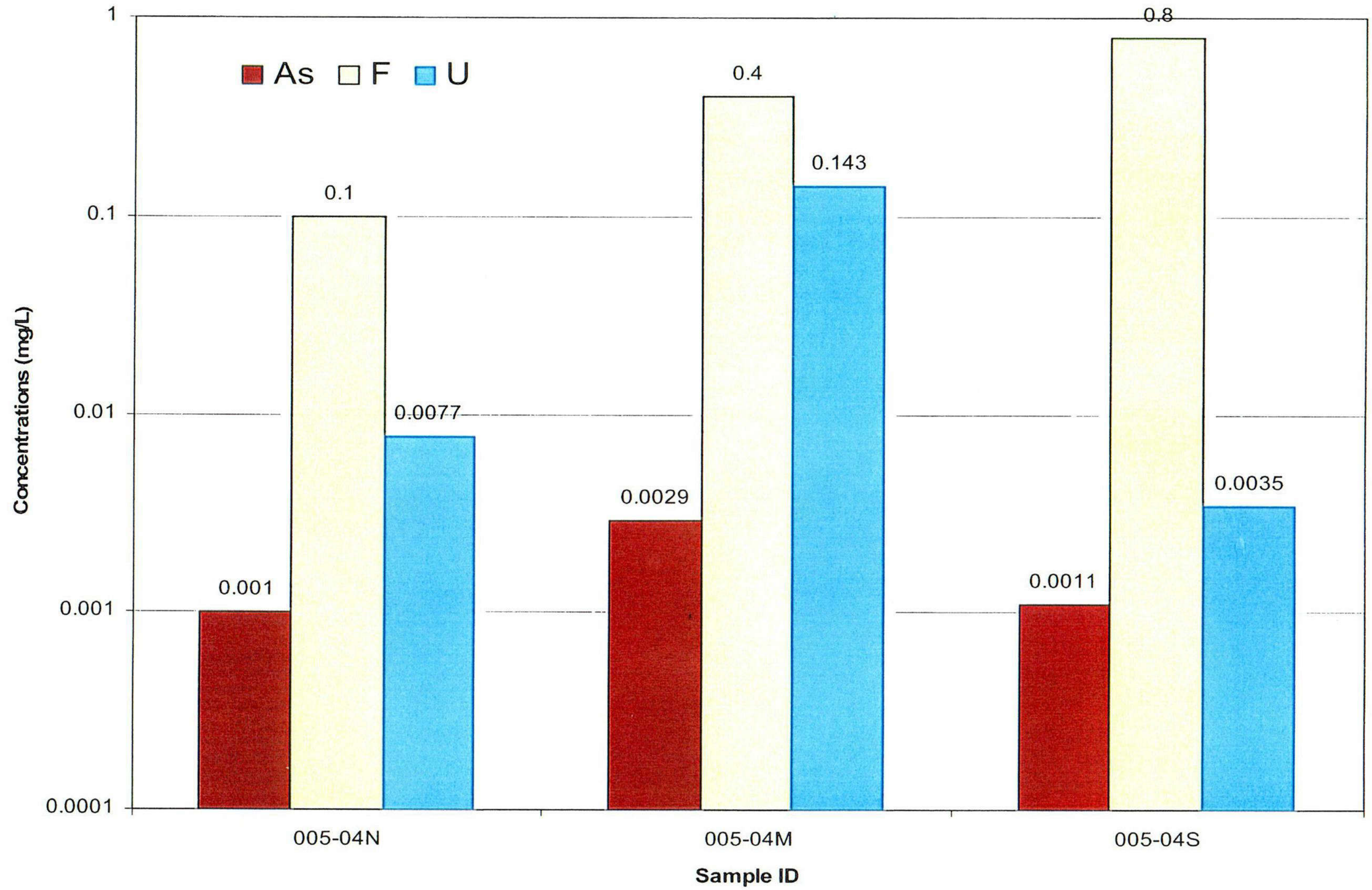

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FIGURE 11
AQUEOUS ANALYTICAL RESULTS FOR 005 DRAINAGE TRENCH 4

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

C08

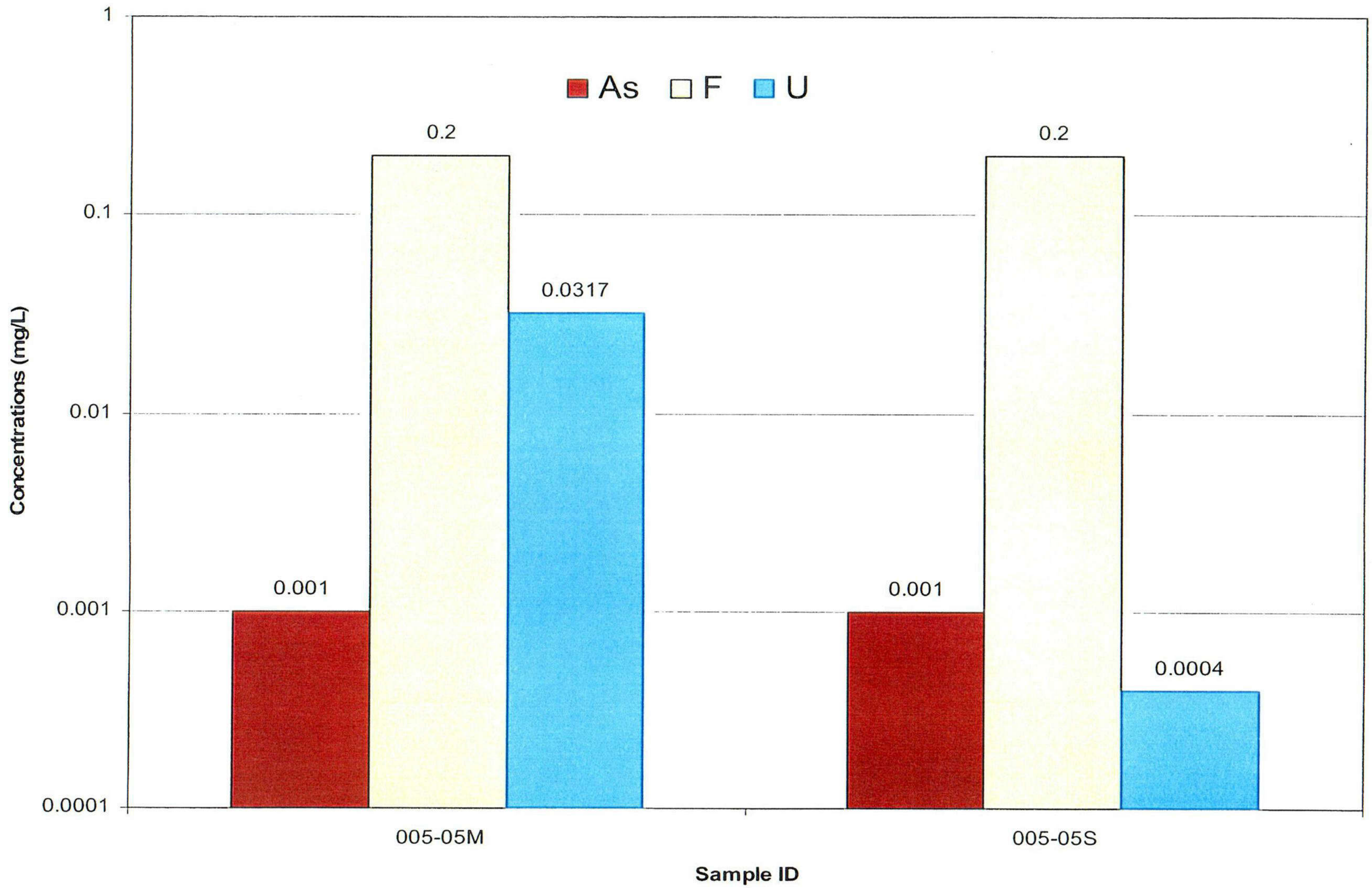

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FIGURE 12
AQUEOUS ANALYTICAL RESULTS FOR 005 DRAINAGE TRENCH 5

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

C09

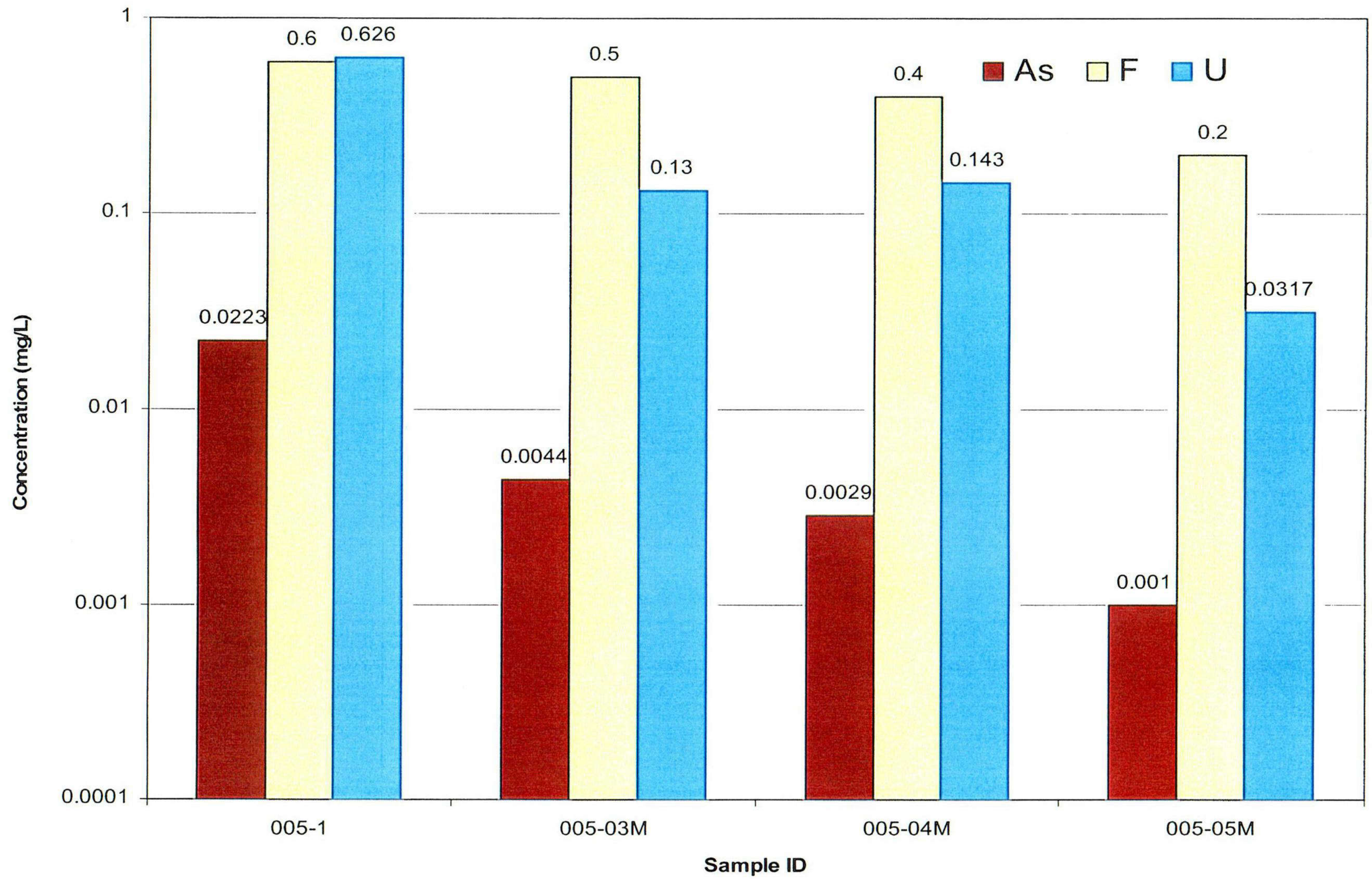

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FIGURE 13
AQUEOUS ANALYTICAL RESULTS FOR 005 DRAINAGE FOR DOWNSTREAM THROUGH MIDDLE TRENCH

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

C10

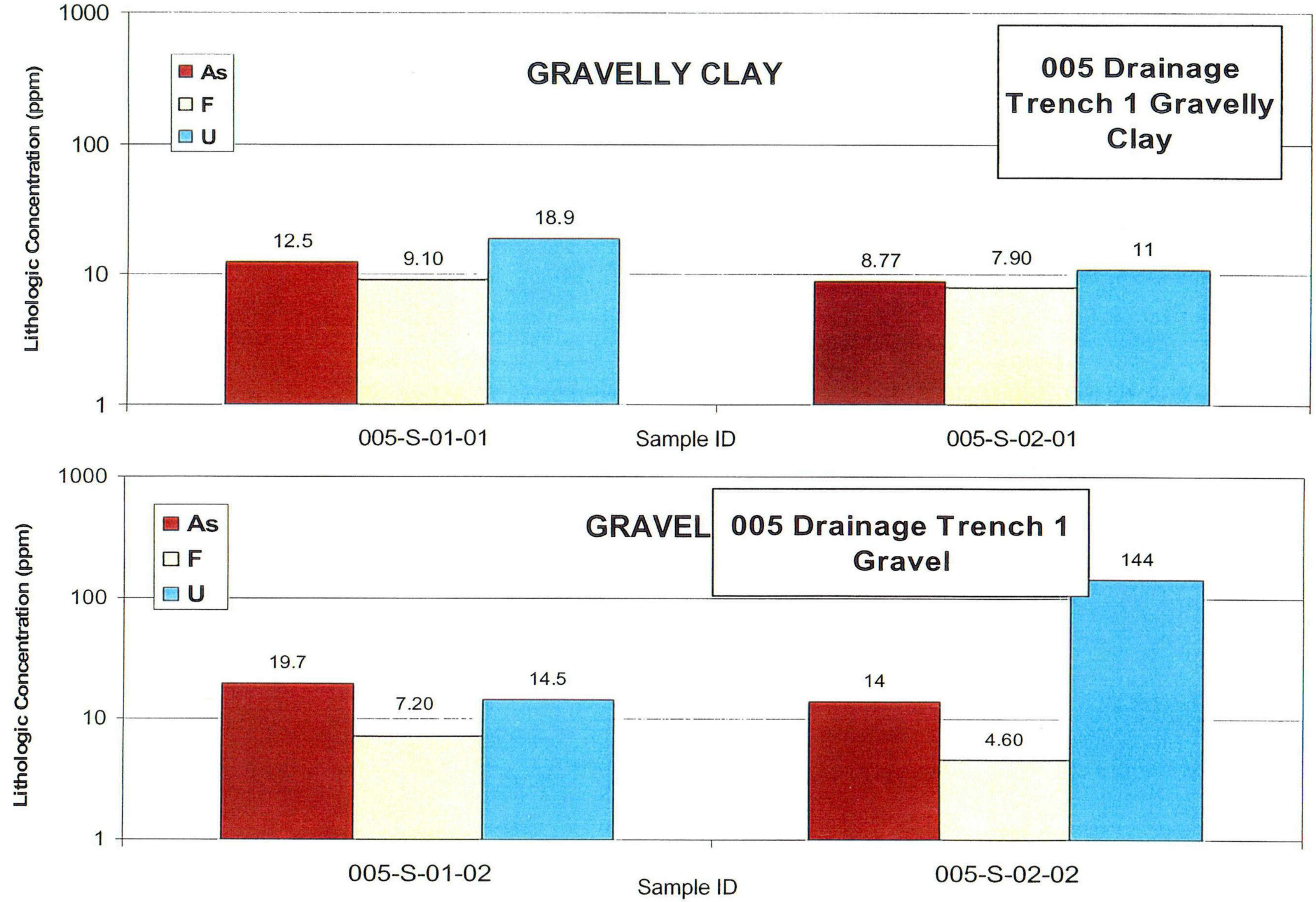

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FIGURE 14
SOLIDS ANALYTICAL RESULTS
DRAINAGE 005 TRENCH 1

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

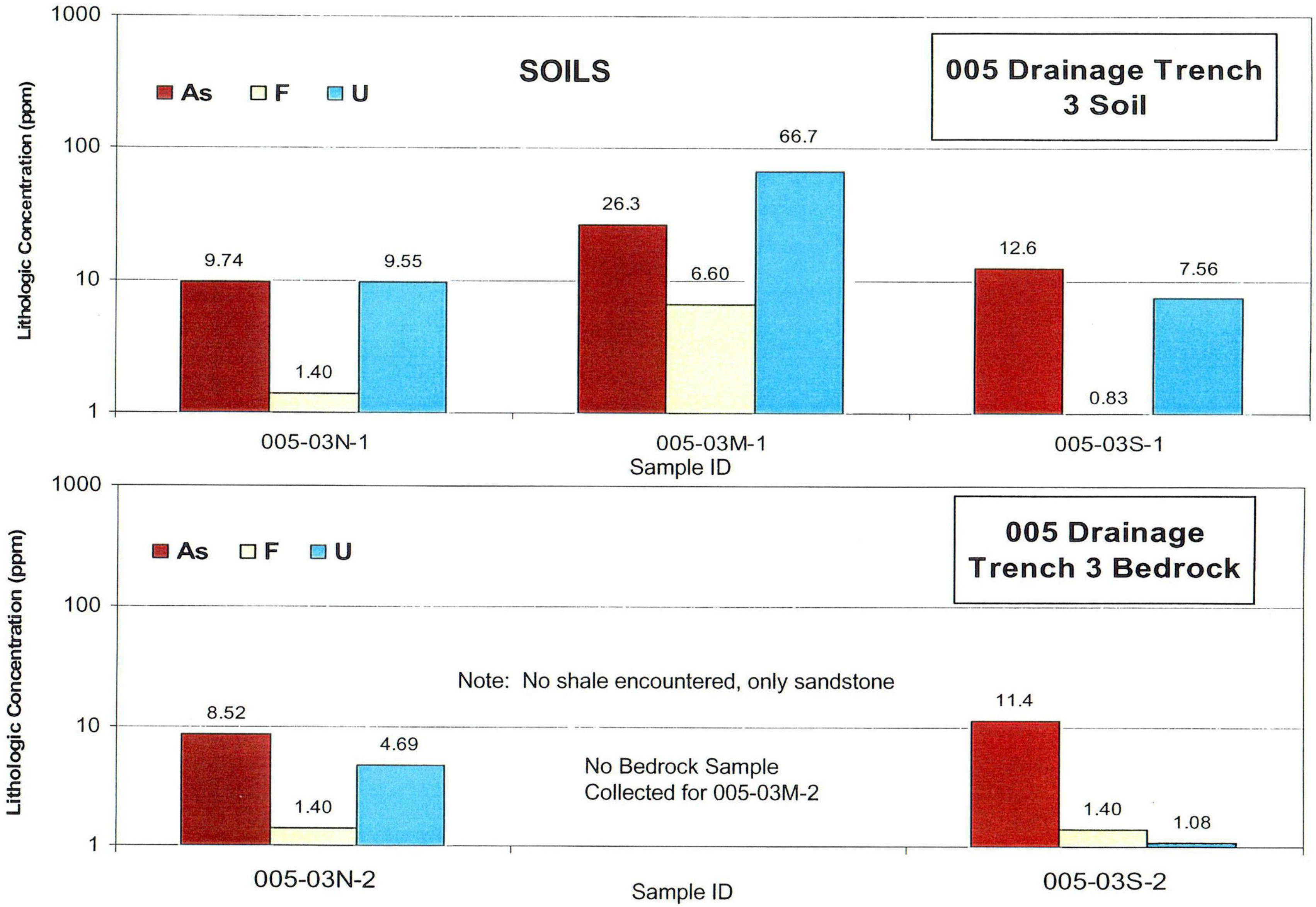

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FIGURE 15
SOLIDS ANALYTICAL RESULTS
DRAINAGE 005 TRENCH 3

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

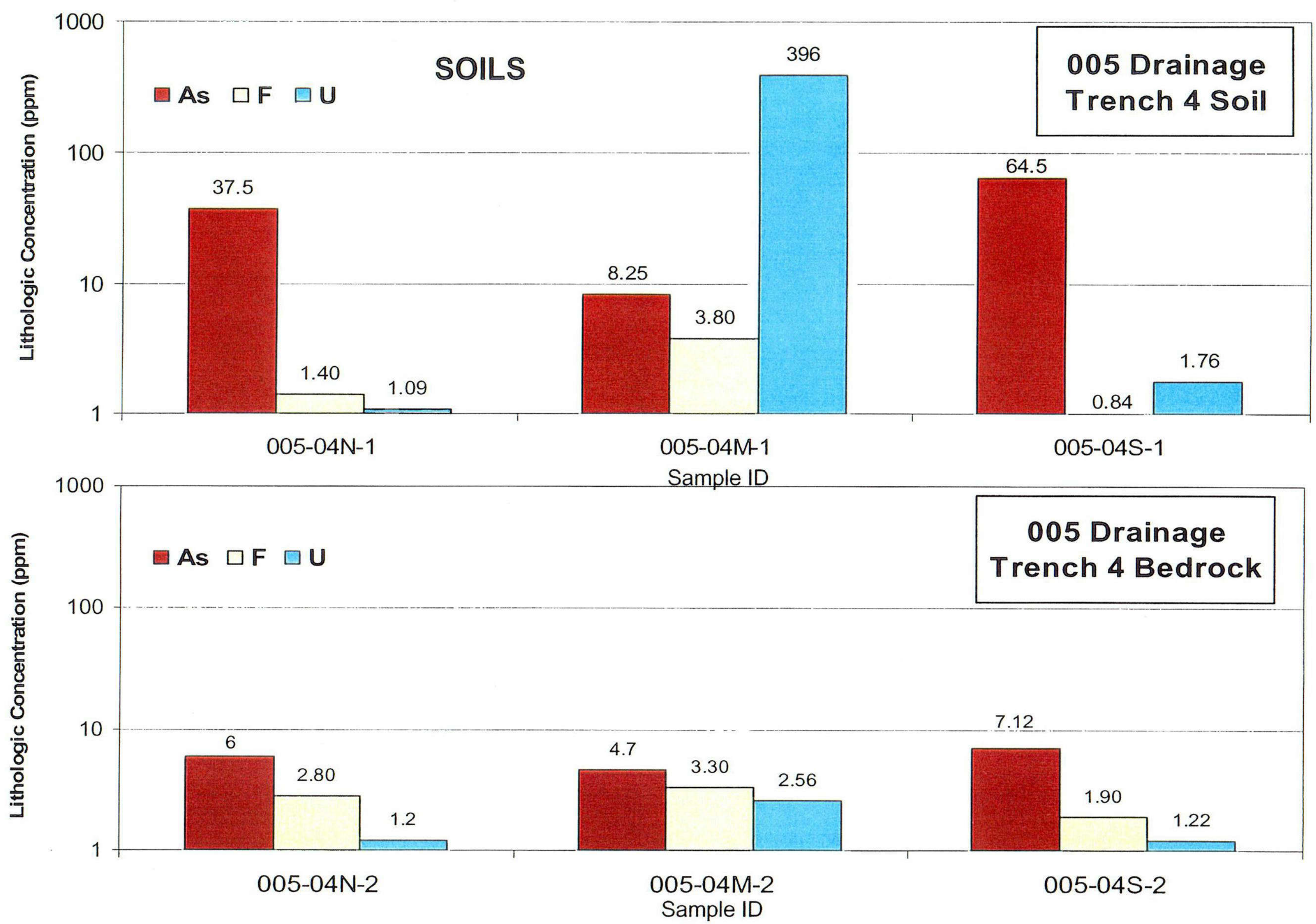

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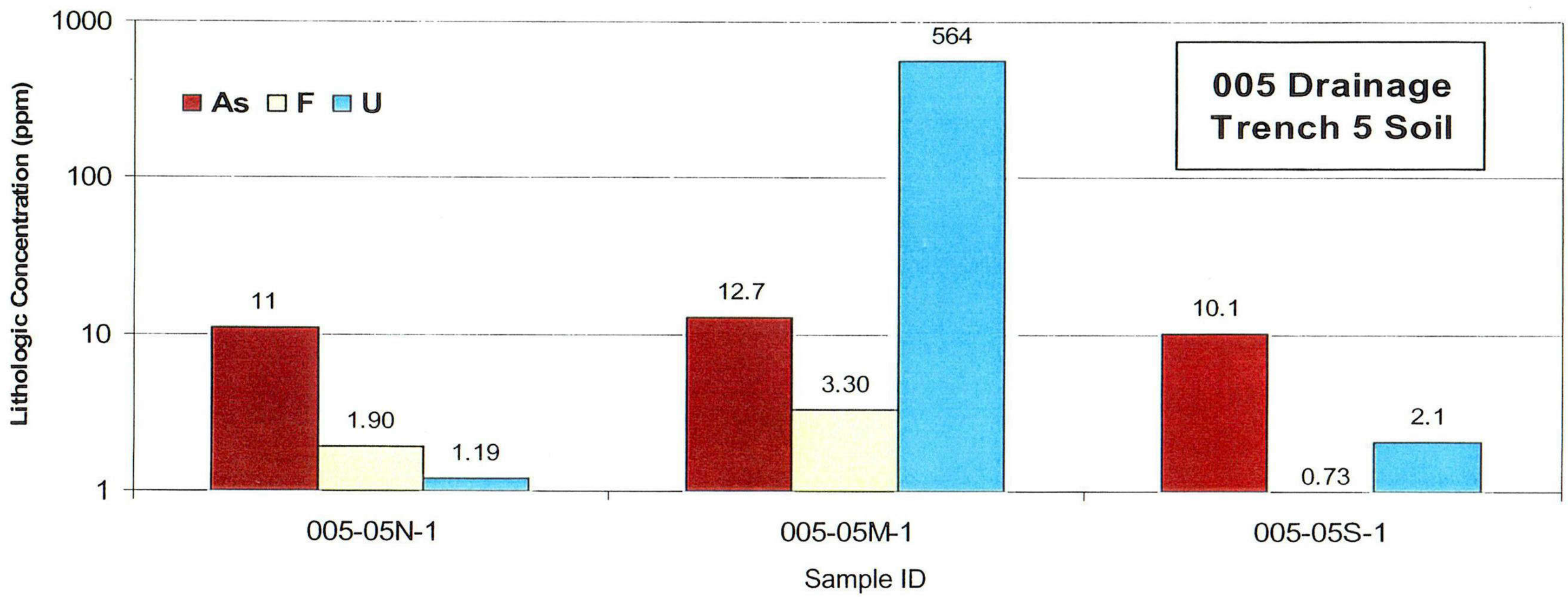
FIGURE 16
SOLIDS ANALYTICAL RESULTS
005 DRAINAGE TRENCH 4

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

C13



NO BEDROCK SAMPLE

NO BEDROCK SAMPLE

NO BEDROCK SAMPLE

Note: No bedrock sample, only sandstone present, no shale.

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FIGURE 17
SOLIDS ANALYTICAL RESULTS
005 DRAINAGE TRENCH 5

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

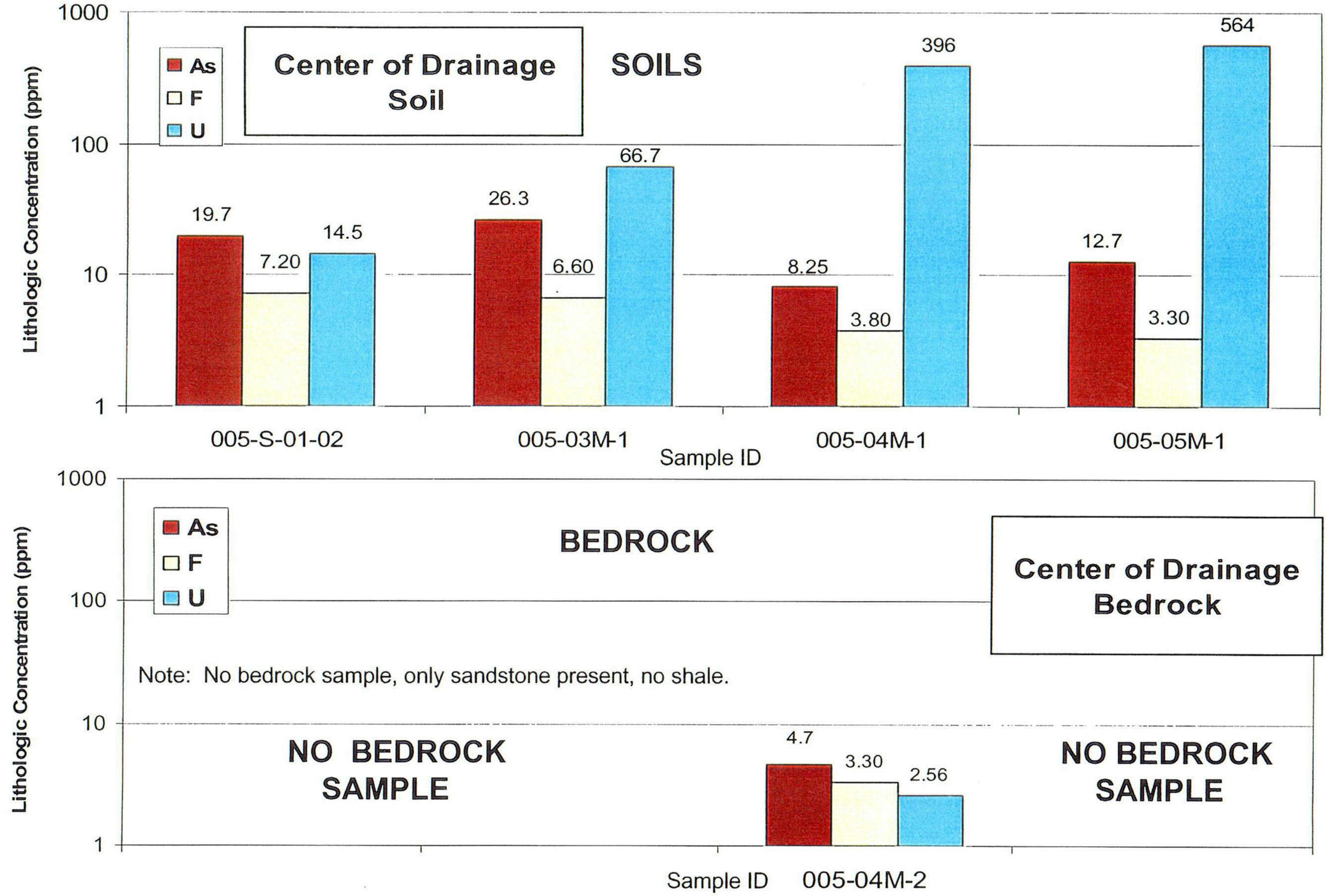

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FIGURE 18
SOLIDS ANALYTICAL RESULTS
DOWNSTREAM THROUGH MIDDLE TRENCH

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

C15

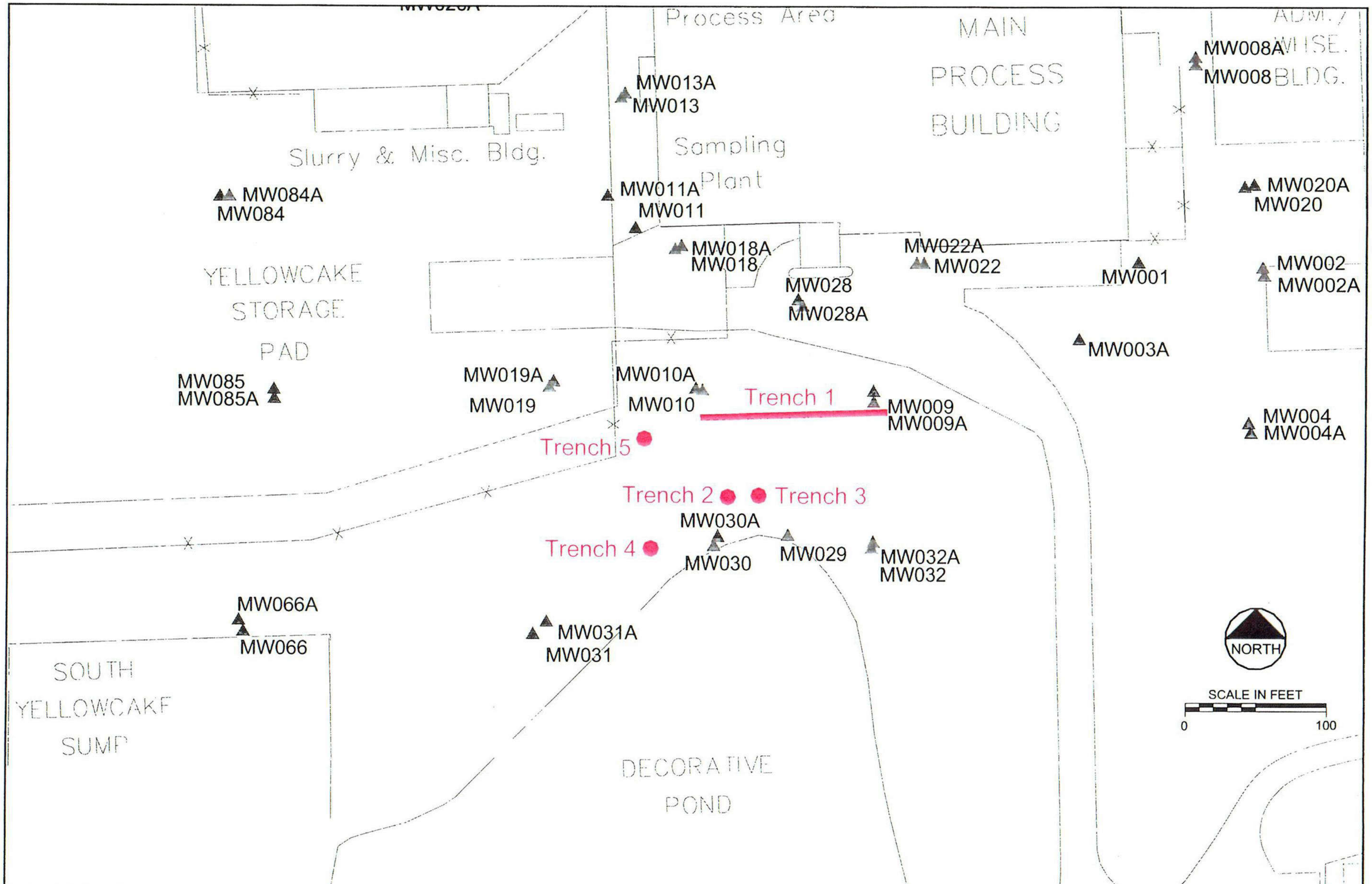

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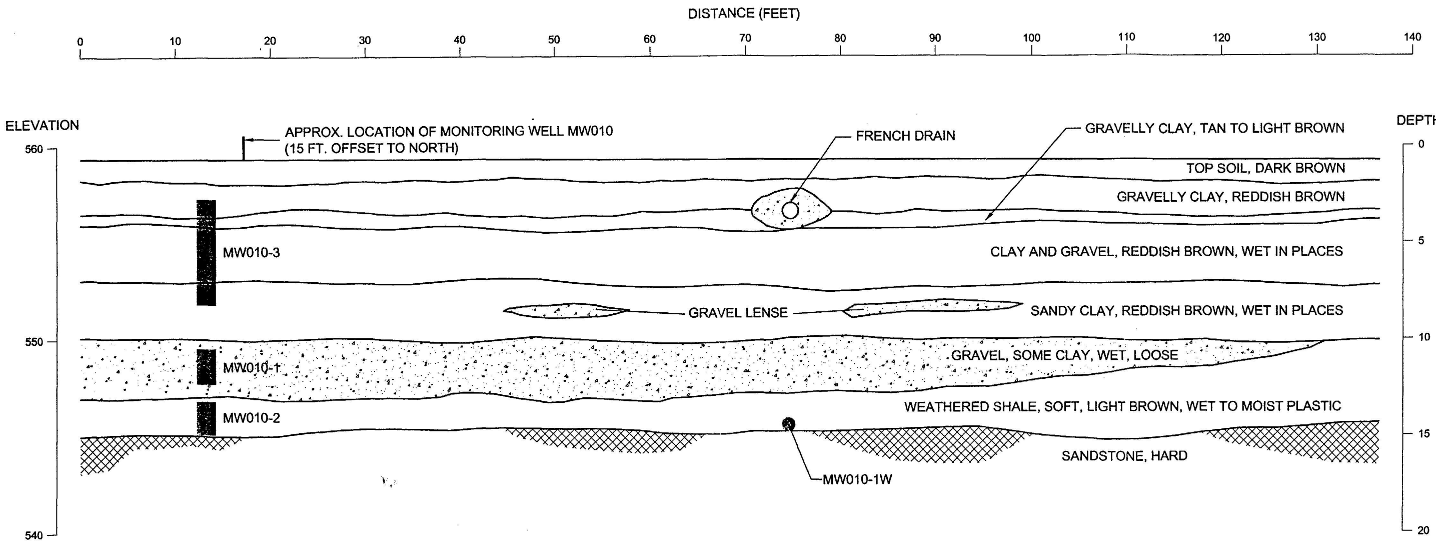
FIGURE 19
MW010 SWALE AREA TRENCH LOCATIONS

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

C16



LEGEND

- SOIL SAMPLE LOCATIONS AND ASSOCIATED SAMPLE NUMBER
- WATER SAMPLE LOCATIONS AND ASSOCIATED SAMPLE NUMBER

SEE TABLE 3 FOR SOIL AND WATER SAMPLE SUMMARY

FIGURE 20
CROSS SECTION VIEW OF MW010
AREA TRENCH 1

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Date:	APRIL 2002
Project:	100734
File:	PROFILES-01.DWG

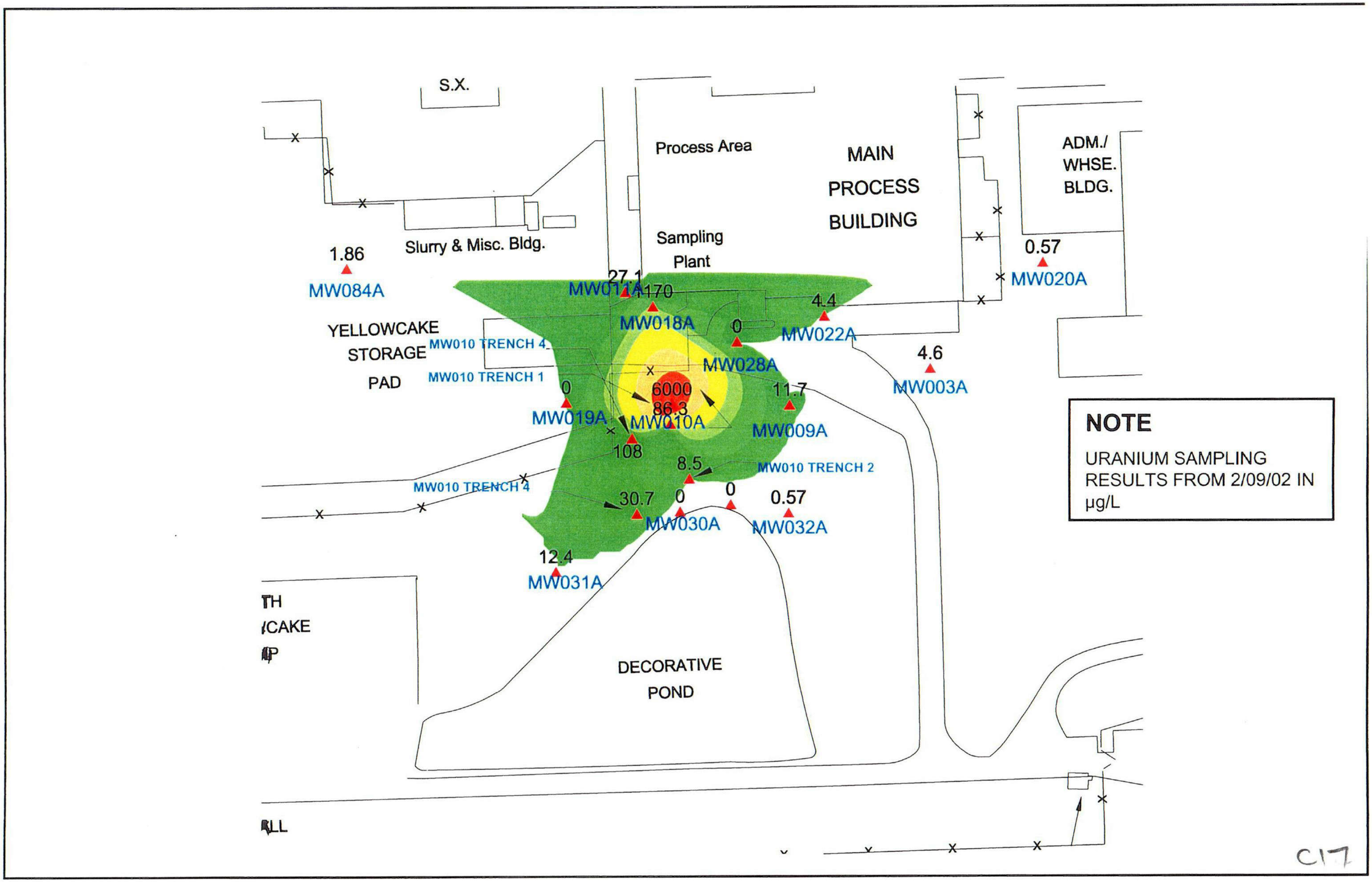

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FIGURE 21
MW010 SWALE URANIUM CONCENTRATIONS
IN GROUNDWATER OF UNCONSOLIDATED MATERIAL

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

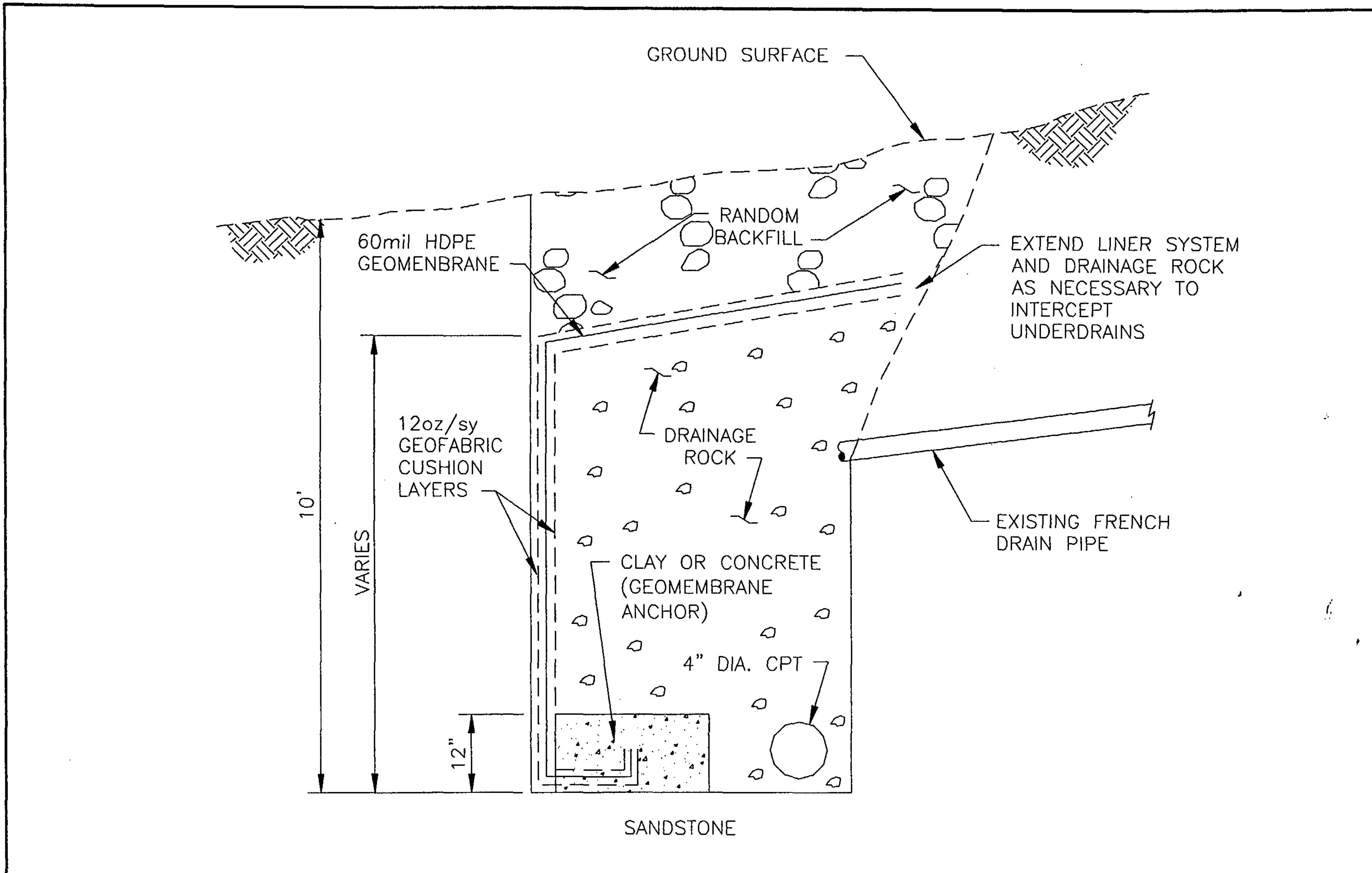

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FIGURE 22
HYDRAULIC CONTAINMENT / PUMP BACK SYSTEM DESIGN

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Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

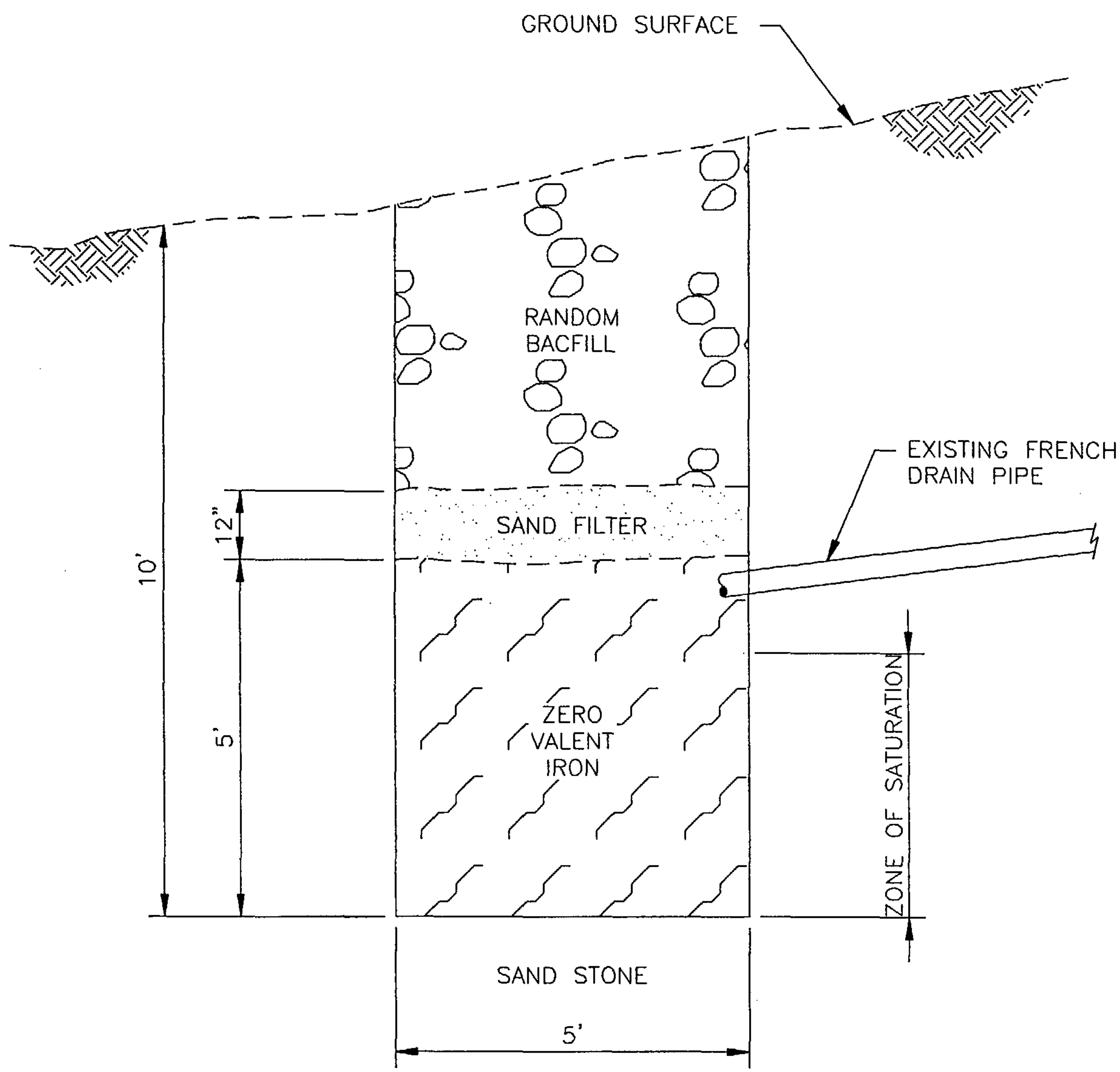

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FIGURE 23
PERMEABLE REACTIVE BARRIER WITH ZERO VALENT IRON DESIGN

Date:	MARCH 2002
Project:	P:100734\PRJMGT\
File:	TRIPFIGS.ppt

PHOTOS

Photo 1 **Excavation of 005 Drainage Trench 1 at Head of Drainage**

Photo 2 **Photograph of 005 Drainage Trench 1 Features, South End**

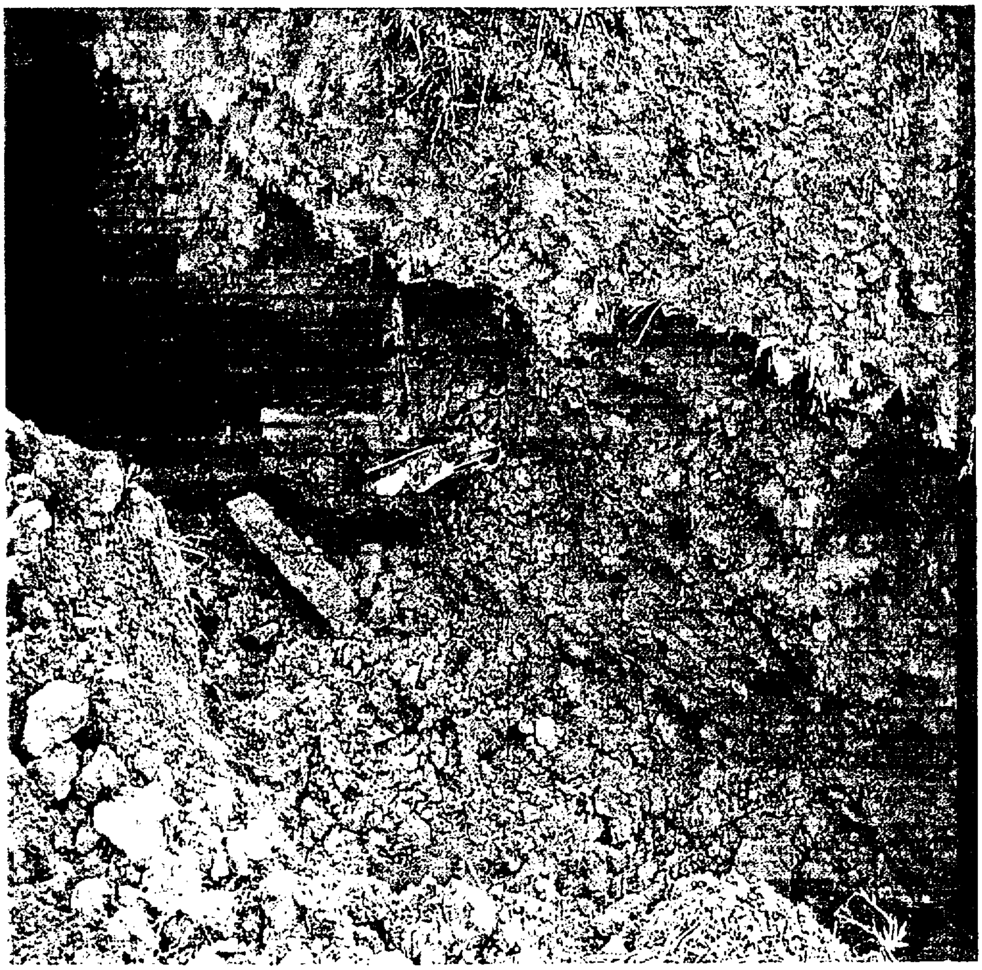

Photo 3 Photograph of MW010 Trench 1 Features, West End

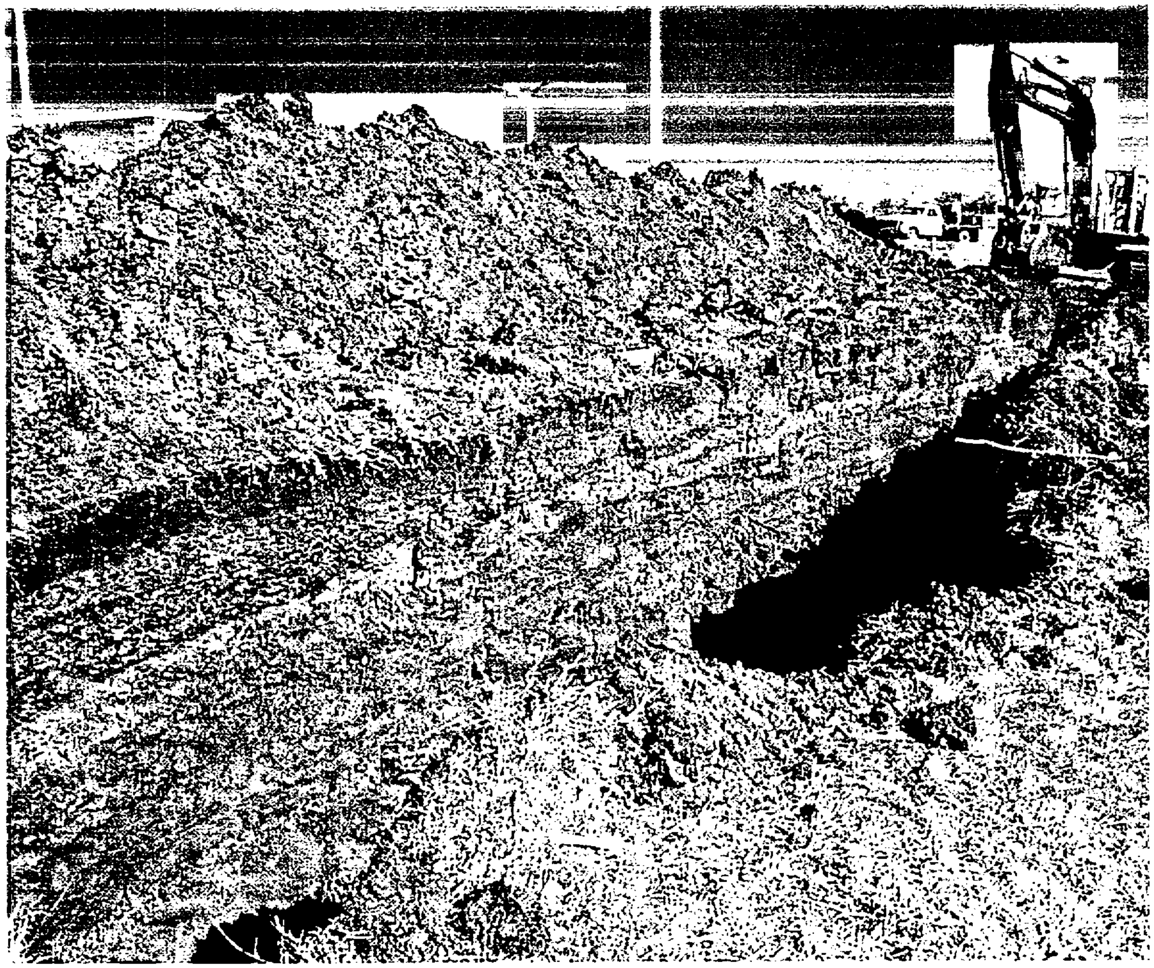

Photo 4 **Photograph of MW010 Trench 1 Features, South End Bottom**

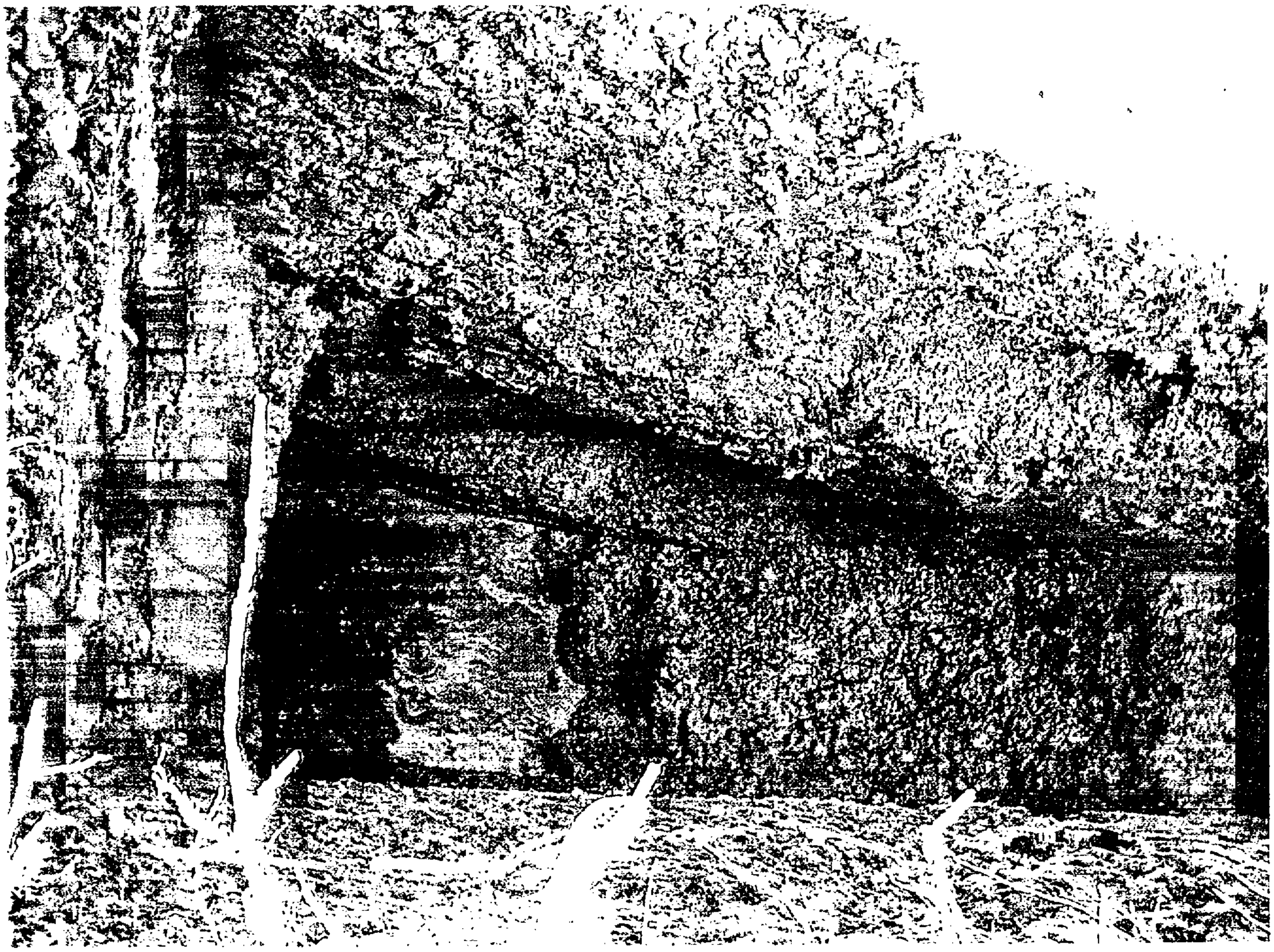

Photo 5 **Photograph of MW010 Trench 4 Features**