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RCRA Facility Assessment Sampling Visit Work Plan

for the

Naval Weapons Industrial Reserve Plant Calverton, New York



**Northern Division
Naval Facilities Engineering Command
Contract Number N62472-90-D-1298
Contract Task Order 0090**

January 1993



HALLIBURTON NUS
Environmental Corporation

**RCRA FACILITY ASSESSMENT
SAMPLING VISIT WORK PLAN
NAVAL WEAPONS INDUSTRIAL RESERVE PLAN
CALVERTON, NEW YORK**

**COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) PROGRAM**

**Submitted to:
Northern Division
Environmental Branch, Code 18
Naval Facilities Engineering Command
10 Industrial Highway, Mail Stop #82
Lester, Pennsylvania 19113-2090**

**Submitted by:
HALLIBURTON NUS Environmental Corporation
993 Old Eagle School Road, Suite 415
Wayne, Pennsylvania 19087-1710**

**Contract Number N62472-90-D-1298
Contract Task Order 0090**

January 1993

PREPARED BY:



**DAVID D. BRAYACK, P.E.
PROJECT MANAGER
HALLIBURTON NUS ENVIRONMENTAL CORP.
PITTSBURGH, PENNSYLVANIA**

APPROVED BY:



**DEBRA A. SCHEIB
QUALITY ASSURANCE MANAGER
HALLIBURTON NUS ENVIRONMENTAL CORP.
PITTSBURGH, PENNSYLVANIA**

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1.0 PROJECT DESCRIPTION

1.1 AUTHORIZATION

As requested by the U.S. Navy, HALLIBURTON NUS Environmental Corporation (HALLIBURTON NUS) has prepared this Resource Conservation and Recovery Act (RCRA) Facility Assessment Sampling Visit (RFA-SV) Work Plan for the Naval Weapons Industrial Reserve Plant (NWIRP), located in Calverton, New York. This RFA-SV Work Plan is being prepared under the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract No. N62472-90-D-1298, Contract Task Order (CTO) 0090. The Work Plan was prepared in accordance with the New York State RCRA Hazardous Waste Permit for the facility (NYSDEC 1-4730-00013/00001-0), dated March 25, 1992. The permit references the New York State Department of Environmental Conservation (NYSDEC) RCRA Quality Assurance Project Plan (QAPP) Guidance document (NYSDEC, 1991) for direction in preparing the work plan. As a result, this document has been prepared in accordance with the NYSDEC QAPP format.

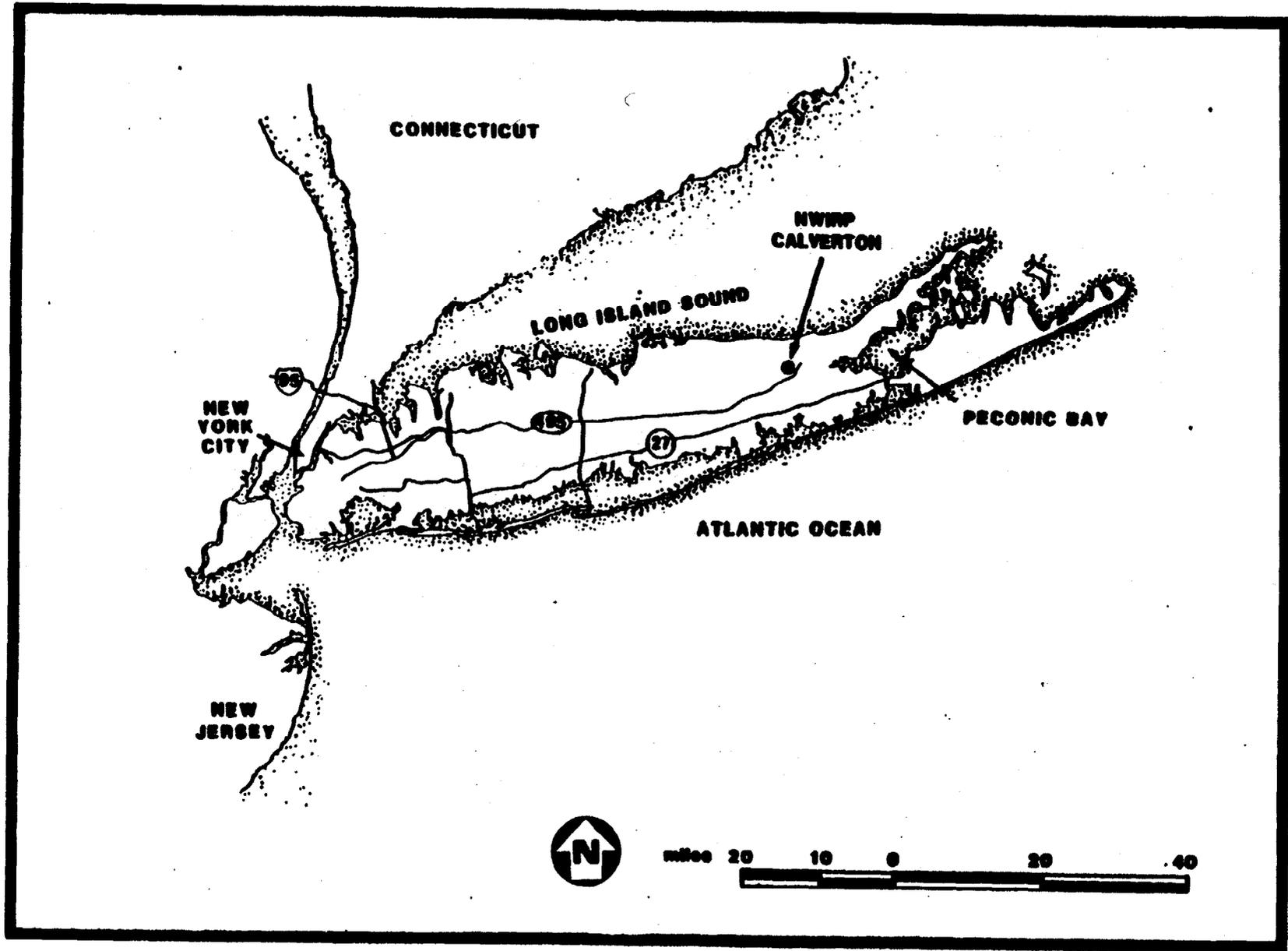
This work plan is also intended to comply with the requirements of the United States Environmental Protection Agency (EPA) facility permit (EPA ID Number NYD003995198), dated May 11, 1992. The EPA permit requests the performance of a First Phase RCRA Facility Investigation. The requirements of both permits appear to be the same, although terminology and format vary.

The Calverton NWIRP is located in Suffolk County on Long Island, New York, see Figures 1-1 and 1-2. The primary mission at the facility is to assemble and test aircraft. The NWIRP is a Government-Owned Contractor Operated (GOCO) facility operated by Grumman Corporation.

1.2 PURPOSE

The objective of this study is to obtain environmental information in order to:

- Eliminate from further investigation those sites that pose no definable threat to the environment or to human health under RCRA.
- Document the release or potential release of hazardous substances at each site and determine if additional action is required.

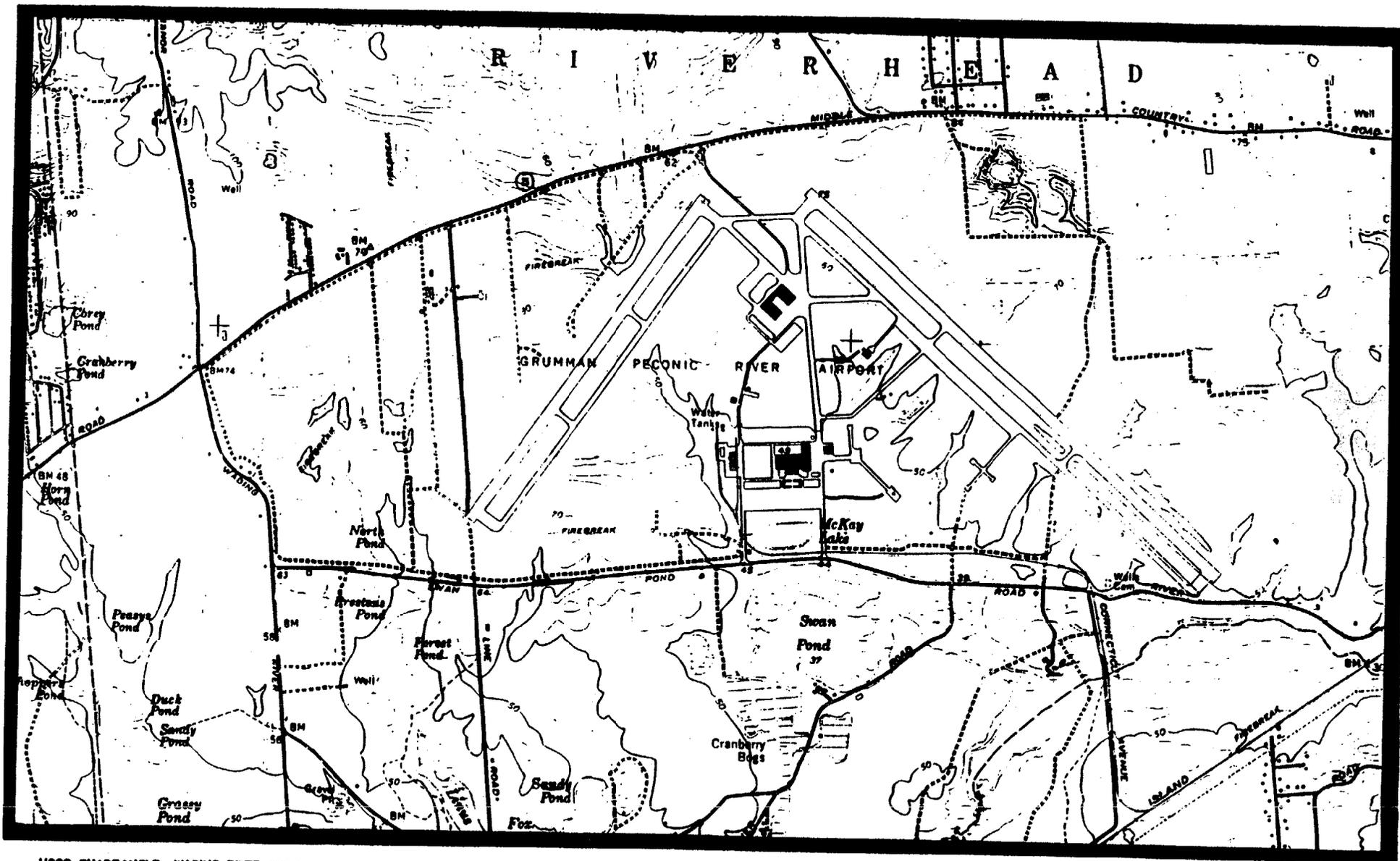


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FIGURE 1-1

GENERAL LOCATION MAP
RFA - SV WORK PLAN
NWRP, CALVERTON, NEW YORK





USGS QUADRANGLE: WADING RIVER 1967

FIGURE 1-2

SITE LOCATION
REA - SV WORK PLAN
NWRRP, CALVERTON, NEW YORK



HALLIBURTON NUS

1.3 SCOPE OF WORK

HALLIBURTON NUS has been tasked to perform a RFA-SV Work Plan for three sites at the NWIRP Calverton. In 1986, an Initial Assessment Study (IAS) identified potentially contaminated sites at NWIRP Calverton (RGH, 1986). Based on the IAS, a Site Investigation (SI) was conducted for the NWIRP Calverton between July 1991 through April 1992 (HALLIBURTON NUS, 1992). This SI evaluated environmental contamination at seven areas. Environmental contamination has been confirmed at four of these areas and is being addressed under a separate Full RFI and QAPP. These areas are the Site 1 - Northeast Pond Disposal Area (SWMU 1), Site 2 - Fire Training Area (SWMU 13), Site 6A - Fuel Calibration Area (AOC 1A), and Site 7 - Fuel Depot. Contaminants detected at one or more of these sites include solvents, fuels, heavy metals, and PCBs/pesticides.

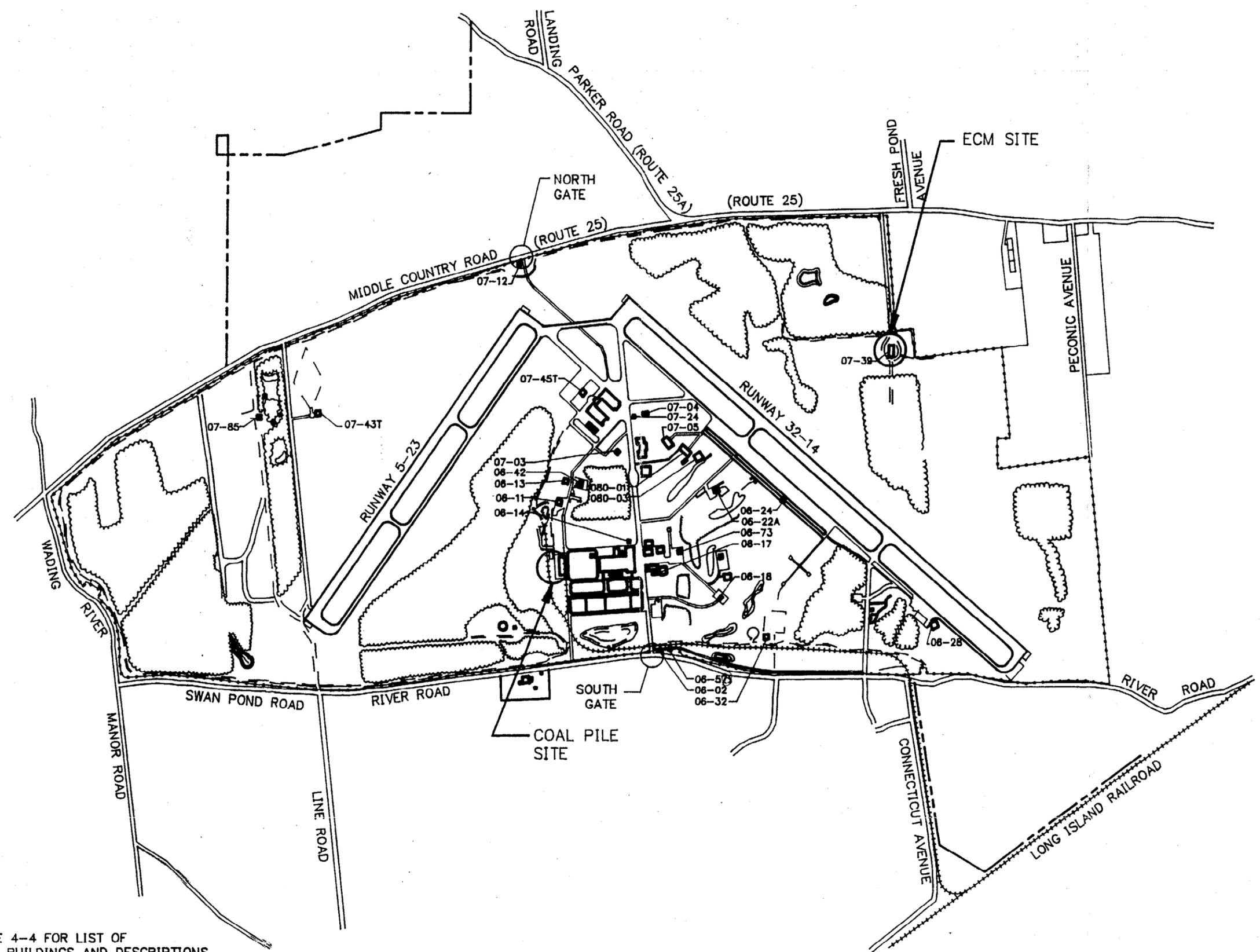
Since the scoping of the SI, additional areas have been identified as potentially contaminated and are being addressed under this work plan. The specific areas to be addressed under this work plan are as follows.

- Site 8 - Coal Storage Pile Area
- Site 9 - Electronic Counter Measures (ECM) Area
- Site 10 - Cesspool/Leach Field Areas (multiple locations)

The location of each of these areas is presented in Figure 1-3.

1.4 SAMPLE MATRICES, PARAMETERS, AND FREQUENCY COLLECTION

As part of the RFA-SV, environmental samples will be collected from the following matrices: soil, sediment, waste (coal and others if encountered), groundwater, and surface water. A listing of the sample matrices, parameters, and frequency of collection is found in Table 1-1. Sampling protocols to be used in this study are provided in Section 4.0 of this work plan. All samples (except for six background samples) submitted for offsite laboratory analysis will be analyzed for the Target Compound List (TCL) volatiles organics plus freon 113 (trichloro, trifluoroethane). Target Analyte List (TAL) metals and cyanide will be analyzed on select soil and water samples, and waste samples (if encountered and other than coal). Also, TCL PCBs/pesticides and TCL semivolatile organics will be analyzed on waste samples (if encountered and other than coal). Additional parameters are summarized in Table 3-1 of Section 3.0.



NOTES: SEE TABLE 4-4 FOR LIST OF NUMBERED BUILDINGS AND DESCRIPTIONS
 NUMBERED BUILDINGS INDICATE LOCATIONS OF CESSPOOLS/LEACHFIELDS TO BE INVESTIGATED
 --- = TREELINE

**LOCATION OF SITES
 RFA - SV WORK PLAN
 NWIRP, CALVERTON, NEW YORK**

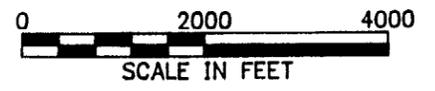


FIGURE 1-3

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TABLE 1-1

FIELD AND QA/QC SAMPLES RCRA FACILITY ASSESSMENT SAMPLING VISIT
NWIRP CALVERTON, NEW YORK

Number of Samples	Number of Duplicates	Number of Field Blanks ¹	Number of MS/MSD/LD ²	Number of Rinsate Blanks ³	Number of Trip Blanks ⁴	Total Number of Samples	Analysis	Analytical Method
MATRIX - GROUNDWATER/SURFACE WATER								
6*	1	-	1	1	1	10	TCL Volatiles, freon ⁶ , TAL metals and cyanide	CLP SOW
MATRIX - SOIL GAS⁵								
64	7	NA	-	1	NA	72	Volatile organics ⁵	SW846 8010/5030
MATRIX - SOLID WASTE								
9	1	-	-	1	1	12	TCL Volatiles plus freon ⁶	CLP SOW
6	1	1	2	1	-	11	TCL semi-volatiles, freon, TAL Metals, cyanide, and PCB/pesticides	CLP SOW
MATRIX - SEDIMENT								
6	1	-	1	1	1	10	TCL Volatiles plus freon ⁶	CLP SOW

TABLE 1-1 (continued)
FIELD AND QA/QC SAMPLES, RCRA FACILITIES ASSESSMENT SAMPLING VISIT
NWIRP CALVERTON, NEW YORK
PAGE 2

Number of Samples	Number of Duplicates	Number of Field Blanks ¹	Number of MS/MSD/LD ²	Number of Rinsate Blanks ³	Number of Trip Blanks ⁴	Total Number of Samples	Analysis	Analytical Method
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MATRIX - SOILS

22	3	-	2	2	3	32	TCL Volatiles plus freon ⁶	CLP SOW
6	1	-	1	1	0	9	TAL metals	CLP SOW
30	3	2	2	3	5	45	TCL Volatiles, freon ⁶ , TAL metals and cyanide	CLP SOW

- 1 - Field blank consist of one driller's decontamination water and one analyte-free water used for decontamination and rinsate per week of sampling activities. Frequency of analysis is one sample/water source/event.
- 2 - Single sample collected with additional volume for MS/MSD/LD analyses.
- 3 - Collected on a 1/day/media frequency. (Sample from every other day analyzed initially). # shown reflects # analyzed.
- 4 - TCL Volatiles only.
- 5 - The target analyte list for soil gas include: benzene, ethylbenzene, 1,1-dichloroethene, cis-1,2-dichloroethene, trichloroethene, 1,1,1-trichloroethane, chloroform, carbon tetrachloride, toluene, total xylenes, 1,1-dichloroethane, trans-1,2-dichloroethene, 1,1,2-TCA, methylene chloride, and freon⁶.
- 6 - The freon referenced herein applies to Freon-113 (trichlorotrifluoroethane).
- * - Surface water at the Coal Pile area and the three offsite groundwater samples near the ECM area (to be obtained contingent upon Suffolk County's approval) are to be sampled for TCL volatiles plus freon only.
- NA - Not applicable.

1.5 QUALITY ASSURANCE OVERVIEW

HALLIBURTON NUS has established quality assurance/quality control (QA/QC) measures and a program to ensure that these measures are applied to the collection and interpretation of environmental quality data at the NWIRP facility. The work plan is designed to assure that the precision, accuracy, representativeness, comparability, and completeness (the PARCC parameters) of the data are known, documented, and adequate to satisfy the data quality objectives of the study.

This plan presents the policies, organization, objectives, data-collection activities, and QA/QC activities that will be utilized to ensure that all data collected during, and reported by, this study are representative of existing conditions. Chemical testing will be conducted by a laboratory subcontractor. The laboratory will have prior Naval Energy and Environmental Support Activity (NEESA) approval. QA/QC procedures for the chemical analysis will conform to or exceed the requirements of the NYSDEC Analytical Services Protocols (ASP) and will satisfy NEESA requirements for Level D QC.

2.0 PROJECT ORGANIZATION AND RESPONSIBILITY

HALLIBURTON NUS will be responsible for the overall management of the project, including the field inspection and conduct of all drilling and sampling activities. Personnel from the Navy will be actively involved in the investigation and will coordinate with personnel from HALLIBURTON NUS in a number of areas.

2.1 PROJECT ORGANIZATION

The key firms and personnel involved in the RFA Sampling Visit, as well as the chain-of-communication and responsibility of the project personnel are as follows. The Navy Remedial Project Manager is responsible for the overall management of the IR Program for the NWIRP Calverton.

Northern Division
Naval Facilities Engineering Command
10 Industrial Highway, Mail Stop #82
Lester, Pennsylvania 19113
(215) 595-0567

Debra Felton, P.E (Code 1821)
Remedial Project Manager

The project is being conducted by HALLIBURTON NUS.

HALLIBURTON NUS Environmental Corporation
Foster Plaza 7
661 Andersen Drive
Pittsburgh, Pennsylvania
(412) 931-7090

David D. Brayack, P.E.
Project Manager

Elizabeth Rodman
Project Geologist

Debra Scheib
Quality Assurance/Quality Control Advisor

Matthew Soltis
Health and Safety Specialist

The Project Manager has the primary responsibility for project and technical management of this project. He is responsible for the coordination of all onsite personnel, and for providing technical assistance for all activities that are directly related to the determination of the of the environmental quality of the site. If quality assurance problems or deficiencies requiring specific action are identified, the project manager and project QA/QC advisor will identify the appropriate corrective action.

2.2 FIELD ORGANIZATION

The HALLIBURTON NUS field investigation team will be organized according to the activity planned. For onsite sampling, the sampling team members will be selected based upon the type and extent of effort required. The team will consist of a combination of the following personnel.

Field Operation Leader (FOL)
Field Geologist
Quality assurance/quality control advisor
Site health and safety specialist

The FOL will be responsible for the coordination of all onsite personnel and for providing technical assistance when required. The FOL, or his designee, will coordinate and be present during all sampling activities and will assure the availability and maintenance of all sampling materials and equipment. The FOL will be responsible for the completion of all sampling and chain-of-custody documentation, will assume custody of all samples, and ensure the proper handling and shipping of samples.

The Field Geologist will be responsible for providing technical supervision of the drilling subcontractor and for maintaining a geologic log of all borings drilled. Copies of the forms to be used in this investigation are provided as Appendix B.

The QA/QC advisor will be responsible for the adherence of all QA/QC guidelines as defined in this work plan. Strict adherence to these procedures is critical to the collection of acceptable and representative data.

The site health and safety specialist will be responsible for assuring that all team members adhere to the site health and safety requirements. Additional responsibilities of the site health and safety specialist are as follows:

- Updating equipment or procedures based upon new information gathered during the site operation.
- Modifying the levels of protection based upon site observations.
- Determining and posting locations and routes to medical facilities, including poison control centers, and arranging for emergency transportation to medical facilities.
- Notifying local public emergency officers, including police and fire departments, of the nature or the team's operations and for posting these department's telephone numbers.
- Examining work-party members for symptoms of exposure of stress.
- Providing emergency medical care and first aid as necessary on site. The site health and safety manager also has the responsibility to stop any field operation that threatens the health or safety of the team or the surrounding populace.

2.3 LABORATORY OPERATIONS

Analysis of all environmental samples will be performed by a NEESA-approved laboratory. The laboratory work will be performed in accordance with QC level D guidance as stipulated in the NEESA guidelines (20.2-0478; 6/88), which requires CLP methods and CLP-type deliverables. The QA/QC procedures should meet or exceed NYSDEC requirements.

3.0 QUALITY ASSURANCE OBJECTIVES FOR DATA MANAGEMENT

The overall QA objective is to develop and implement procedures for field sampling, chain-of-custody, laboratory analysis, and reporting that will provide environmental monitoring data of known and acceptable quality. Specific procedures to be used for sampling, chain-of-custody, calibration of field instruments, laboratory analysis, reporting, internal quality control, audits, preventative maintenance, and corrective actions are described in later sections of this work plan. The purpose of this section is to address the data quality objectives in terms of the (PARCC) parameters, quantitation and detection limits, field blanks, trip blanks, rinsate blanks, and bottleware cleanliness.

3.1 Data Quality Objectives

Data Quality Objectives (DQOs) are qualitative and/or quantitative statements regarding the quality of data needed to support the RFA-SV activities. The sampling rationale provided in Section 4.0 of this work plan explains the choice of sample locations and media which will supply information needed for the RFA-SV. The use of Contract Laboratory Program (CLP) analyses listed in Table 3-1 following current CLP SOW protocols is expected to satisfy data quality needs in accordance with NEESA, NYSDEC, and CLP requirements.

3.2 Quantitation Limits

Both aqueous and solid quantitation limits are those required as Contract Required Quantitation Limits (CRQLs - for organics) and Contract Required Detection Limits (CRDLs - for inorganics) for a current CLP SOW with allowances for dilutions and dry weight conversions. The CRQLs and CRDLs for the 1990 SOW are presented in Table 3-1. The laboratory also reports Method Detection Limits (MDLs) and Instrument Detection Limits (IDLs). These limits, by contract, must be equal to or less than the CRQLs and CRDLs, respectively. For the RFA-SV report, the MDLs and IDLs of the laboratory selected and instruments used will be presented. For soil gas measurements, the detection limit for each chemical is expected to be about 1 ug/l. The actual detection limit is based on vendor selected and instruments used. These detection limits will also be documented.

3.3 Detection Limits

Instrument detection limits (IDL) are reported quarterly under CLP protocol. The quarterly IDLs applicable at the date of analysis will be supplied in each data package. IDLs must be less than or equal to CRQLs.

TABLE 3-1

CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT REQUIREMENTS
 RCRA FACILITY ASSESSMENT - SITE VISIT WORK PLAN
 NWIRP
 CALVERTON, NEW YORK

A. Groundwater and Surface Water Samples					
Parameter	Container	Preservative	Holding Time	CRQL ($\mu\text{g/L}$)	Methodology
TCL Volatile Organic Compounds	G, Teflon-lined septum Three 40-ml vials	Cool, 4°C HCl to pH <2	14 days		CLP SOW¹
Chloromethane				10	
Bromomethane				10	
Vinyl Chloride				10	
Chloroethane				10	
Methylene Chloride				10	
Acetone				10	
Carbon Disulfide				10	
1,1-Dichloroethene				10	
1,1-Dichloroethane				10	
1,2-Dichloroethene (total)				10	
Chloroform				10	
1,2-Dichloroethane				10	
2-Butanone				10	
1,1,1-Trichloroethane				10	
Carbon Tetrachloride				10	
Vinyl Acetate				10	
Bromodichloromethane				10	

TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
RCRA FACILITY ASSESSMENT - SITE VISIT WORK PLAN
NWIRP
CALVERTON, NEW YORK
PAGE 2

A. Groundwater and Surface Water Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/L)	Methodology
TCL Volatile Organic Compounds (Continued)	G, Teflon-lined septum Three 40-ml vials	Cool, 4°C HCl to pH < 2	14 days		CLP SOW ¹
1,2-Dichloropropane				10	
cis-1,3-Dichloropropane				10	
Trichloroethene				10	
Dibromochloromethane				10	
1,1,2-Trichloroethane				10	
Benzene				10	
trans-1,3-Dichloropropane				10	
Bromoform				10	
4-Methyl-2-pentanone				10	
2-Hexanone				10	
Tetrachloroethene				10	
Toluene				10	
1,1,2,2-Tetrachloroethane				10	
Chlorobenzene				10	
Ethyl Benzene				10	
Styrene				10	
Xylenes (total)				10	
Trichlorodifluoroethane				10	
Trichlorotrifluoroethane				10	

**TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
RCRA FACILITY ASSESSMENT - SITE VISIT WORK PLAN
NWIRP
CALVERTON, NEW YORK
PAGE 3**

A. Groundwater and Surface Water Samples					
Parameter	Container	Preservative	Holding Time	CRDL (µg/L)	Methodology
<u>TAL Metals, Cyanide</u>	P; one 1-liter bottle total	HNO ₃ to pH <2 Cool, 4°C	180 days		CLP SOW ¹
Aluminum				200	
Antimony				60	
Arsenic				10	
Barium				200	
Beryllium				5	
Cadmium				5	
Calcium				5,000	
Chromium				10	
Cobalt				50	
Copper				25	
Iron				100	
Lead				3	
Magnesium				5,000	
Manganese				15	
Mercury			28 days	0.2	
Nickel				40	
Potassium				5,000	

**TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
RCRA FACILITY ASSESSMENT - SITE VISIT WORK PLAN
NWIRP
CALVERTON, NEW YORK
PAGE 4**

A. Groundwater and Surface Water Samples					
Parameter	Container	Preservative	Holding Time	CRDL ($\mu\text{g/L}$)	Methodology
TAL Metals, Cyanide (Continued)	P; one 1-liter bottle total	HNO₃ to pH <2 Cool, 4°C	180 days		CLP SOW¹
Selenium				5	
Silver				10	
Sodium				5,000	
Thallium				10	
Vanadium				50	
Zinc				20	
Cyanide	P; one 1-liter bottle	NaOH pH > 12 Cool 4°C	14 days	10	

**TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
RCRA FACILITY ASSESSMENT - SITE VISIT WORK PLAN
NWIRP
CALVERTON, NEW YORK
PAGE 5**

B. Soils, Solid Waste, and Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL ($\mu\text{g}/\text{kg}$)	Methodology
<u>TCL Volatile Organic Compounds</u>	G, Teflon-lined septum Three 60-ml vials	Cool, 4°C	7 days		CLP SOW¹
Chloromethane				10	
Bromomethane				10	
Vinyl Chloride				10	
Chloroethane				10	
Methylene Chloride				10	
Acetone				10	
Carbon Disulfide				10	
1,1-Dichloroethene				10	
1,1-Dichloroethane				10	
1,2-Dichloroethene (total)				10	
Chloroform				10	
1,2-Dichloroethane				10	
2-Butanone				10	
1,1,1-Trichloroethane				10	
Carbon Tetrachloride				10	
Vinyl Acetate				10	
Bromodichloromethane				10	

**TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
RCRA FACILITY ASSESSMENT - SITE VISIT WORK PLAN
NWIRP
CALVERTON, NEW YORK
PAGE 6**

B. Soils, Solid Waste, and Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL ($\mu\text{g}/\text{kg}$)	Methodology
TCL Volatile Organic Compounds (Continued)	G, Teflon-lined septum Three 60-mL vials	Cool, 4°C	7 days		CLP SOW¹
1,2-Dichloropropane				10	
cis-1,3-Dichloropropane				10	
Trichloroethene				10	
Dibromochloromethane				10	
1,1,2-Trichloroethane				10	
Benzene				10	
trans-1,3-Dichloropropane				10	
Bromoform				10	
4-Methyl-2-pentanone				10	
2-Hexanone				10	
Tetrachloroethene				10	
Toluene				10	
1,1,2,2-Tetrachloroethane				10	
Chlorobenzene				10	
Ethyl Benzene				10	
Styrene				10	
Xylenes (total)				10	
Trichlorodifluoroethane				10	
Trichlorotrifluoroethane				10	

**TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
RCRA FACILITY ASSESSMENT - SITE VISIT WORK PLAN
NWIRP
CALVERTON, NEW YORK
PAGE 7**

B. Soils, Solid Waste, and Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/kg)	Methodology
<u>TCL Semivolatile Compounds</u>	G, Teflon-lined cap 1, 8-oz. jar	Cool, 4°C	7 days from collection to extraction, 40 days after extraction		CLP SOW¹
Phenol				10	
bis(2-Chloroethyl)ether				10	
2-Chlorophenol				10	
1,3-Dichlorobenzene				10	
1,4-Dichlorobenzene				10	
Benzyl Alcohol				10	
1,2-Dichlorobenzene				10	
2-Methylphenol				10	
bis(2-Chloroisopropyl)ether				10	
4-Methylphenol				10	
n-Nitroso-di-n-dipropylamine				10	
Hexachloroethane				10	
Nitrobenzene				10	
Isophorone				10	
2-Nitrophenol				10	
2,4-Dimethylphenol				50	
Benzoic Acid				10	

TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
RCRA FACILITY ASSESSMENT - SITE VISIT WORK PLAN
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B. Soils, Solid Waste, and Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL ($\mu\text{g}/\text{kg}$)	Methodology
<u>TCL Semivolatile Compounds</u> <u>(Continued)</u>	G, Teflon-lined cap 1, 8-oz. jar	Cool, 4°C	7 days from collection to extraction, 40 days after extraction		CLP SOW ¹
bis(2-Chloroethoxy)methane				10	
2,4-Dichlorophenol				10	
1,2,4-Trichlorobenzene				10	
Naphthalene				10	
4-Chloroaniline				10	
Hexachlorobutadiene				10	
4-Chloro-3-methylphenol (para-chloro-meta-cresol)				10	
2-Methylnaphthalene				10	
Hexachlorocyclopentadiene				10	
2,4,6-Trichlorophenol				10	
2,4,5-Trichlorophenol				50	
2-Chloronaphthalene				10	
2-Nitroaniline				50	
Dimethylphthalate				10	
Acenaphthylene				10	

**TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
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B. Soils, Solid Waste, and Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/kg)	Methodology
<u>TCL Semivolatile Compounds</u> (Continued)	G, Teflon-lined cap 1, 8-oz. jar	Cool, 4°C	7 days from collection to extraction, 40 days after extraction		CLP SOW¹
2,6-Dinitrotoluene				10	
3-Nitroaniline				50	
Acenaphthene				10	
2,4-Dinitrophenol				50	
4-Nitrophenol				50	
Dibenzofuran				10	
Diethylphthalate				10	
4-Chlorophenyl-phenyl ether				10	
Fluorene				10	
4-Nitroaniline				50	
4,6-Dinitro-2-methylphenol				50	
n-Nitrosodiphenylamine				10	
4-Bromophenyl-phenyl ether				10	
Hexachlorobenzene				10	
Pentachlorophenol				50	
Phenanthrene				10	

TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
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B. Soils, Solid Waste, and Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/kg)	Methodology
<u>TCL Semivolatile Compounds</u> (Continued)	G, Teflon-lined cap 1, 8-oz. jar	Cool, 4°C	7 days from collection to extraction, 40 days after extraction		CLP SOW ¹
Anthracene				10	
Di-n-butylphthalate				10	
Fluoranthene				10	
Pyrene				10	
Butylbenzylphthalate				10	
3,3'-Dichlorobenzidine				20	
Benzo(a)anthracene				10	
Chrysene				10	
bis(2-Ethylhexyl)phthalate				10	
Di-n-octylphthalate				10	
Benzo(b)fluoranthene				10	
Benzo(k)fluoranthene				10	
Benzo(a)pyrene				10	
Indeno(1,2,3-cd)pyrene				10	
Dibenz(a,h)anthracene				10	
Benzo(g,h,i)perylene				10	

**TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
RCRA FACILITY ASSESSMENT - SITE VISIT WORK PLAN
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B. Soils, Solid Waste, and Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRQL (µg/kg)	Methodology
<u>TCL Pesticides/PCBs</u>	G, Teflon-lined cap 1, 8-oz. jar	Cool, 4°C	7 days from collection to extraction, 40 days after extraction		CLP SOW¹
alpha-BBC				0.05	
beta-BHC				0.05	
delta-BHC				0.05	
gamma-Bhc (lindane)				0.05	
Heptachlor				0.05	
Aldrin				0.05	
Heptachlor Epoxide				0.05	
Endosulfan I				0.05	
Dieldrin				0.10	
4,4'-DDE				0.10	
Endrin				0.10	
Endosulfan II				0.10	
4,4'-DDD				0.10	
Endosulfan Sulfate				0.10	
4,4'-DDT				0.10	
Methoxychlor				0.5	
Endrin Ketone				0.10	

**TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
RCRA FACILITY ASSESSMENT - SITE VISIT WORK PLAN
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B. Soils, Solid Waste, and Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRDL ($\mu\text{g}/\text{kg}$)	Methodology
<u>TCL Pesticides/PCBs</u> <u>(Continued)</u>	G, Teflon-lined cap 1, 8 oz. jar	Cool, 4°C	7 days from collection to extraction, 40 days after extraction		CLP SOW ¹
alpha-Chlordane				0.5	
gamma-Chlordane				0.5	
Toxaphene				1.0	
Aroclor-1016				0.5	
Aroclor-1221				0.5	
Aroclor-1232				0.5	
Aroclor-1242				0.5	
Aroclor-1248				0.5	
Aroclor-1254				1.0	
Aroclor-1260				1.0	

**TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
RCRA FACILITY ASSESSMENT - SITE VISIT WORK PLAN
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B. Soils, Solid Waste, and Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRDL (mg/kg)	Methodology
TAL Metals and Cyanide	G; one 8-oz glass jar	Cool, 4°C	180 days		CLP SOW¹
Aluminum				40	
Antimony				12	
Arsenic				2	
Barium				40	
Beryllium				1	
Cadmium				1	
Calcium				1,000	
Chromium				2	
Cobalt				10	
Copper				5	
Iron				20	
Lead				0.6	
Magnesium				1,000	
Manganese				3	
Mercury			28 days	0.2	
Nickel				8	
Potassium				1,000	

**TABLE 3-1
CONTAINER, AMOUNT, PRESERVATION, HOLDING TIME, AND CONTRACT-REQUIRED QUANTITATION LIMIT
REQUIREMENTS
RCRA FACILITY ASSESSMENT - SITE VISIT WORK PLAN
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B. Soils, Solid Waste, and Sediment Samples					
Parameter	Container	Preservative	Holding Time	CRDL (mg/kg)	Methodology
TAL Metals and Cyanide (Continued)	G; one 8-oz glass jar	Cool, 4°C	180 days		CLP SOW¹
Selenium				1	
Silver				2	
Sodium				1,000	
Thallium				2	
Vanadium				10	
Zinc				4	
Cyanide			14 days	10	

- 1) Contract Laboratory Program Statement Of Work - CRQL's and CRDL'S presented are for 1990 SOW. CRQLs and CRDLs will vary with dilution factor and sample % solids.
- NA - Not applicable.
- CRDL - Contract Required Detection Limits
- CRQL - Contract Required Quantitation Limits
- P - Polyethylene
- G - Glass

3.4 PARCC Parameters

The quality of the data set is measured by certain characteristics of the data, namely the PARCC (precision, accuracy, representativeness, comparability, and completeness) parameters. Some of the parameters are expressed quantitatively, while others are expressed qualitatively. The objectives of the RFA-SV and the intended use of the data define the PARCC goals.

3.4.1 Precision

Precision characterizes the amount of variability and bias inherent in a data set. Precision describes the reproducibility of measurements of the same parameter for a sample under the same or similar conditions. Precision is expressed as a range (the difference between two measurements of the same parameter) or as a relative percent difference (the range relative to the mean, expressed as a percent). Range and Relative Percent Difference (RPD) values are calculated as follows:

$$\text{Range} = \text{OR} - \text{DR}$$

$$\text{RPD} = (\text{OR} - \text{DR}) / [(1/2)(\text{OR} + \text{DR})] \times 100\%$$

where: OR = original sample result

DR = duplicate sample result

The internal laboratory control limits for precision are three times the standard deviation of a series of RPD or range values. RPD values may be calculated for both laboratory and field duplicates, and can be compared to the control limits as a QA check. Laboratory duplicates will be analyzed at the rate required by the CLP. Field duplicates will be collected for 10 percent of all samples collected.

3.4.2 Accuracy

Accuracy is the comparison between experimental and known or calculated values expressed as a percent recovery (%R). Percent recoveries are derived from analysis of standards spiked into deionized water (standard recovery) or into actual samples (matrix spike or surrogate spike recovery). Recovery is calculated as follows:

$$\%R = E/T \times 100\%$$

where: E = experimental result

T = true value (theoretical result)

and

$$T = [(sample\ aliq.)(sample\ conc.) + (spike\ aliq.)(spike\ conc.)]/(sample\ aliq. + spike\ aliq)$$

Control limits for accuracy are set at the mean plus or minus three times the standard deviation of a series of %R values. Organic %R values are set at the mean plus or minus two times the standard deviation. Accuracy for aqueous and solid samples will be evaluated by use of surrogate and matrix spikes at the CLP-required incidences. CLP acceptance criteria and corrective actions apply. Out-of-criteria results will be reviewed for data applicability as a part of data validation.

3.4.3 Representativeness

All data obtained should be representative of actual conditions at the sampling location. The work plan is designed so that the samples taken will present an accurate representation of actual site conditions. The rationales discussed in the work plan are designed to ensure this. All sampling activities will conform to the protocols given in Section 4.0 of this work plan. The use of CLP analytical protocols and data deliverables will ensure that analytical results and deliverables are representative, and both consistently performed and reported.

3.4.4 Comparability

Comparability will be achieved by utilizing standardized sampling and analysis methods and data reporting format. Both analytical procedures and sample collection techniques will maximize the comparability of this new data to previous data. Additionally, consideration will be given to seasonal conditions and other environmental conditions that could influence analytical results.

3.4.5 Completeness

Completeness is a measure of the amount of valid data obtained from the measurement program, compared to the total amount collected. For relatively clean, homogeneous matrices, 100-percent completeness is expected.

However, as matrix complexity and heterogeneous increase, completeness may decrease. Where analysis is precluded or where DQOs are compromised, effects on the overall investigation must be considered. Whether any particular sample is critical to the investigation will be evaluated in terms of the sample location, the parameter in question, the intended data use, and the risk associated with the error.

Critical data points may not be evaluated until all the analytical results are evaluated. If in the evaluation of results it becomes apparent that the data for a specific medium are of insufficient quality (95 percent), either with respect to the number of samples or an individual analysis, resampling of the deficient data points may be necessary.

3.5 Field Blanks

To determine whether cross-contamination of samples has occurred, field blanks will be obtained. Field blanks will be taken at the rate of one per source per sampling event, and will be analyzed for TCL Volatiles, freon 113, TAL metals, semivolatile organics, PCBs/pesticides and/or cyanide in accordance with NEESA guidelines and depending on the sampling activities. In general, field blanks will be taken of water used for equipment decontamination purposes, once per week.

3.6 Trip Blanks

To determine whether contamination of samples or bottleware has occurred in the field, trip blanks will be used. Trip blanks consist of analyte-free water taken from the laboratory to the site, and returned. Trip blanks are taken at the rate of one per cooler of volatile organic samples and will be analyzed for TCL VOAs only.

3.7 Rinsate Blanks

An equipment rinsate blank consists of the final analyte-free water rinse from equipment cleaning. Rinsate blanks are collected daily during the sampling event and media, and the samples from every other day are analyzed for inorganic and/or organic contaminants. If potential contamination is observed, the remaining rinsate blanks are also analyzed.

3.8 Bottleware

NEESA requires specific bottleware cleaning procedures. Precleaned bottles will be used at the NWIRP Calverton. The required certification will be provided.

4.0 FIELD SAMPLING PLAN

4.1 GENERAL SITE BACKGROUND

HALLIBURTON NUS has been tasked to perform a RFA-SV Work Plan at the NWIRP Calverton for three sites. In 1986, an Initial Assessment Study (IAS) identified potentially contaminated sites at NWIRP Calverton (RGH, 1986). Based on the IAS, a Site Investigation (SI) was conducted for the NWIRP Calverton between July 1991 and April 1992 (HALLIBURTON NUS, 1992). This SI evaluated environmental contamination at seven areas. Environmental contamination has been confirmed at four of these areas and are being addressed under a separate Full RFI and QAPP. These areas are the Site 1 - Northeast Pond Disposal Area, Site 2 - Fire Training Area, Site 6A - Fuel Calibration Area, and Site 7 - Fuel Depot. Contaminants detected at one or more of these sites include solvents, fuels, heavy metals, and PCBs/pesticides.

Since the scoping of the SI, additional areas have been identified as potentially contaminated and are being addressed under the work plan. The specific areas to be addressed under this work plan are as follows.

Site 8 - Coal Storage Pile Area

Site 9 - ECM Area

Site 10 - Cesspool/Leach Field Areas

The location of each of these areas is present in Figure 1-3.

4.2 SAMPLING OBJECTIVES

The objective of this study is to obtain environmental information in order to:

- Eliminate from further investigation those sites that pose no definable threat to the environment or to human health under RCRA.
- Document the release or potential release of hazardous substances at each site and determine if additional action is required.

4.3 FIELD OPERATIONS

The three sites to be addressed under this work plan are Site 8 - Coal Pile Storage Area, Site 9 - ECM Area, and Site 10 - Cesspool/Leach Field Areas. The site background, sampling rationale, and sampling activities are discussed as follows.

4.3.1 Site 8 - Coal Pile Storage Area

4.3.1.1 Site Background

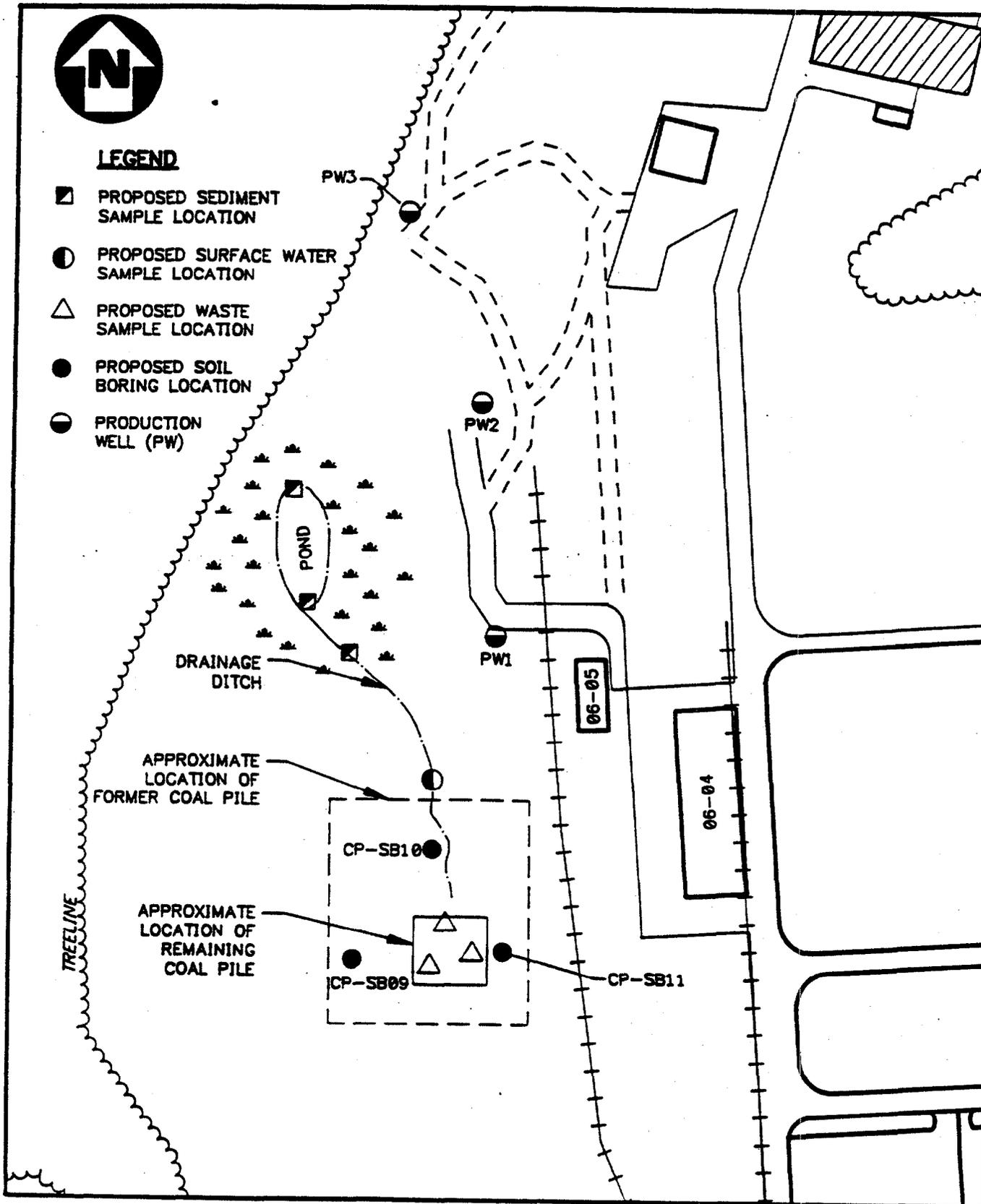
The coal pile storage area was used for the storage of coal and was present as a backup fuel source for the boiler house (see Figure 4-1). Reportedly, the coal was never used in the boiler house, and currently, the boiler house is no longer able to burn coal. As a result, the coal is being used at the facility as a road base material, particularly on the perimeter roads. Based on the residual mounded coal pile and residual surface coal, the majority of coal has been removed from this area.

4.3.1.2 Sampling Rationale

The former coal pile area is being investigated because of reports of solvents being placed on the piles for eventual destruction during the burning of the coal. Solvents may have entered the soils and groundwater in the area. During an initial reconnaissance of the area in October 1992, it was observed that precipitation runoff from the coal pile enters a small marshy area north of the coal pile (see Figure 4-1). This marsh is near drinking water wells for the facility. Two of these wells (Production Wells 2 and 3) have been identified to be contaminated with low levels of solvents. The solvents and concentrations detected at levels near and above drinking water standards in these Production Wells are summarized as follows.

1,1,1-trichloroethane	5 ug/l
freon 113	14 ug/l
vinyl chloride	2 ug/l

Activities in this area should concentrate on investigating potential solvent (volatile organic) contamination in the remaining coal pile, in the soils and groundwater underneath the coal pile, and in the sediments and surface water in marsh. Other organics (except for those naturally found in coal) and inorganic contaminants are not be expected to be a concern for this area.



APPROXIMATE SCALE 1" = 250'

FIGURE 4-1

SITE LAYOUT MAP
SITE 8 - COAL PILE STORAGE AREA
REA - SV WORK PLAN
NWIRP, CALVERTON, NEW YORK



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4.3.1.3 Sampling Activities

The field investigation will consist of the following tasks:

- Subsurface soil borings and subsurface soil sampling
- Waste Sampling
- Surface water sampling
- Sediment sampling

Soil, sediment, waste, and surface water samples will be collected in accordance with NEESA methodology for TCL Volatiles Organics and freon. Waste samples (other than coal), if encountered, will be analyzed for TCL volatile organics, semivolatile organics, PCB/pesticides, TAL metals, and cyanide. A list of analytes, analytical methods, contract required quantitation limits, containers, preservatives, and holding times is provided on Table 3-1. Field samples and analytical testing are summarized in Table 4-1.

Subsurface Soil Borings and Subsurface Soil Sampling

Three subsurface soil borings (6 subsurface soil samples) will be drilled at the coal pile site (see Table 4-1 and Figure 4-1). Borings CP-SB09, CP-SB10, and CP-SB11 will be drilled on the west, north, and east side of the remaining coal pile, respectively. The subsurface soils at the coal pile will be analyzed for TCL Volatiles plus freon. The borings will be drilled in the area surrounding the existing coal pile and within the area of the larger, former coal pile. These three borings will investigate the potential downward migration of contamination from the existing and/or former coal pile into the underlying soils.

Test borings will be drilled and subsurface soil samples will be collected at selected sites to determine the presence or absence of subsurface soil contamination. Borings will be advanced to the water table (estimated depth of 5 to 20 feet bgs). Drilling operations for soil borings will be conducted using the hollow-stem auger method. During drilling operations of overburden material, Standard Penetration Tests and split-spoon sampling will be performed continuously in all soil borings. All split-spoon samples will be screened with an Organic Vapor Analyzer (OVA) and visually inspected for lithologic description. Soil borings will be backfilled to the surface upon completion with cement/bentonite grout. Based on the OVA measurements of the soil, cuttings will be containerized in 55-gallon drums if readings above background levels are present or spread on the ground near the boring if no OVA readings above background levels are observed.

TABLE 4-1

**SITE 8 - COAL PILE STORAGE AREA - FIELD ACTIVITIES
RCRA FACILITIES ASSESSMENT SITE VISIT
NWIRP, CALVERTON, NY**

SITE	DESCRIPTION OF ACTIVITIES	ANALYSIS
Site 8 - Coal Pile Storage Area	3 subsurface soil borings - 2 subsurface soil samples/boring	TCL Volatile Organics and freon
	1 surface water sample (rain event)	TCL Volatile Organics and freon
	3 sediment locations - 2 sediment samples/location	TCL Volatile Organics and freon
	3 waste samples taken in remaining coal pile	TCL Volatile Organics and freon
	0 to 2 waste samples taken in soil borings, if waste sludges are encountered	TCL Volatile Organics, Semi- volatile Organics, PCB/pesticides, TAL Metals, freon, and cyanide

Two samples per boring will be submitted for chemical analysis as outlined in Tables 4-1 and 1-1. Sampled intervals for chemical analysis shall include one between the surface and the water table, and one across the water table. The upper sample will be selected based on elevated OVA readings and/or visual evidence of contamination (i.e. staining or discoloration of soil). The sample above the soil/water interface with the highest OVA reading (primary determination) or appearing discolored (secondary determination) will be retained for testing. To obtain this sample, the initial split spoon sample in each boring will be collected as a sample for chemical analysis (i.e. placed into the required sample containers, labeled, and temporarily stored in a cooler). If the next split spoon sample in the boring has higher OVA readings than the first, or greater visual evidence of contamination, the first sample will be discarded and the second split spoon sample will be collected for chemical analysis. The third, fourth, and subsequent split spoon samples in the boring will be compared to the previous samples in the boring in the same way to the total depth of the boring. In each boring, the sample at the soil/water interface will be submitted for chemical analysis.

In addition to soil samples, sludge samples (if encountered) may be collected as described under the Waste Sampling section below.

Samples for analysis will be collected by splitting the soil sample open longitudinally and extracting soil from the entire length of the interior of the sample. Portions of the sample submitted for TCL Volatiles plus freon analysis will be placed directly in to the required containers. Remaining portions of the sample will be homogenized and distributed to the appropriate containers. A stainless steel will be used to place the sample into the required containers. Any remaining sample material will be placed and retained in an 8-ounce jar as a lithologic sample, as will those split-spoon samples not submitted for chemical analysis. Drilling and sampling will be performed in accordance with HALLIBURTON NUS SOPs GH-1.3 and GH-1.5 (Appendix A). Decontamination of drilling and sampling equipment will be performed as described in Section 4.7.

A complete log of each boring will be maintained by the field geologist. Appendix B contains an example of the boring log form. At a minimum, the boring log will contain the following information, when applicable, for each overburden boring:

- Sample numbers and types

- Sample depths

- Standard Penetration Test data

- Sample recovery/sample interval

- Soil density or cohesiveness

- Soil color

- Unified Soil Classification System (USCS) material description and symbol

In addition, depths of changes in lithology, sample moisture observations, depth to water, OVA readings, drilling method, and total depth of each borehole should be included on each boring log, as well as any other pertinent observations. Sample bottles containing soil samples collected solely for lithologic description will be numbered consecutively starting with S-1. In addition, the following information shall be recorded on the lid of the sample jars:

Job number and name
Boring and sample number
Date
Depth interval
Blow counts

As an alternative to obtaining samples with hollow stem augers, during the subcontractor procurement process, alternative sample collection techniques will be considered. One potential alternative is the "direct push" method of obtaining samples. Under this method, the samples are collected by hydraulically driving a 1-inch diameter piston-type sampler to the top of the desired sample interval; the piston within the sampler is released and the pipe advanced through the target interval. The soil core then enters the sampler, which contains a non-reactive plastic or stainless steel liner. After the drive rod is removed from the soil, the liner containing the soil column can be removed.

Waste Sampling

Three samples of waste material will be collected from the coal pile (see Table 4-1 and Figure 4-1). These samples of potential source material will be collected from approximately 10 to 20 inches below the outside surface of the coal pile and be analyzed for TCL volatile organics. The samples will be collected using stainless steel trowels to transfer material directly to the required sample jars. Samples will be collected in accordance with HALLIBURTON NUS SOP GH-1.3 (Appendix A). Decontamination of sampling equipment will be conducted as described in Section 4.7.

If sludges are encountered during the soil borings activities, up to two samples of the sludge will be collected for full TCL/TAL parameters plus freon. These samples will be collected as described for subsurface soil sampling. The identification of sludges will be determined in the field by the field geologist. Properties distinguishing sludges from natural soils include differences in particle size, moisture content, cohesion, color, and oil content from the natural soils. Materials which can be confidently identified in the field as construction debris such as asphalt, concrete, and wood will not be sampled.

Surface Water Sampling

A surface water sample will be collected in accordance with HALLIBURTON NUS SOP SA-1.2 (Appendix A) from the north trending ditch that drains the coal pile into a marsh/pond located approximately 500 feet to the northwest of the coal pile (see Table 4-1 and Figure 4-1). The surface water sample will be analyzed for TCL Volatiles plus freon. The sample will be collected during a rain event to determine if water flowing over and through the coal pile is carrying contamination away from the site. The sample will be collected either by directly dipping the sample bottles into the water, or using a stainless steel beaker to transfer sample water to the required containers. Decontamination of sampling equipment, if used, will be conducted as described in Section 4.7.

In addition, field measurements will be obtained on the surface water sample prior to sample collection. These field measurements include:

- pH
- Specific Conductance
- Temperature

Relative color and turbidity will also be noted on the sample log form. A blank sample log form is provided in Appendix B. Procedures for obtaining these field measurements are described in HALLIBURTON NUS SOP SF-1.1 (Appendix A).

Sediment Sampling

Six sediment samples will be collected from three locations (2 samples per location) in the pond/marshy area located approximately 500 feet northwest of the coal pile (see Table 4-1 and Figure 4-1). All samples will be collected in accordance with HALLIBURTON NUS SOP SA-1.2 (Appendix A) and analyzed for TCL Volatiles plus freon. These samples will be used to confirm the presence or absence of solvents from the coal pile in the pond sediments. Stainless steel bucket-type hand augers and trowels will be used to collect two samples at each location. Sampled material will be transferred directly from the bucket auger to the required containers. The upper sample at each location will be collected from 4 to 8 inches below the surface. The lower sample will be collected from 18 to 24 inches below the surface. Decontamination of sampling equipment will be conducted as described in Section 4.7.

4.3.2 Site 9 - ECM Area

4.3.2.1 Site Background

The ECM area was constructed in the early 1970s. There are no manufacturing activities occurring at the site, although 1,1,1-trichloroethane is used for cleaning purposes, (approximately 10 gallons per year).

In June 1992, Suffolk County Department of Health Services notified Grumman Corporation that up to 190 ug/l of TCA were detected in offsite wells adjacent to this area. These wells were installed in support of a municipal sludge/sod growing experiment by the county. Based on groundwater flow patterns estimated by the county, the ECM is a potential source area of TCA lying hydraulically upgradient of these wells, (see Figure 4-2 for the approximate location of these wells).

4.3.2.2 Sampling Rationale

The ECM area is being investigated because volatile organics were detected in an area immediately adjacent to the east (and potentially hydraulically downgradient) of the ECM area (see Figure 4-2). Based on the reconnaissance of the area in October 1992, there is visual evidence that construction debris was disposed near the area in the past. Historic photographs of the facility indicate disturbances of the soils in the area during the 1960s and 1970s. Also, solvents (volatile organics) have been used at the site in the past. The disposal of other materials in this area cannot be ruled out. Field activities in this area will focus on the disposal area, the former solvent storage area, and the cesspool for solvent contamination of the soils. There is no evidence that suggests other organics or inorganic contaminants would be present at the site.

4.3.2.3 Sampling Activities

The field investigation will consist of the following tasks:

- Subsurface soil borings and subsurface soil sampling
- Groundwater sampling
- Waste sampling

Soil and groundwater samples will be collected in accordance with NEESA methodology for TCL Volatiles Organics and freon. Waste samples, if encountered, will be analyzed for TCL volatile organics, semivolatile organics,

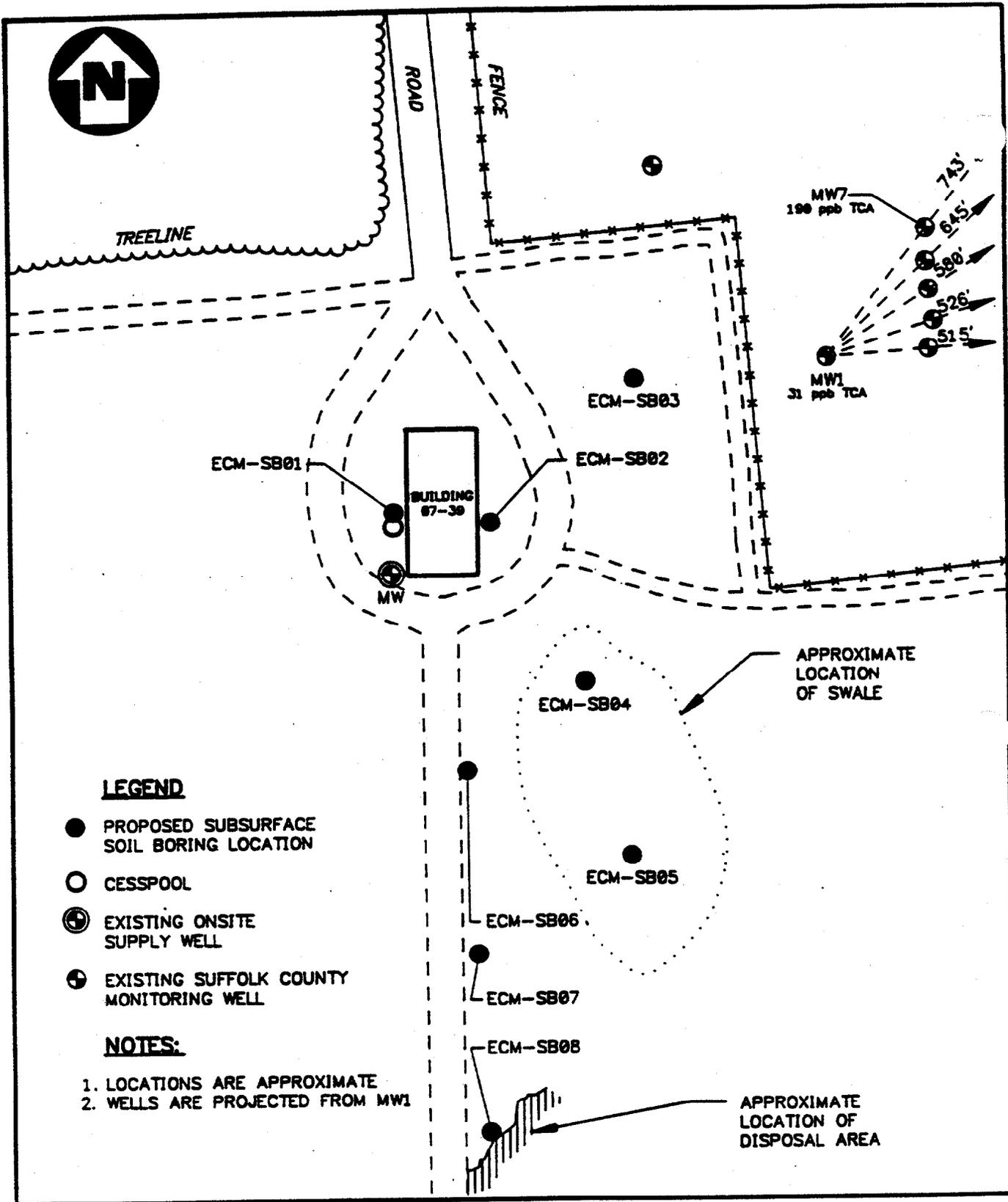


FIGURE 4-2

SITE LAYOUT
SITE 9 - ECM AREA
REA - SV WORK PLAN
NWIRP, CALVERTON, NEW YORK



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PCB/pesticides, TAL metals, and cyanide. A list of analytes, analytical methods, contract required quantitation limits, containers, preservatives, and holding times is provided on Table 3-1. Field samples and analytical testing are summarized in Table 4-2.

Subsurface Soil Borings and Subsurface Soil Sampling

Eight subsurface soil borings (16 subsurface soil samples) will be completed to the water table at the ECM site (see Table 4-2). Groundwater flow directions are not clearly defined, but are expected to be approximately from west to east-southeast, based on regional information. Figure 4-2 shows the locations of all sampling locations at the ECM site. Preliminary subsurface soil boring locations were determined during a recent site visit. Exact boring locations will be adjusted in the field to avoid underground and overhead utility lines. Subsurface soil samples at the ECM site will be analyzed for TCL Volatiles plus freon.

One boring (ECM-SB01) will be drilled adjacent to the cesspool on the west side of the radar installation building. A second boring (ECM-SB02) will be drilled on the east side of the building where a 55-gallon drum of 111 TCA (trichloroethane) was formerly stored. The drum was equipped with a spigot and an open catch-pan used for evaporation of spent solvent. Boring ECM-SB03 will be drilled down gradient of the building, between the former solvent storage location and offsite monitoring well MW-7. These three borings will be used to establish the presence or absence of soil contamination associated with activities at building and the former solvent storage area.

Borings ECM-SB04 and ECM-SB05 will be drilled in the swale to the southeast of the building. These two borings are located to investigate potential contamination from undetermined historic activities in the swale and potential contamination because of activities at the existing installation. Air photographs indicate activity in this area prior to the construction of the present ECM installation in 1972.

Borings ECM-SB06, ECM-SB07, and ECM-SB08 will be drilled along a north-south line between the building and an above ground disposal area south of the building. ECM-SB08 will be drilled as close as possible into this disposal area. The disposal area is located along a north-south trending road that extends from the ECM building to the south. Concrete, asphalt, large steel equipment, generators, and miscellaneous construction debris were observed in the disposal area during the recent site visit.

Test borings will be drilled and subsurface soil samples will be collected at selected sites to determine the presence or absence of subsurface soil contamination. Borings will be advanced to the water table (estimated depth of 5 to 20 feet bgs). Drilling operations for soil borings will be conducted using the hollow-stem auger method. During

TABLE 4-2

**SITE 9 - ECM AREA - FIELD ACTIVITIES
RCRA FACILITIES ASSESSMENT SITE VISIT
NWIRP, CALVERTON, NY**

SITE	DESCRIPTION OF ACTIVITIES	ANALYSIS
Site 9 - ECM Area	8 subsurface soil borings - 2 subsurface soil samples/boring	TCL Volatile Organics and freon
	3 groundwater samples - existing offsite Suffolk County wells	TCL Volatile Organics and freon
	1 groundwater sample - existing well at Building 07-39	TCL Volatile Organics, freon, TAL Metals, and cyanide
	0 to 2 waste samples taken in soil borings, if waste sludges are encountered	TCL Volatile Organics, Semi-volatile Organics, PCB/pesticides, TAL Metals, freon, and cyanide

drilling operations of overburden material, Standard Penetration Tests and split-spoon sampling will be performed continuously in all soil borings. All split-spoon samples will be screened with an Organic Vapor Analyzer (OVA) and visually inspected for lithologic description. Borings will be backfilled to the surface upon completion with cement/bentonite grout. Based on the OVA measurements of the soil, cuttings will be containerized in 55-gallon drums if OVA readings above background levels are present or spread on the ground near the boring if no OVA readings above background levels are observed.

Two samples per boring will be submitted for chemical analysis as outlined in Tables 4-2 and 1-1. Sampled intervals for chemical analysis shall include one between the surface and the water table, and one across the water table. The upper sample will be selected based on elevated OVA readings and/or visual evidence of contamination (i.e. staining or discoloration of soil). The sample above the water table with the highest OVA reading (primary determination) or appearing discolored (secondary determination) will be retained for testing. To obtain this sample, the initial split spoon sample in each boring will be collected as a sample for chemical analysis (i.e. placed into the required sample containers, labeled, and temporarily stored in a cooler). If the next split spoon sample in the boring has higher OVA readings than the first, or greater visual evidence of contamination, the first sample will be discarded and the second split spoon sample will be collected for chemical analysis. The third, fourth, and subsequent split spoon samples in the boring will be compared to the previous samples in the boring in the same way to the total depth of the boring. In each boring, the sample at the soil/water interface will be submitted for chemical analysis.

In addition to soil samples, sludge samples (if encountered) may be collected as described under the Waste Sampling section below.

Samples for analysis will be collected by splitting the soil sample open longitudinally and extracting soil from the entire length of the interior of the sample. Portions of the sample submitted for TCL Volatiles plus freon analysis will be placed directly in to the required containers. Remaining portions of the sample will be homogenized and distributed to the appropriate containers. A stainless steel trowel will be used to place the sample into the required containers. Any remaining sample material will be placed and retained in an 8-ounce jar as a lithologic sample, as will those split-spoon samples not submitted for chemical analysis. Drilling and sampling will be performed in accordance with HALLIBURTON NUS SOPs GH-1.3 and GH-1.5 (Appendix A). Decontamination of drilling and sampling equipment will be performed as described in Section 4.7.

A complete log of each boring will be maintained by the field geologist. Appendix B contains an example of the boring log form. At a minimum, the boring log will contain the following information, when applicable, for each overburden boring:

Sample numbers and types

Sample depths

Standard Penetration Test data

Sample recovery/sample interval

Soil density or cohesiveness

Soil color

Unified Soil Classification System (USCS) material description and symbol

In addition, depths of changes in lithology, sample moisture observations, depth to water, OVA readings, drilling method, and total depth of each borehole should be included on each boring log, as well as any other pertinent observations. Sample bottles containing soil samples collected solely for lithologic description will be numbered consecutively starting with S-1. In addition, the following information shall be recorded on the lid of the sample jars:

Job number and name

Boring and sample number

Date

Depth interval

Blow counts

As an alternative to obtaining samples with hollow stem augers, during the subcontractor procurement process, alternative sample collection techniques will be considered. One potential alternative is the "direct push" method of obtaining samples. Under this method, the samples are collected by hydraulically driving a 1-inch diameter piston-type sampler to the top of the desired sample interval; the piston within the sampler is released and the pipe advanced through the target interval. The soil core then enters the sampler, which contains a non-reactive plastic or stainless steel liner. After the drive rod is removed from the soil, the liner containing the soil column can be removed.

Groundwater Sampling

The purpose of groundwater sampling is to determine if groundwater has been contaminated by constituents in the site area. A groundwater sample will be collected from the existing supply well at this site and three groundwater samples will be collected from the Suffolk County monitoring wells located to the east of the site. New wells will not be installed during this field investigation.

The groundwater sample from the supply well will be collected from the tap on the line that is closest to the pump and before the lines encounter any storage tanks or filtration apparatus. Samples will be collected by filling the required sample bottles directly from the tap. Prior to obtaining groundwater samples, the lines and wells will be purged. The tap that is to be sampled will be opened to its maximum flow and allowed to run for approximately 15 minutes. Field measurements of pH, temperature, and specific conductance will be taken as described in HALLIBURTON NUS SOP SF-1.1 (Appendix A) during purging. The field measurements will be collected at the beginning of purging and at 5 minute intervals until the above parameters stabilize. Stabilization of the above parameters is defined as follows: temperature +/- 1°C, pH +/- 0.2 units, SC +/- 5 percent. If these parameters do not stabilize after 15 minutes, the tap will be run for an additional 10 minutes before sampling. Additional information concerning groundwater sampling is included in HALLIBURTON NUS SOP SA-1.1 (Appendix A).

A groundwater sample will be collected from a supply well located at the southwest corner of the building at the ECM site (Figure 4-2). The sample will be analyzed for TCL Volatiles, freon, TAL metals, and cyanide.

Samples from the offsite monitoring wells will be collected using a dedicated stainless steel bailer with dedicated polyethylene rope. Sampling will be conducted in accordance with HALLIBURTON NUS SOP SA-1.1. Prior to obtaining samples, water levels and the depth of the well will be measured. Three to six well volumes will be purged.

Waste Sampling

If sludges are encountered during the soil boring activities, up to two samples of the sludge will be collected for full TCL/TAL parameters plus freon. These samples will be collected as described for subsurface soil sampling. The identification of sludges will be determined in the field by the field geologist. Properties distinguishing sludges from natural soils include differences in particle size, moisture content, cohesion, color, and oil content from the natural soils. Materials which can be confidently identified in the field as construction debris such as asphalt, concrete, and wood will not be sampled.

4.3.3 Site 10 - Cesspool/Leach Field Areas

4.3.3.1 Site Background

There are approximately 22 cesspool/leach field areas at the NWIRP Calverton. The primary function of the leach fields is to treat sanitary wastes and to dispose of residual water. Many of these facilities are linked only to rest rooms and as a result, there is a very low potential that industrial type chemicals may have entered the environment

through these points. In other areas, where manufacturing facilities are present, and in particular where solvents may have been used, these cesspools and leach fields represent a potential pathway for environmental contamination. Information is currently being collected on activities conducted in each of the buildings. If there is uncertainty regarding current or historic activities at each area, environmental testing would be conducted.

4.3.3.2 Sampling Rationale

The cesspools/leach field sites are being investigated because of the potential for wastes to have been discharged to them in the past (see Figure 1-3). Because of the large number of cesspools/leach fields at the facility, and the consideration that some are used only for sanitary wastes (no industrial-type activity), a preliminary screening was conducted to limit the number of areas to be investigated during this RFA-SV. Activities for these areas will focus on soil contamination for solvents and to a lesser extent, inorganic contaminants.

4.3.3.3 Field Activities

The field investigation will consist of the following tasks:

- Soil gas survey
- Subsurface soil borings and subsurface soil sampling
- Groundwater sampling
- Waste sampling

Soil gas samples will be collected and analyzed for field screening purposes and soil samples will be collected in accordance with NEESA methodology for TCL Volatiles plus freon, and TAL metals and cyanide. Waste samples, if encountered, will be analyzed for TCL volatile organics, semivolatile organics, PCB/pesticides, TAL metals, and cyanide. A list of analytes, analytical methods, contract required quantitation limits, containers, preservatives, and holding times is provided on Table 3-1.

A concurrent two-phase field investigation is planned at this facility. Phase 1 is a soil gas survey and Phase 2 is a soil sampling investigation. The soil gas survey will be used to identify potential areas of soil and groundwater contamination associated with selected facility cesspools/leach fields. The soil gas samples will be analyzed at an onsite mobile field gas chromatograph laboratory and/or depending on capacity, at the subcontractors facility. Each of the samples will be analyzed on a quick turn around basis (1 to 3 days). The decision to sample soils at specific sites and the location of any soil borings at cesspool/leach field areas will be based on the soil gas results, with sampling planned for locations with the highest soil gas concentrations. The second phase consists of subsurface soil sampling.

Soil Gas Survey

Contaminant specific soil gas surveys will be conducted at those cesspool/leach field sites identified by an initial evaluation of cesspool locations and building activities as a potential source of contamination. Several cesspool/leach field areas were eliminated from further consideration without any environmental testing because there was a low potential for industrial-type solvent or metal contaminants to be present. The quantitative results of the soil gas surveys will be used to identify areas of potential subsurface soil and/or groundwater contamination, and as a basis for selection subsurface soil boring locations. Table 4-3 and Table 4-4 present a summary of the initial cesspool/leach field evaluation and summarizes the proposed soil gas and boring program for the cesspool/leach field sites. Figure 1-3 presents the locations of buildings with associated cesspools/leach fields to be investigated during soil gas survey activities.

Both sampling grids and discrete sampling locations will be used to provide suitable coverage of the area of suspected contamination at each site. In areas containing several cesspools (greater than four), a rectangular sampling grid will be set up over the entire area. Grid spacing will vary according to the overall size of each site and the number of cesspools at each site. Grid spacing will be adjusted in the field to place approximately 1 to 2 sampling points adjacent to each cesspool. At sites containing a single or a small number of cesspools (less than four), two soil gas sampling points per cesspool with a minimum of three soil gas sampling locations per site is proposed. Soil gas sampling points will be located within 5 to 10 feet of known cesspool edges. In addition, one soil gas sample will be collected in an area believed to be free of contamination to serve as a background sample.

Each potential sampling location will be marked with a surveyor's pin flag. Groundwater is estimated to lie between approximately 5 and 20 feet below ground surface (bgs) at the NWIRP, Calverton. Soil gas samples will be collected by driving a steel sampling probe approximately 3 to 6 feet into the ground. The drive point on the probe is slotted to allow soil gas to flow through the sampling probe. The sampling probe will be evacuated with sample prior to collection the soil gas sample. The soil gas sample will be collected into an air sample bag from a dedicated inert sampling tube that connects the steel probe to a pump. The samples will be analyzed onsite using a portable gas chromatograph (GC). Decontamination of steel sampling equipment will be performed as described in Section 4.7.

TABLE 4-3

**SITE 10 - CESSPOOL/LEACH FIELD - FIELD ACTIVITIES
RCRA FACILITIES ASSESSMENT SITE VISIT
NWIRP, CALVERTON, NY**

SITE	DESCRIPTION OF ACTIVITIES	ANALYSIS
Site 10 - Cesspools/ Leach Fields	Soil gas survey at each site - 8 sites, 64 soil gas samples	Select Volatile Organics
	Subsurface soil borings - up to 15 borings - 2 subsurface soil samples/boring	TCL Volatile Organics, freon, TAL metals, and cyanide
	1 groundwater sample - existing well at Building 07-43T	TCL Volatile Organics, freon, TAL metals, and cyanide
	0 to 2 waste samples taken in soil borings, if waste sludges are encountered	TCL Volatile Organics, Semi- volatile Organics, PCB/pesticides, TAL Metals, freon, and cyanide

TABLE 4-4

**CESSPOOL/LEACH FIELD SCREENING AND
SOIL GAS AND SOIL BORING QUANTITY ESTIMATES
NWIRP CALVERTON, NEW YORK**

Building Number	Description	Number of Pools	Number of Soil gas points	Number of Soil borings	Potential for Solvent Contamination
06-02	Main Gate House	STTF	0	0	Low
06-11	Fuel System Test Lab	2	4	1	Medium
06-13	Facilities Maintenance Building	?	4	1	Medium
06-14	Yellow Shack	2	0	0	Low
06-17	Sewage Pump Station	24	24	4	Medium
06-18	Engine Test House	STTF	6	1	Medium
06-22A	Gun Firing Butt ¹	STTF	0	0	Low
06-24	Flight Line Shack ¹	2	0	0	Low
06-28	Thrust Stand Shack	1	0	0	Low
06-32	Lunar Test Building	1	0	0	Low
06-42	Vehicle Transportation Building	?	4	1	Medium
06-57	Credit Union	1	0	0	Low
06-73	New Fuel Calibration Building	1	3	1	Medium
07-03	Sewage Pump Station	8	10	4	Medium
07-04	Flight Emergency Shelter	2	0	0	Low
07-05	Anechoic Chamber	STTF	0	0	Low
07-12	Guard Building at North Gate # ¹	1	0	0	Low
07-43T	Rotodome Range Trailers ¹	1	0	0	Low
07-45T	Line Crew Trailer	1	0	0	Low
07-85	Picnic Grounds Toilet ¹	5	0	0	Low
080-01	Avionics Noise Check	4	8	2	Medium
080-03	AWSACS Development Building	STTF	0	0	Low
-	Background		1	0	
	Total		64	15	

STTF - Septic Tank Tile Field

1) - Wells are reported to be present at these locations.

Prior to soil gas sample collection, a gas chromatograph compound library will be established using certified gas standards for the following target compounds:

Benzene	Ethylbenzene
1,1-dichloroethene (DCE)	c-1,2-DCE
t-1,2-DCE	1,1-dichloroethane (DCA)
Trichloroethene (TCE)	Tetrachloroethene (PCE)
1,1,1 trichloroethane (TCA)	1,1,2-TCA
Chloroform	Carbon tetrachloride
Toluene	Total (m-, p-, and o-,) xylenes
Methylene chloride	Freon-113

Areas at each site found to have elevated soil gas concentrations of volatile organics will be further investigated by collecting and analyzing subsurface soil boring samples.

Subsurface Soil Boring and Subsurface Soil Sampling

A minimum of one subsurface soil boring (2 samples/boring) will be drilled at each cesspool/leach field site identified by a soil gas survey as a potential source of contamination (see Table 4-3 and Figure 1-3). Subsurface soil samples collected at cesspool/leach field sites will be analyzed for TCL Volatiles, freon, TAL metals and cyanide. At large cesspool/leach field sites (greater than four cesspools), up to four subsurface soil borings will be drilled, based on the results of the soil gas surveys. The soil borings will be located near the highest soil gas volatile organic measurements observed. In addition, at two of the sites where elevated soil gas readings are not found, subsurface soil samples will be collected to confirm the absence of contamination. Table 4-4 summarizes the proposed soil boring program for the cesspool/leach field sites. Soil boring numbers will be assigned in the field chronologically beginning with CL-SB18.

Test borings will be drilled and subsurface soil samples will be collected at selected sites to determine the presence or absence of subsurface soil contamination. Borings will be advanced to the water table (estimated depth of 5 to 20 feet bgs). Drilling operations for soil borings will be conducted using the hollow-stem auger method. During drilling operations of overburden material, Standard Penetration Tests and split-spoon sampling will be performed continuously in all soil borings. All split-spoon samples will be screened with an Organic Vapor Analyzer (OVA) and visually inspected for lithologic description. Borings will be backfilled to the surface upon completion with cement/bentonite grout. Based on the OVA measurements of the soil, cuttings will be containerized in 55-gallon

drums is OVA readings above background levels are present or spread on the ground near the boring if no OVA readings above background levels are observed.

Two samples per boring will be submitted for chemical analysis as outlined in Tables 4-3 and 1-1. Sampled intervals for chemical analysis shall include one between the surface and the water table, and one across the water table. The upper sample will be selected based on elevated OVA readings and/or visual evidence of contamination (i.e. staining or discoloration of soil). The sample above the water table with the highest OVA reading (primary determination) or appearing discolored (secondary determination) will be retained for testing. To obtain this sample, the initial split spoon sample in each boring will be collected as a sample for chemical analysis (i.e. placed into the required sample containers, labeled, and temporarily stored in a cooler). If the next split spoon sample in the boring has higher OVA readings than the first, or greater visual evidence of contamination, the first sample will be discarded and the second split spoon sample will be collected for chemical analysis. The third, fourth, and subsequent split spoon samples in the boring will be compared to the previous samples in the boring in the same way to the total depth of the boring. In each boring, the sample at the soil/water interface will be submitted for chemical analysis.

In addition to soil samples, sludge samples (if encountered) may be collected as described under the Waste Sampling section below.

Samples for analysis will be collected by splitting the soil sample open longitudinally and extracting soil from the entire length of the interior of the sample. Portions of the sample submitted for TCL Volatiles plus freon analysis will be placed directly in to the required containers. Remaining portions of the sample will be homogenized and distributed to the appropriate containers. A stainless steel trowel will be used to place the sample into the required containers. Any remaining sample material will be placed and retained in an 8-ounce jar as a lithologic sample, as will those split-spoon samples not submitted for chemical analysis. Drilling and sampling will be performed in accordance with HALLIBURTON NUS SOPs GH-1.3 and GH-1.5 (Appendix A). Decontamination of drilling and sampling equipment will be performed as described in Section 4.7.

A complete log of each boring will be maintained by the field geologist. Appendix B contains an example of the boring log form. At a minimum, the boring log will contain the following information, when applicable, for each overburden boring:

Sample numbers and types

Sample depths

Standard Penetration Test data

Sample recovery/sample interval

Soil density or cohesiveness

Soil color

Unified Soil Classification System (USCS) material description and symbol

In addition, depths of changes in lithology, sample moisture observations, depth to water, OVA readings, drilling method, and total depth of each borehole should be included on each boring log, as well as any other pertinent observations. Sample bottles containing soil samples collected solely for lithologic description will be numbered consecutively starting with S-1. In addition, the following information shall be recorded on the lid of the sample jars:

Job number and name

Boring and sample number

Date

Depth interval

Blow counts

As an alternative to obtaining samples with hollow stem augers, during the subcontractor procurement process, alternative sample collection techniques will be considered. One potential alternative is the "direct push" method of obtaining samples. Under this method, the samples are collected by hydraulically driving a 1-inch diameter piston-type sampler to the top of the desired sample interval; the piston within the sampler is released and the pipe advanced through the target interval. The soil core then enters the sampler, which contains a non-reactive plastic or stainless steel liner. After the drive rod is removed from the soil, the liner containing the soil column can be removed.

Groundwater Sampling

The purpose of groundwater sampling is to determine if groundwater has been contaminated by constituents in the site area. A groundwater sample will be collected from the existing supply well at this site. New wells will not be installed during this field investigation.

The groundwater sample will be collected from the tap on the line that is closest to the pump and before the lines encounter any storage tanks or filtration apparatus. Samples will be collected by filling the required sample bottles directly from the tap. Prior to obtaining groundwater samples, the lines and wells will be purged. The tap that is to be sampled will be opened to its maximum flow and allowed to run for approximately 15 minutes. Field

measurements of pH, temperature, and specific conductance will be taken as described in HALLIBURTON NUS SOP SF-1.1 (Appendix A) during purging. The field measurements will be collected at the beginning of purging and at 5 minute intervals until the above parameters stabilize. Stabilization of the above parameters is defined as follows: temperature +/- 1°C, pH +/- 0.2 units, SC +/- 5 percent. If these parameters do not stabilize after 15 minutes, the tap will be run for an additional 10 minutes before sampling. Additional information concerning groundwater sampling is included in HALLIBURTON NUS SOP SA-1.1 (Appendix A).

A sample will be collected from the supply well at Building 07-43T (Figure 1-3). The sample will be analyzed for TCL Volatiles, freon, TAL metals, and cyanide.

Waste Sampling

If sludges are encountered during the soil boring activities, up to two samples of the sludge will be collected for full TCL/TAL parameters plus freon. These samples will be collected as described under subsurface soil sampling. The identification of sludges will be determined in the field by the field geologist. Properties distinguishing sludges from natural soils include differences in particle size, moisture content, cohesion, color, and oil content from the natural soils. Materials which can be confidently identified in the field as construction debris such as asphalt, concrete, and wood will not be sampled.

4.3.4 Background Soil Samples

Six background soil samples will be collected at six separate locations throughout the NWIRP (one at each location). The locations will be selected in the area away from known or suspected activities. These samples will be collected with a hand auger at a depth of 6 to 12 inches bgs and analyzed for TAL metals. The results of testing will be used to statistically develop site-specific background soil concentration action levels for TAL metals. Background soil samples will be numbered BG-SB12 through BG-SB17.

4.4 **SAMPLE IDENTIFICATION SYSTEM**

Each sample collected will be assigned a unique sample tracking number. The sample tracking number will consist of a four-segment, alpha-numeric code that identifies the site (plus building number), sample medium and location, and sample depth (in the case of soil and sediment samples). QA sample designations will be blind relative to sample duplicates.

Any other pertinent information regarding sample identification will be recorded in the field log books and sample log sheets.

The alpha-numeric coding to be used in the sample system is explained below.

Field Samples

(AAA) - (AANN) - (NNN)

(Site name) (Medium & Location) (Sample depth)

QA Samples

(AA) - (NN)

(QA Type) (Number)

Character Type:

A = Alpha

N = Numeric

Site name:

ECM = Electronic Counter Measures (no building #s)

CP = Coal Pile (no building #s)

CL = Cesspool/Leach Field (plus 4-digit building number)

BG = Background

Medium:

GW = Groundwater

SB = Subsurface Soil from soil boring

WS = Waste from coal pile

SW = Surface water

SD = Sediment

Sample Location:

Subsurface soil = soil boring number (i.e. 01, 02, 03...)

Surface water or Sediment = sample location number

Groundwater = well number

Sample Identifier:

For soil and sediment samples = Start depth, in feet, of sample.

Not used for groundwater or surface water/sediment samples.

QA Sample Designation:

DU = Duplicate

RB = Equipment Rinsate Blank

FB = Field Blank

TB = Trip Blank

QA samples will be numbered sequentially starting with 01. Matrix Spike and Matrix Spike Duplicate (MS/MSD) samples will be designated on the field documentation forms and sample labels.

For example, a subsurface soil sample and its duplicate (with the duplicate being the third obtained during the sampling activities) from soil boring number 04 at the ECM site at a depth of 10 to 12 feet would be:

ECM-SB04-10.0, and

DU-03

4.5 SAMPLING EQUIPMENT AND PROTOCOLS

The sampling equipment and protocols to be used are presented in Appendix A and are HALLIBURTON NUS Standard Operating Procedures.

4.6 SAMPLE HANDLING

Sample handling includes the field-related considerations regarding the selection of sample containers, preservatives, allowable holding times and analyses requested. Table 3-1 summarizes the sample handling considerations for this field investigation. The EPA User's Guide to the Contract Laboratory Program (EPA, December 1988), and the Federal Register (EPA, October 26, 1984) address the topics of containers and sample preservations.

4.6.1 Sample Packaging and Shipping

Samples will be packaged and shipped in accordance with HALLIBURTON NUS SOP SA-6.2 (Appendix A). The FOL will be responsible for completion of the following forms:

- Sample Labels
- Chain-of-Custody Forms
- Appropriate labels applied to shipping coolers
- Chain-of-Custody Labels
- Federal Express Air Bills

4.6.2 Sample Custody

Custody of samples must be maintained and documented at all times. Chain-of-custody begins with the collection of the samples in the field. Section 5.3 of HALLIBURTON NUS SOP SA-6.1 (Appendix A) provides a description of the chain-of-custody procedures to be followed. A sample chain-of-custody form is attached in Appendix B.

4.7 EQUIPMENT DECONTAMINATION

The equipment involved in field sampling activities will be decontaminated prior to and during drilling and sampling activities. This equipment includes soil gas probes, drilling rigs, downhole tools, augers, well casing and screens, and all sampling equipment.

4.7.1 Major Equipment

All downhole drilling or soil gas equipment and sampling tools shall be steam cleaned prior to beginning work, between well borings, any time the drilling rig leaves the site prior to completing a boring, and at the completion of the drilling program.

These decontamination operations will consist of washing the equipment using a high-pressure steam wash. All decontamination activities will take place at a location determined during mobilization. It is assumed that the facility will provide a suitable location for decontamination operations along with potable water and electricity. Additional requirements for drilling equipment decontamination can be found in HALLIBURTON NUS SOP SA-7.1: Section 5 (Appendix A).

4.7.2 Sampling Equipment

All sampling equipment used for collecting samples will be decontaminated both prior to beginning field sampling and between samples. The following decontamination steps will be taken:

- Potable water rinse
- Alconox or liquinox detergent wash
- Potable water rinse
- Nitric acid rinse (for TAL metals samples only)
- Steam distilled water rinse (for TAL metal samples only)
- Methanol rinse
- Steam distilled water rinse
- Air dry

Field analytical equipment such as pH, conductivity and temperature instrument probes will be rinsed first with steam distilled water, then with the sample liquid.

4.8 RESIDUE MANAGEMENT

Four types of potentially contaminated residues are expected to be generated during this field investigation, namely Personal Protection Equipment (PPE), drill rig decontamination fluids, sampling equipment decontamination fluids, and auger soil cuttings. Based on the activities and types of contaminants present, none of these residues are expected to represent a significant risk to human health or the environment if properly managed. Planned management of each of these residues is provided below.

PPE - PPE will be placed in the trash receptacles at the facility.

Drill Rig Decontamination Fluids - Drill rig decontamination fluids will be containerized in 55-gallon drums at the fire training area. Pending the results of the RFA-SV testing, these decontamination fluids will be discharged to the onsite wastewater treatment plant.

Sampling Equipment Decontamination Fluids - Equipment decontamination fluids will be containerized and handled with the drill rig decontamination fluids.

Auger Soil Cuttings - Auger soil cutting will be screened with an OVA. If OVA readings are detected above background levels or discoloration of the soils is noted, then the cutting will be containerized in 55-gallon drums and stored at the fire training area for additional testing. Otherwise, the cuttings will be spread on the ground near the soil boring.

5.0 DOCUMENTATION AND CHAIN-OF CUSTODY

Sample custody procedures are designed to provide documentation of preparation, handling, storage, and shipping of all samples collected. An example of the chain-of-custody form, which will be used during this investigation, is included in Appendix B.

Samples collected during the site investigation will be the responsibility of identified persons from the time they are collected until they, or their derived data, are incorporated into the final report. Stringent chain-of-custody procedures will be followed to document sample possession.

5.1 Field Custody

- The FOL, or his or her designee, is responsible for the care and custody of the samples collected until they are delivered to the analyzing laboratory or entrusted to a carrier.
- Sample logs or other records will always be signed and dated.
- Chain-of-custody sample forms will be completed to the fullest extent possible prior to sample shipment. They will include the following information: project name, sample number, time collected, source of sample and location, description of sample location, matrix, type of sample, grab or composite designation, preservative, number and size of bottle, analysis, and name of sampler.

These forms will be filled out in a legible manner, using waterproof ink, and will be signed by the sampler. Similar information will be provided on the sample label which will be securely attached to the sample bottle. The label will also include the general analyses to be conducted. In addition, sampling forms will be used to document collection, filtration, and preparation procedures. Copies of all field documentation forms are provided in Appendix B.

5.2 Transfer of Custody and Shipment

The following procedures will be used when transferring custody of samples:

- Samples will always be accompanied by a chain-of-custody record. When transferring samples, the individuals relinquishing and receiving them will sign, date, and note the time of the chain-of-custody record. This record documents the sample custody transfer from the sampler to the laboratory, often through another person or agency (common carrier). Upon arrival at the laboratory, internal sample custody procedures will be followed.
- Prior to shipment to the laboratory for analysis, samples will be properly packaged. Individual custody records will accompany each shipment. Shipping containers will then be sealed for shipment to the laboratory. The methods of shipment, courier name, and other pertinent information, will be entered in the remarks section of the custody record.
- All shipments will be accompanied by the chain-of-custody record identifying the contents. The original record will accompany the shipment; and a copy will be retained by the field sampler.
- Proper documentation will be maintained for shipments by common carrier.

5.3 Sample Shipment Procedures

The following procedures will be followed when shipping samples for laboratory analysis:

- Samples requiring refrigeration will be promptly chilled with ice or Blue Ice to a temperature of 4°C and will be packaged in an insulated cooler for transport to the laboratory. Ice will be sealed in containers to prevent leakage of water. Samples will not be frozen.
- Only shipping containers that meet all applicable state and Federal standards for safe shipment will be used.
- Shipping containers will be sealed with nylon strapping tape, custody seals will be signed, dated, and affixed, in a manner that will allow the receiver to quickly identify any tampering that may have occurred during transport to the laboratory.

- Shipment will be made by overnight courier. After samples have been taken, they must be sent to the laboratory within 24 hours.

5.4 Field Documentation Responsibilities

It will be the responsibility of the FOL to secure all documents produced in the field (geologist's daily logs, lithologic and sampling logs, communications) at the end of each work day.

The possession of all records will be documented; however, only the project FOL or designee may remove field data from the site for reduction and evaluation.

The data generated by the laboratory will be sent to HALLIBURTON NUS, validated, and stored by HALLIBURTON NUS until completion and acceptance of the RFA-SV investigation reports. A final QC data report will be issued to the NCR at least 3 weeks before the final report is issued.

6.0 CALIBRATION PROCEDURES

Field equipment such as the portable gas chromatograph (GC), the Organic Volatile Analyzer (OVA), the pH and specific conductance meters, and any geophysical equipment used during this project will be calibrated and operated in accordance with the manufacturer's instructions and manuals. A log will be kept documenting the calibration results for each field instrument. The log will include the date, standards, personnel, and results of the calibration.

Calibration procedures for laboratory equipment used in the analysis of environmental samples will be performed in accordance with CLP requirements.

7.0 SAMPLE PREPARATION AND ANALYTICAL PROCEDURES

Environmental samples collected during the field investigation for chemical analyses will be analyzed using the appropriate analytical procedures as outlined in Table 3-1 of this work plan. The methods are referenced to the appropriate CLP, EPA, or other guidance.

8.0 DATA REDUCTION, VALIDATION, AND REPORTING

Data reduction, validation, and reporting are basic steps in the control and processing of field and laboratory project-generated data. Data will be presented in tabular form with site background result (for inorganics) and relevant requirements for organic results used as screening criteria. Data validation procedures are described below.

Data validation consists of a stringent review of an analytical chemical data package with respect to sample receipt and handling, analytical methods, data reporting and deliverables, and document control. The quality of data generated by a laboratory is extremely important; it is an integral part of the investigation and should be clearly tied to the project goals. Data used to develop qualitative trends, for example, will not have the same data validation requirements as data used for litigation purposes.

A qualified HALLIBURTON NUS chemist will evaluate the analytical data package using EPA procedures (i.e. the National Functional Guidelines for Evaluating Analytical Data). After the data is validated, a listing of non-conformities will be generated and used to determine whether the data can be utilized for its intended purpose (assessment, enforcement, litigation). Non-conformities yield data qualifiers, which are used to alert the data user to inaccurate or imprecise data. For example, if the calibration criteria are not met, the data reviewer must qualify all affected positive results as estimated and all affected sample quantitation limits as directed in the National Functional Guidelines (NFGs). For situations in which there are several quality control criteria out of specification with regard to method-specific quality control criteria, the quality control criteria outlined in the NFGs and/or the quality control criteria stipulated in the Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Program (20.2-047B; 6/88), the data validator may make professional judgments and/or comments on the validity of the overall data package. In situations where the validity of an entire data package is in question, it may be necessary for the sample(s) to be re-analyzed. As a component of the data validation process, the validator will generate a technical memorandum presenting changes in the data, if necessary, and the rationale for making such changes.

The net result is a data package that has been carefully reviewed for its adherence to prescribed requirements and is suitable for its intended use. Data validation thus plays a major role in determining the confidence with which key technical evaluations may be made.

A QC data report shall be sent to the NCR at least 3 weeks before issuance of the final report. For Level D QC, a subset of data from the CLP data packages shall be submitted. For 20 percent of the water samples and 20

percent of the soil samples, the subcontractor shall submit the full CLP package. The report shall indicate the duration and location of storage for all raw data, QC charts, corrective action, sample lists, COC information, notebooks, work sheets, automated data processing system output, and calibration.

The final report, which shall be reviewed by the NCR prior to its release, will include a data summary. The summary of analytical data will exclude non-detected compounds. No subtraction of blank contaminants will be allowed; data will be flagged if associated blank contamination occurs. All data flags will follow the result in the summary.

The final report will also include a QC summary section. The QC summary will discuss flagged data, matrix spikes/spike duplicates, control charts, laboratory duplicates, surrogate spike recoveries, holding times, field blanks, trip blanks, rinsates, field duplicates, precision, accuracy, and completeness.

The laboratory data for each sample will be reported in an appendix. These data will be presented in a spreadsheet format with all trip, field, and rinsate blanks marked. The format recommended by NEESA will be used.

Field logs and forms will be included in another appendix. Another appendix will include method blank spike control charts, surrogate recoveries, matrix spike and duplicate, field, and laboratory duplicates for all spike samples.

9.0 INTERNAL QUALITY CONTROL CHECKS

Quality control samples generated by HALLIBURTON NUS will include the collection of field duplicates, the preparation of field blanks and rinsate blanks, and the use of laboratory-prepared trip blanks. An approximate 10 percent duplication - one per 10 samples or one per sample matrix if less than 10 samples are collected (see Table 3-1) of soil, sediment, surface water/groundwater samples will be used to monitor the laboratory's performance.

Trip blanks (volatiles only) will be shipped along with the sample bottles and will be analyzed concurrently with the collected environmental samples. These trip blanks will be submitted at a rate of one per sample shipment of samples for TCL volatile analysis. Rinsates, prepared by running distilled water through the sampling equipment, will be analyzed to determine whether the decontamination procedures may be biasing the data. Field blanks will be prepared at a rate of one per source per event.

There are two types of quality assurance mechanisms used to ensure the production of analytical data of known and documented quality. The internal laboratory quality control procedures for the analytical services are specified in the CLP protocol and Table 3-1. These specifications include the types of control samples required (sample spikes, surrogate spikes, controls, and blanks), the frequency of each control, the compounds to be used for sample spikes and surrogate spikes, and the quality control acceptance criteria. It will be the laboratory's responsibility to document, in each data package, that both initial and on-going instrument and analytical QC criteria are met.

Analytical results of field-collected quality control samples will also be compared to acceptance criteria, and documentation will be performed showing that criteria have been met. Any samples in nonconformance with the QC criteria will be identified and reanalyzed by the laboratory, as required. The following procedures will be employed for the processing of NWIRP Calverton samples:

- Proper storage of samples.
- Use of qualified and/or certified technicians.
- Use of calibrated equipment traceable to the CLP Protocol.
- Formal independent confirmation of all computation and reduction of laboratory data and results.

- **Use of standardized test procedures.**
- **Inclusion of duplicate samples at a frequency of one replicate per 10 samples or one per sample matrix if less than 20 samples are collected.**

10.0 PERFORMANCE AND SYSTEM AUDITS

System audits will be performed on a semi-continuous basis, as appropriate, to assure that the work is being implemented in accordance with the approved project SOPs and in an overall satisfactory manner.

- The FOL will supervise and check on a daily basis that the soil borings are installed correctly, field measurements are made accurately, equipment is thoroughly decontaminated, samples are collected and handled properly, and the field work is accurately and neatly documented.
- The data validator will review (on a timely basis) the data packages submitted by the laboratory. The data validator will check that the data was obtained through the approved methodology, that the appropriate level of QC effort and reporting was conducted, that holding times were met, and that the results are in conformance with the applicable QC criteria. On the basis of these factors, the data validator will evaluate the data quality and limitations.
- The project manager will oversee the FOL and data validator, and check that management of the acquired data proceeds in an organized and expeditious manner.
- System audits for the laboratory are performed on a regular basis.

A formal audit of the field sampling procedures may be conducted in addition to the auditing that is an inherent part of the daily project activities. If so conducted, the auditors will check that sample collection, sample handling, decontamination protocols, and instrument calibration and use are in accordance with the approved project SOPs. The auditors will also check that the field documentation logs and chain-of-custody forms are being filled out properly.

Performance audits of laboratories participating in the CLP are performed quarterly in accordance with the procedures and frequencies established by the CLP.

11.0 PREVENTATIVE MAINTENANCE

HALLIBURTON NUS has established a program for the maintenance of field equipment to ensure the availability of equipment in good working order when and where it is needed. This program consists of the following elements:

- **The equipment manager keeps an inventory of the equipment in terms of items (model and serial number) quantity and condition. Each item of equipment is signed out when in use, and its operating condition and cleanliness checked upon return.**
- **The equipment manager conducts routine checks on the status of equipment and is responsible for the stocking of spare parts and equipment readiness.**
- **The equipment manager maintains the equipment manual library and trains field personnel in the proper use and care of equipment.**
- **The FOL is responsible for working with the equipment manager to make sure that the equipment is tested, cleaned, charged, and calibrated in accordance with the manufacturer's instructions before being taken to the job site.**

The laboratory follows a well-defined program to prevent the failure of laboratory equipment and instrumentation. This preventative program, includes the periodic inspection, lubrication, cleaning, and replacement of parts of the equipment.

12.0 DATA ASSESSMENT PROCEDURES

12.1 Representativeness, Accuracy, and Precision

All data generated in the investigation will be assessed for its representativeness, accuracy, and precision. The completeness of the data will also be assessed by comparing the valid acquired data to the project objectives to see that these objectives are being addressed and met. The specific procedures used to determine data precision, accuracy, and completeness will be provided in the analytical reports. Accuracy will be determined using laboratory spiked samples and laboratory field blanks.

The representativeness of the data will be assessed by determining if the data are consistent with known or anticipated hydrogeologic or chemical conditions and accepted principles. Field measurements will be checked for completeness of procedures and documentation of procedures and results.

Precision and accuracy will be determined using replicate samples and blank and spiked samples, respectively. The specific procedures for determining PARCC parameters are outlined in Section 5.0.

12.2 Validation

One hundred percent of the analytical data packages will be validated.

12.3 Data Evaluation

The evaluation of the data collected during the field investigation will be a comparison of: chemical concentrations in groundwater and surface water versus ARARs (such as the Safe Drinking Water Act MCLs and the Ambient Water Quality Criteria) and risk-based concentrations; and chemical concentrations in soils versus background and risk-based concentrations.

The groundwater and surface water evaluation will be based directly on standards established under Federal and state drinking water and surface water standards for volatile organics and metals. For soil and sediment samples organic results, any organics detected will be considered potentially significant. Contaminants detected will only be discounted if very low levels are found (near the detection limit) and they are found infrequently at the site; or if a higher concentration is found but that the concentration in combination with the toxicity of the chemical would not be considered a significant risk to human health or the environment. For soil and sediment sample inorganic

results, the result will be compared to soil background sample results. Action levels will be based on a normal frequency distribution of inorganics in the background soils at the upper 95% of the frequency distribution (one in twenty chance that a background soil sample at that concentration has been "incorrectly" identified as contaminated. The contaminant specific action levels will be calculated as follows.

$$\text{Action Level} = 1.645 * \sigma + x_n$$

where: σ = standard deviation (with $n - 1$ samples)

$$\sigma^2 = 1/(n - 1) * \Sigma(x_i - x_n)^2$$

x_i = individual value

x_n = mean value

n = number of samples

13.0 CORRECTIVE ACTIONS

The QA program will enable problems to be identified, controlled, and corrected. Potential problems may involve nonconformance with the SOPs and/or analytical procedures established for the project or other unforeseen difficulties. Any person identifying an unacceptable condition will notify the project manager. The project manager, with the assistance of the project QA/QC officer, will be responsible for developing and initiating appropriate corrective action and verifying that the correction action has been effective. Corrective actions may include the following: resampling and/or reanalysis of sample, amending or adjusting project procedures. If warranted by the severity of the problem (for example, if a change in the approved work plan is required), the Navy will be notified in writing and their approval will be obtained prior to implementing any change. Additional work that is dependent on a nonconforming activity will not be performed until the problem has been eliminated.

The laboratory maintains an internal closed-loop corrective action system that operates under the direction of the laboratory QA coordinator.

14.0 QUALITY ASSURANCE REPORTS TO MANAGEMENT

The QA/QC advisor will review all aspects of the implementation of the work plan on a regular basis and with the use of designated support personnel, will prepare a summary report. Reviews will be performed at the completion of each field activity and reports will be completed at this time. These reports will include an assessment of data quality and the results of system and/or performance audits. Any significant QA deficiencies will be reported and identified, and corrective action possibilities discussed. The laboratory will issue monthly progress reports. Other QA/QC reports are listed in Section 8.0.

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APPENDIX A

- GH-1.3 SOIL AND ROCK DRILLING AND SAMPLING METHODS
- GH-1.5 BOREHOLE AND SAMPLE LOGGING
- SA-1.1 GROUNDWATER SAMPLE ACQUISITION
- SA-1.2 SURFACE WATER AND SEDIMENT SAMPLING
- SA-6.1 SAMPLE HANDLING
- SA-6.2 FIELD DOCUMENTATION
- SA-7.1 DECONTAMINATION OF FIELD EQUIPMENT AND WASTE HANDLING
- SF-1.1 ONSITE WATER QUALITY TESTING



HALLIBURTON NUS
Environmental Corporation

**ENVIRONMENTAL
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**STANDARD
OPERATING
PROCEDURES**

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Approved D. Senovich	

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SOIL AND ROCK DRILLING AND SAMPLING METHODS

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1.0 PURPOSE

The purpose of this procedure is to describe the methods and equipment necessary to perform soil and rock borings and identify the equipment, sequence of events, and appropriate methods necessary to obtain soil, both surface and subsurface, and rock samples during field sampling activities.

2.0 SCOPE

This guideline addresses most of the accepted and standard drilling techniques, their benefits, and drawbacks. It should be used generally to determine what type of drilling techniques would be most successful depending on site-specific geologic conditions and the type of sampling required.

The sampling methods described within this procedure are applicable while collecting surface and subsurface soil samples; obtaining rock core samples for lithologic and hydrogeologic evaluation; excavation/foundation design and related civil engineering purposes.

3.0 GLOSSARY

Hand Auger. A sampling device used to extract soil from the ground in a relatively undisturbed form.

Thin-Walled Tube Sampler. A thin-walled metal tube (also called Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches O.D. and 18 to 54 inches long. A stationary piston device may be included in the sampler to reduce sampling disturbance and increase sample recovery.

Split-Barrel Sampler. A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into resistant materials using a drive weight mounted in the drilling string. A standard split-spoon sampler (used for performing Standard Penetration Tests) is 2 inches outside diameter (OD) and 1-3/8 inches inside diameter (ID). This standard spoon typically is available in two common lengths, providing either 20-inch or 26-inch longitudinal clearance for obtaining 18-inch or 24-inch-long samples, respectively. These split-spoon samplers range in size from 2-inch O.D. to 3-1/2-inch O.D., depending upon manufacturer. The larger sizes are commonly used when a larger volume of material is required.

Rock Coring. A method in which a continuous solid cylindrical sample of rock or compact rock-like soil is obtained by the use of a double tube core barrel that is equipped with an appropriate diamond-studded drill bit which is advanced with a hydraulic rotary drilling machine.

Wire-Line Coring. As an alternate for conventional coring, this is valuable in deep hole drilling, since this method eliminates trips in and out of the hole with the coring equipment. With this technique the core barrel becomes an integral part of the drill rod string. The drill rod serves as both a coring device and casing.

4.0 RESPONSIBILITIES

Project Manager. In consultation with the project geologist, responsible for evaluating the drilling requirements for the site and specifying drilling techniques that will be successful given the study objectives and geologic conditions at the site. He should also determine the disposal methods for

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products generated by drilling, such as drill cuttings and well development water, as well as any specialized supplies or logistical support required for the drilling operations.

Site Geologist. Responsible for insuring that standard and approved drilling procedures are followed. The geologist will generate a detailed boring log for each test hole. This log shall include a description of materials, samples, method of sampling, blow counts, and other pertinent drilling and testing information that may be obtained during drilling (see Attachment A of Procedure GH-1.7). Often this position for inspecting the drilling operations may be filled by other geotechnical personnel, such as soils and foundation engineers, civil engineers, etc.

Determination of the exact location for borings is the responsibility of the site geologist. The final location for drilling must be properly documented on the boring log. The general area in which the borings are to be located will be shown on a site map included in the Work Plan.

Field Operations Leader. Responsible for overall supervision and scheduling of drilling activities.

Drilling Subcontractor. Responsible for obtaining all drilling permits and clearances, and supplying all services (including labor), equipment and material required to perform the drilling, testing, and well installation program, as well as maintenance and quality control of such required equipment except as stated in signed and approved subcontracts.

The driller must report any major technical or analytical problems encountered in the field to the Field Operations Leader within 24 hours, and must provide advance written notification for any changes in field procedures describing and justifying such changes. No such changes shall be made unless requested and authorized in writing by the Field Operations Leader.

The drilling subcontractor will be responsible for following decontamination procedures specified in the Work Plan. Upon completion of the work, the Drilling Subcontractor will be responsible for demobilizing all equipment, cleaning up any materials deposited on site during drilling operations, and properly backfilling any open borings.

5.0 PROCEDURES

5.1 GENERAL

The purpose of drilling boreholes is:

- To determine the type, thickness, and certain physical and chemical properties of the soil, water and rock strata which underlie the site.
- To install monitoring wells or piezometers.

All drilling and sampling equipment will be cleaned using appropriate decontamination procedures (see Procedure SA-7.1) between samples and borings. Unless otherwise specified, it is generally advisable to drill borings at "clean" locations first, and at the most contaminated locations last, to reduce the risk of spreading contamination between locations. All borings must be logged by the rig geologist as they proceed (see Procedure GH-1.4). Situations where logging would not be required would include installation of multiple well points within a small area, or a "second attempt" boring adjacent to a boring that could not be continued through resistant material. In the latter case, the boring log can be resumed 5 feet above the depth at which the initial boring was abandoned,

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although the rig geologist should still confirm that the stratigraphy at the redrilled location conforms essentially with that encountered at the original location. If significant differences are seen, each hole should be logged separately.

5.2 DRILLING METHODS

The selected drilling methods described below apply to drilling in subsurface materials, including, but not limited to, sand, gravel, clay, silt, cobbles, boulders, rock and man-made fill. Drilling methods should be selected after studying the site geology and terrain, purpose of drilling, waste conditions at the site, and the overall subsurface investigation program proposed for the site. The full range of different drilling methods applicable to the proposed program should be identified with final selection based on relative cost, availability, time constraints, and how well each method meets the sampling and testing requirements of the individual drilling program.

5.2.1 Continuous-Flight Hollow-Stem Auger Drilling

This method of drilling consists of screwing augers with a hollow stem into the ground. Cuttings are brought to the surface by the rotating action of the auger. This method is relatively quick and inexpensive. Advantages of this type of drilling include:

- Samples can be obtained without pulling the augers out of the hole. However, this is a poor method for obtaining grab samples from thin, discrete formations because of mixing of soils which occurs as the material is brought to the surface. Sampling of such formations will require the use of split-barrel or thin-wall tube samplers advanced through the hollow core of the auger.
- No drilling fluids are required.
- A well can be installed inside the auger stem and backfilled as the augers are withdrawn.

Disadvantages and limitations of this method of drilling include:

- Augering can only be done in unconsolidated materials.
- The inside diameter of hollow stem augers used for well installation should be at least 4 inches greater than the well casing. Use of such large-diameter hollow-stem augers is more expensive than the use of small-diameter augers in boreholes not used for well installation. Furthermore, the density of unconsolidated materials and depths become more of a limiting factor. More friction is produced with the larger diameter auger and subsequently greater torque is needed to advance the boring.
- The maximum effective depth for drilling is 150 feet or less, depending on site conditions and the size of augers used.
- In augering through clean sand formations below the water table, the sand will tend to flow into the hollow stem when the plug is removed for soil sampling or well installation. If the condition of "running" or "flowing" sands is persistent at a site, an alternative method of drilling is recommended, in particular for wells or boreholes deeper than 25 feet. Hollow-stem auger drilling is the preferred method of drilling. Most alternative methods require the introduction of water or mud downhole (air rotary is the exception).

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to maintain the open borehole. With these other methods great care must be taken to ensure that the method does not interfere with the collection of a representative sample which is the object of the construction. With this in mind, the preferred order of choice of drilling method after hollow-stem augering (HSA) is:

- Cable tool
- Casing drive (air)
- Air rotary
- Mud rotary
- Drive and wash
- Jetting

However, the use of any method will also depend on efficiency and cost effectiveness. In many cases, mud rotary is the only feasible alternative to hollow-stem augering. Thus, mud rotary drilling is generally acceptable as a first substitute for HSA.

The procedures for sampling soils through holes drilled by hollow-stem auger shall conform with the applicable ASTM Standards: D1587-83 and D1586-84. The hollow-stem auger may be advanced by any power-operated drilling machine having sufficient torque and ram range to rotate and force the auger to the desired depth. The machine must, however, be equipped with the accessory equipment needed to perform required sampling, or rock coring.

When taking soil samples for chemical analysis, the hollow-stem auger shall be plugged until the desired sampling depth is reached. Samples can be taken using split-spoon or thin-wall tube samplers driven into the formation in advance of the auger (see Procedure GH-1.3). If the sample is to be taken at a relatively deep point, the auger may be advanced without a plug to within 5 feet of the sample depth. Then clean out the auger stem, insert a plug and continue to the sampling depth. The plug is then removed and samples taken as specified by the rig geologist. Samples should be taken according to the specifications of the sampling plan. Any required sampling shall be performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool. The sequence shall be repeated for each sample desired.

The hollow-stem auger may be used without the plug when boring for geotechnical examination or for well installation.

When drilling below the water table, specially designed plugs which allow passage of formation water but not solid material shall be used (see Reference 1 of this guideline). This method also prevents blow back and plugging of the auger when the plug is removed for sampling.

Alternately, it may be necessary to keep the hollow stem full of water, at least to the level of the water table, to prevent blowback and plugging of the auger. If water is added to the hole, it must be sampled and analyzed to determine if it is free from contaminants prior to use. In addition, the amount of water introduced, the amount recovered upon attainment of depth, and the amount of water extracted during well development must be carefully logged in order to ensure that a representative sample of the formation water can be obtained. Well development should occur as soon after well completion as practicable (see GH-1.7 for Well Development Procedures). If gravelly or hard material is encountered which prevents advancing the auger to the desired depth, augering should be halted and either driven casing or hydraulic rotary methods should be attempted. If the depth to the bedrock/soil interface and bedrock lithology must be determined, then a 5-foot confirmatory core run should be conducted (see Section 5.2.9).

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At the option of the Field Operations Leader, when resistant materials prevent the advancement of the auger, a new boring can be attempted. The original boring must be properly backfilled and the new boring started a short distance away at a location determined by the site geologist. If multiple water bearing strata were encountered, the original boring must be grouted. In some formations it may be prudent to also grout borings which only penetrate the water table aquifer, since loose soil backfill in the boring would still provide a preferred pathway for surface liquids to reach the water table.

5.2.2 Continuous-Flight Solid-Stem Auger Drilling

This method is similar to hollow-stem augering. Practical application of this method is severely restricted as compared with hollow-stem augers. Split-barrel (split-spoon) sampling cannot be done without pulling the augers which may allow the hole to collapse. The method is therefore very time consuming and is not cost effective. Also, augers would have to be withdrawn before installing a monitoring well, which again, may allow the hole to collapse. Furthermore, geologic logging by examining the soils brought to the surface is unreliable as in the case of the hollow-stem auger, and depth to water may be difficult to determine while drilling.

There would be very few situations where use of a solid stem auger would be preferable to other drilling methods. The only practical applications of this method would be to drill boreholes for well installation where no lithologic information is desired and the soils are such that the borehole can be expected to remain open after the augers are withdrawn. Alternatively, the technique can be used to find depth to bedrock in an area when no other information is required from drilling.

5.2.3 Rotary Drilling

Direct rotary drilling includes air rotary and fluid rotary drilling. Air rotary drilling is a method of drilling where the drill rig simultaneously turns and exerts a downward pressure on the drilling rods and bit while circulating compressed air down the inside of the drill rods, around the bit, and out the annulus of the borehole. Air circulation serves to both cool the bit and remove the cuttings from the borehole. Advantages of this method include:

- The drilling rate is high (even in rock).
- The cost per foot of drilling is relatively low.
- Air rotary rigs are common in most areas.
- No drilling fluid is required (except when water is injected to keep down dust).
- The borehole diameter is large, to allow room for proper well installation procedures.

Disadvantages to using this method include:

- Formations must be logged from the cuttings that are blown to the surface and thus the depths of materials logged are approximate.
- Air blown into the formation during drilling may "bind" the formation and impede well development and natural groundwater flow.
- In-situ samples cannot be taken, unless the hole is cased.

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- Casing must generally be used in unconsolidated materials.
- Air rotary drill rigs are large and heavy.

A variation of the typical air-rotary drill bit is a down hole hammer which hammers the drill bit down as it drills. This makes drilling in hard rock faster. Air rotary drills can also be adapted to use for rock coring although they are generally slower than other types of core drills. A major application of the air-rotary drilling method would be to drill holes in rock for well installation.

Fluid-Rotary drilling operates in a similar manner to air rotary drilling except that a drilling fluid ("mud") or clean water is used in place of air to cool the drill bit and remove cuttings. There are a variety of fluids that can be used with this drilling method, including bentonite slurry and synthetic slurries. If a drilling fluid other than water/cuttings is used, it must be a natural clay (i.e., bentonite) and a "background" sample of the fluid should be taken for analysis of possible organic or inorganic contaminants.

Advantages to the fluid-rotary drilling method include:

- The ability to drill in many types of formations.
- Relatively quick and inexpensive.
- Split-barrel (split-spoon) or thin-wall tube samples can be obtained without removing drill rods if the appropriate size drill rods and bits (i.e., fish-tail or drag bit) are used.
- In some borings temporary casing may not be needed as the drilling fluids may keep the borehole open.
- Drill rigs are readily available in most areas.

Disadvantages to this method include:

- Formation logging is not as accurate as with hollow-stem auger method if split-barrel (split-spoon) samples are not taken (i.e., the depths of materials logged from cuttings delivered to the surface are approximate).
- Drilling fluids reduce permeability of the formation adjacent to the boring to some degree, and require more extensive well development than "dry" techniques (augering, air-rotary).
- No information on depth to water is obtainable while drilling.
- Fluids are needed for drilling, and there is some question about the effects of the drilling fluids on water samples obtained. For this reason as well, extensive well development may be required.
- In very porous materials (i.e., rubble fill, boulders, coarse gravel) drilling fluids may be continuously lost into the formation. This will require either constant replenishment of the drilling fluid, or the use of casing through this formation.

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- Drill rigs are large and heavy, and must be supported with supplied water.
- Groundwater samples can be potentially diluted with drilling fluid.

The procedures for performing direct rotary soil investigations and sampling shall conform with the applicable ASTM standards: D2113-83, D1587-83, and D1586-84.

For air or fluid rotary drilling, the rotary drill may be advanced to the desired depth by any power-operated drilling machine having sufficient torque and ram range to rotate and force the bit to the desired depth. The drilling machine must, however, be equipped with any accessory equipment needed to perform required sampling, or coring. Prior to sampling, any settled drill cuttings in the borehole must be removed.

Soil samples shall be taken as specified by the Work Plan or more frequently if requested by the field geologist. Any required sampling shall be performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool.

When field conditions prevent the advancement of the hole to the desired depth, a new boring may be drilled at the request of the Field Operations Leader. The original boring shall be backfilled using methods and materials appropriate for the given site and a new boring started a short distance away at a location determined by the site geologist.

5.2.4 Reverse Circulation Rotary Drilling

The common reverse-circulation rig is a water or mud rotary rig with a large-diameter drill pipe which circulates the drilling water down the annulus and up the inside of the drill pipe (reverse flow direction from direct mud rotary). This type of rig is used for the construction of large-capacity production water wells and is not suited for small, water-quality sampling wells because of the use of drilling muds and the large-diameter hole which is created. A few special reverse-circulation rotary rigs are made with double-wall drill pipe. The drilling water or air is circulated down the annulus between the drill pipes and up inside the inner pipe.

Advantages of the latter method include:

- The formation water is not contaminated by the drilling water.
- Formation samples can be obtained, from known depths.
- When drilling with air, immediate information is available regarding the water-bearing properties of formations penetrated.
- Collapsing of the hole in unconsolidated formations is not as great a problem as when drilling with the normal air rotary rig.

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Disadvantages include:

- Double-wall, reverse-circulation drill rigs are very rare and expensive to operate.
- Placing cement grout around the outside of the well casing above a well screen often is difficult, especially when the screen and casing are placed down through the inner drill pipe before the drill pipe is pulled out.

5.2.5 Drill-through Casing Driver

The driven-casing method consists of alternately driving casing (fitted with a sharp, hardened casing shoe) into the ground using a hammer lifted and dropped by the drill rig or an air hammer and cleaning out the casing using a rotary chopping bit and air or water to flush out the materials. The casing is driven down in stages (usually 5 feet per stage). A continuous record is kept of the blows per foot in driving the casing (see Procedure GH-1.5). The casing is normally advanced by a 300-pound hammer falling freely through a height of 30 inches. Simultaneous washing and driving of the casing is not recommended. If this procedure is used, the elevations between which water is used in driving the casing should be recorded.

The driven casing method is used in unconsolidated formations only. When the boring is to be used for later well installation, the driven casing used should be at least 4 inches larger in diameter than the well casing to be installed. Advantages to this method of drilling include:

- Split-barrel (split-spoon) sampling can be conducted while drilling.
- Well installation is easily accomplished.
- Drill rigs used are relatively small and mobile.
- The use of casing minimizes flow into the hole from upper water-bearing layers; therefore multiple aquifers can be penetrated and sampled for rough field determinations of some water quality parameters.

Some of the disadvantages include:

- This method can only be used in unconsolidated formations.
- The method is slower than other methods (average drilling progress is 30 to 50 feet per day).
- Maximum depth of the borehole varies with the size of the drill rig and casing diameter used, and the nature of the formations drilled.
- The cost per hour or per foot of drilling may be substantially higher than other drilling methods.
- It is difficult and time consuming to pull back the casing if it has been driven very deep (deeper than 50 feet in many formations).

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5.2.6 Cable Tool Drilling

A cable tool rig uses a heavy, solid-steel, chisel-type drill bit ("tool") suspended on a steel cable, which when raised and dropped chisels or pounds a hole through the soils and rock. Drilling progress may be expedited by the use of "slip-jars" which serve as a cable-activated down hole percussion device to hammer the bit ahead.

When drilling through the unsaturated zone, some water must be added to the hole. The cuttings are suspended in the water and then bailed out periodically. Below the water table, after sufficient ground water enters the borehole to replace the water removed by bailing, no further water need be added.

When soft caving formations are encountered, it is usually necessary to drive casing as the hole is advanced to prevent collapse of the hole. Often the drilling can be only a few feet below the bottom of the casing. Because the drill bit is lowered through the casing, the hole created by the bit is smaller than the casing. Therefore, the casing (with a sharp, hardened casing shoe on the bottom) must be driven into the hole (see Section 5.2.5 of this guideline).

Advantages of the cable-tool method include the following:

- Information regarding water-bearing zones is readily available during the drilling. Even relative permeabilities and rough water quality data from different zones penetrated can be obtained by skilled operators.
- The cable-tool rig can operate satisfactorily in all formations, but is best suited for caving, boulder, cable or coarse gravel type formations (e.g., glacial till) or formations with large cavities above the water table (such as limestones).
- When casing is used, the casing seals formation water out of the hole, preventing down-hole contamination and allowing sampling of deeper aquifers for field-measurable water quality parameters.
- Split-barrel (split-spoon) or thin-wall tube samples can be collected through the casing.

Disadvantages include:

- Drilling is slow compared with rotary rigs.
- The necessity of driving the casing in unconsolidated formations requires that the casing be pulled back if exposure of selected water-bearing zones is desired. This process complicates the well completion process and often increases costs. There is also a chance that the casing may become stuck in the hole.
- The relatively large diameters required (minimum of 4-inch casing) plus the cost of steel casing result in higher costs compared to rotary drilling methods where casing is not required, such as use of a hollow-stem auger.
- Cable-tool rigs have largely been replaced by rotary rigs. In some parts of the U.S., availability may be difficult.

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5.2.7 Jet Drilling (Washing)

Jet drilling, which should be used only for piezometer or vadose zone sampler installation, consists of pumping water or drilling mud down through a small diameter (1/2- to 2-inch) standard pipe (steel or PVC). The pipe may be fitted with a chisel bit or a special jetting screen. Formation materials dislodged by the bit and jetting action of the water are brought to the surface through the annulus around the pipe. As the pipe is jetted deeper, additional lengths of pipe may be added at the surface.

Jet percussion is a variation of the jetting method, in which the casing is driven with a drive weight. Normally, this method is used to place 2-inch-diameter casing in shallow, unconsolidated sand formations but has been used to install 3- to 4-inch-diameter casings to 200 feet.

Jetting is acceptable in very soft formations, usually for shallow sampling, and when introduction of drilling water to the formation is acceptable. Such conditions would occur during rough stratigraphic investigation or installation of piezometers for water level measurement. Advantages of this method include:

- Jetting is fast and inexpensive.
- Because of the small amount of equipment required, jetting can be accomplished in locations where access by a normal drilling rig would be very difficult. For example, it would be possible to jet down a well point in the center of a lagoon at a fraction of the cost of using a drill rig.
- Jetting numerous well points just into a shallow water table is an inexpensive method for determining the water table contours, hence flow direction.

Disadvantages include the following:

- A large amount of foreign water or drilling mud is introduced above and into the formation to be sampled.
- Jetting is usually done in very soft formations which are subject to caving. Because of this caving, it is often not possible to place a grout seal above the screen to assure that water in the well is only from the screened interval.
- The diameter of the casing is usually limited to 2 inches; therefore, samples must be obtained by methods applicable to small diameter casings.
- Jetting is only possible in very soft formations that do not contain boulders or coarse gravel, and the depth limitation is shallow (about 30 feet without jet percussion equipment).
- Large quantities of water are often needed.

5.2.8 Drilling with a Hand Auger

This method is applicable wherever the formation, total depth of sampling, and the site and groundwater conditions are such as to allow hand auger drilling. Hand augering can also be

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considered at locations where drill rig access is not possible. All hand auger borings will be performed according to ASTM D1452-80.

Samples should be taken continuously unless otherwise specified by the Work Plan. Any required sampling is performed by rotation, pressing, or driving in accordance with the standard or approved method governing use of the particular sampling tool. Typical equipment used for sampling and advancing shallow "hand auger" holes are Iwan samplers (which are rotated) or post hole diggers (which are operated like tongs). This technique is slow but effective where larger pieces of equipment do not have access and where very shallow holes are desired (less than 5 feet). Surficial soils must be composed of relatively soft and non-cemented formations to allow penetration by the auger.

5.2.9 Rock Drilling and Coring

When soil borings cannot be continued using augers or rotary methods due to the hardness of the soil or when rock or large boulders are encountered, drilling and sampling can be performed using a diamond bit corer in accordance with ASTM D2113.

Drilling is done by rotating and applying downward pressure to the drill rods and drill bit. The drill bit is a circular, hollow, diamond-studded bit attached to the outer core barrel in a double-tube core barrel. The use of single-tube core barrels is not recommended, as the rotation of the barrel erodes the sample and limits its use for detailed geological evaluation. Water or air is circulated down through the drill rods and annular space between the core barrel tubes to cool the bit and remove the cuttings. The bit cuts a core out of the rock which rises into an inner barrel mounted inside the outer barrel. The inner core barrel and rock core are removed by lowering a wire line with a coupling into the drill rods, latching onto the inner barrel and withdrawing the inner barrel. A less efficient variation to this method utilizes a core barrel that cannot be removed without pulling all of the drill rods. This variation is practical only if less than 50 feet of core is required.

Core borings are made through the casing used for the soil borings. The casing must be driven and sealed into the rock formation to prevent seepage from the overburden into the hole to be cored (see Section 5.3 of this guideline). A double-tube core barrel with a diamond bit and reaming shell or equivalent should be used to recover rock cores of a size specified in the Work Plan. The most common core barrel diameters are listed in Attachment A. Soft or decomposed rock should be sampled with a driven split barrel whenever possible or cored with a Denison or Pitcher sampler.

When coring rock, including shale and claystone, the speed of the drill and the drilling pressure, amount and pressure of water, and length of run can be varied to give the maximum recovery from the rock being drilled. Should any rock formation be so soft or broken that the pieces continually fall into the hole, causing unsatisfactory coring, the hole should be reamed and a flush-joint casing installed to a point below the broken formation. The size of the flush-joint casing must permit securing the core size specified. When soft or broken rock is anticipated, the length of core runs should be reduced to less than 5 feet to avoid core loss and minimize core disturbance.

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Advantages of core drilling include:

- Undisturbed rock cores can be recovered for examination and/or testing.
- In formations in which the cored hole will remain open without casing, water from the rock fractures may be recovered from the well without the installation of a well screen and gravel pack.
- Formation logging is extremely accurate.
- Drill rigs are relatively small and mobile.

Disadvantages include:

- Water or air is needed for drilling.
- Coring is slower than rotary drilling (and more expensive).
- Depth to water cannot accurately be determined if water is used for drilling.
- The size of the borehole is limited.

This drilling method is useful if accurate determinations of rock lithology are desired or if open wells are to be installed into bedrock. To install larger diameter wells in coreholes, the hole must be reamed out to the proper size after boring, using air or mud rotary drilling methods.

5.2.10 Drilling & Support Vehicles

In addition to the drilling method required to accomplish the objectives of the field program, the type of vehicle carrying the drill rig and/or support equipment, and its suitability for the site terrain, will often be an additional deciding factor in planning the drilling program. The types of vehicles available are extensive, and depend upon the particular drilling subcontractor's fleet. Most large drilling subcontractors will have a wide variety of vehicle and drill types suited for most drilling assignments in their particular region, while smaller drilling subcontractors will usually have a fleet of much more limited diversity. The weight size, and means of locomotion (tires, tracks, etc.) of the drill rig must be selected to be compatible with the site terrain, to assure adequate mobility between borehole locations. Such considerations also apply to necessary support vehicles used to transport water and/or drilling materials to the drill rigs at the borehole locations. When the drill rigs or support vehicles do not have adequate mobility to easily traverse the site, provisions must be made for assisting equipment, such as bulldozers, winches, timber planking, etc., to maintain adequate progress during the drilling program.

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Some of the typical vehicles which are usually available for drill rigs and support equipment are:

- **Totally portable drilling/sampling equipment, where all necessary components (tripods, samplers, hammers, catheads, etc.) may be hand carried to the borehole site. Drilling/sampling methods used with such equipment include:**
 - Hand augers and lightweight motorized augers
 - Retractable plug samplers—driven by hand (hammer)
 - Motorized cathead - a lightweight aluminum tripod with a small gas-engine cathead mounted on one leg, used to install small-diameter cased borings. This rig is sometimes called a "monkey on a stick."
- **Skid-mounted drilling equipment containing a rotary drill or engine-driven cathead (to lift hammers and drill string), a pump, and a dismantled tripod. The skid is pushed, dragged, or winched (using the cathead drum) between boring locations.**
- **Small truck-mounted drilling equipment uses a jeep, stake body or other light truck (4 to 6 wheels), upon which are mounted the drill and/or a cathead, a pump, and a tripod or small drilling derrick. On some rigs the drill and/or a cathead are driven by a power take-off from the truck, instead of by a separate engine.**
- **Track-mounted drilling equipment is similar to truck-mounted rigs, except that the vehicle used has wide bulldozer tracks for traversing soft ground. Sometimes a continuous-track "all terrain vehicle" is also modified for this purpose. Some types of tracked drill rigs are called "bombardier" or "weasel" rigs.**
- **Heavy truck-mounted drilling equipment is mounted on tandem or dual tandem trucks to transport the drill, derrick, winches, and pumps or compressors. The drill may be provided with a separate engine or may use a power take-off from the truck engine. Large augers, hydraulic rotary and reverse circulation rotary drilling equipment are usually mounted on such heavy duty trucks. For soft-ground sites, the drilling equipment is sometimes mounted on and off the road vehicle having low pressure, very wide diameter tires and capable of floating; these vehicles are called "swamp buggy" rigs.**
- **Marine drilling equipment is mounted on various floating equipment for drilling borings in lakes, estuaries and other bodies of water. The floating equipment varies, and is often manufactured or customized by the drilling subcontractor to suit specific drilling requirements. Typically, the range of flotation vehicles includes:**
 - **Barrel float rigs - a drill rig mounted on a timber platform buoyed by empty 55-gallon drums or similar flotation units.**
 - **Barge-mounted drill rigs.**
 - **Jack-up platforms - drilling equipment mounted on a floating platform having retractable legs to support the unit on the sea or lake bed when the platform is jacked up out of the water.**
 - **Drill ships - for deep ocean drilling.**

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In addition to the mobility for the drilling equipment, similar consideration must be given for equipment to support the drilling operations. Such vehicles or floating equipment are needed to transport drill water, drilling supplies and equipment, samples, drilling personnel, etc. to and/or from various boring locations.

5.2.11 Equipment Sizes

In planning subsurface exploration programs, care must be taken in specifying the various drilling components, so that they will fit properly in the boring or well.

For drilling open boreholes using rotary drilling equipment, tri-cone drill bits are employed with air, water or drilling mud to remove cuttings and cool the bit. Tri-cone bits are slightly smaller than the holes they drill (i.e., 5-7/8-inch or 7-7/8-inch bits will nominally drill 6-inch and 8-inch holes, respectively).

For obtaining split-barrel samples of a formation, samplers are manufactured in sizes ranging from 2 inches to 4-1/2 inches in outside diameter. However, the most commonly used size is the 2-inch O.D., 1-3/8-inch I.D. split-barrel sampler. When this sampler is used, and driven by a 140-pound (± 2 -pound) hammer dropping 30 inches (± 1 inch), the procedure is called a Standard Penetration Test, and the blows per foot required to advance the sampler into the formation can be correlated to the formation's density or strength.

In planning the drilling of boreholes using hollow-stem augers or casing, in which thin-wall tube samples or diamond core drilling will be performed, refer to the various sizes and clearances provided in Attachment A of this guideline. Sizes selected must be stated in the Work Plan.

5.2.12 Estimated Drilling Progress

To estimate the anticipated rates of drilling progress for a site the following must be considered:

- The speed of the drilling method employed.
- Applicable site conditions (e.g., terrain, mobility between borings, difficult drilling conditions in bouldery soils, rubble fill or broken rock, etc.).
- Project-imposed restrictions (e.g., drilling while wearing personal protective equipment, decontamination of drilling equipment, etc.).

Based on recent experience in drilling average soil conditions (no boulders) and taking samples at 5-foot intervals, for moderate depth (30 feet to 50 feet) boreholes (not including installation or development of wells), the following daily rates of total drilling progress may be anticipated for the following drilling methods:

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Drilling Method	Average Daily Progress (linear feet)
Hollow-stem augers	75'
Solid-stem augers	50'
Mud Rotary Drilling	100' (cuttings samples)
Reverse Circulation Rotary	100' (cuttings samples)
Skid Rig with driven casing	30'
Rotary with driven casing	50'
Cable Tool	30'
Hand Auger	Varies
Continuous Rock Coring	50'

5.3 PREVENTION OF CROSS-CONTAMINATION

A telescoping or multiple casing technique minimizes the potential for the migration of contaminated groundwater to lower strata below a confining layer. The telescoping technique consists of drilling to a confining layer utilizing a spun casing method with a diamond cutting or augering shoe, (a method similar to the rock coring method described in Section 5.2.9, except that larger casing is used) or a driven-casing method (see Section 5.2.5 of this guideline), and installing a specified diameter steel well casing. The operation consists of three separate steps. Initially, a drilling casing usually of 8-inch diameter is installed followed by installation of the well casing (6-inch-diameter is common for 2-inch wells). This well casing is driven into the confining layer to insure a tight seal at the bottom of the hole. The well casing is sealed at the bottom with a bentonite-cement slurry. The remaining depth of the boring is drilled utilizing a narrower diameter spun or driven casing technique within the outer well casing. A smaller diameter well casing with an appropriate length of slotted screen on the lower end is installed to the surface.

Clean sand is placed in the annulus around and to a point about 2 feet above the screen prior to withdrawal of the drilling casing. The annular space above the screen and to a point 2 feet above the bottom of the outer well casing is sealed with a tremied cement-bentonite slurry which is pressure-grouted or displacement-grouted into the hole. The remaining casing annulus is backfilled with clean material and grouted at the surface, or it is grouted all the way to the surface.

5.4 CLEANOUT OF CASING PRIOR TO SAMPLING

The boring hole must be completely cleaned of disturbed soil, segregated coarse material and clay adhering to the inside walls of the casing. The cleaning must extend to the bottom edge of the casing and, if possible, a short distance further (1 or 2 inches) to bypass disturbed soil resulting from the advancement of the casing. Loss of wash water during cleaning should be recorded.

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For disturbed samples both above and below the water table and where introduction of relatively large volumes of wash water is permissible, the cleaning operation is usually performed by washing the material out of the casing with water; however, the cleaning should never be accomplished with a strong, downward-directed jet which will disturb the underlying soil. When clean-out has reached the bottom of the casing or slightly below (as specified above), the string of tools should be lifted one foot off the bottom with the water still flowing, until the wash water coming out of the casing is clear of granular soil particles. In formations where the cuttings contain gravel and other larger particles, it is often useful to repeatedly raise and lower the drill rods and wash bit while washing out the hole, to surge these large particles upward out of the hole. As a time saver, the drilling contractor may be permitted to use a split-barrel (split-spoon) sampler with the ball check valve removed as the clean-out tool, provided the material below the spoon is not disturbed and the shoe of the spoon is not damaged. However, because the ball check valve has been removed, in some formations it may be necessary to install a flap valve or spring sample retainer in the split-spoon bit, to prevent the sample from falling out as the sampler is withdrawn from the hole. The use of jet-type chopping bits is discouraged except where large boulders and cobbles or hard-cemented soils are encountered. If water markedly softens the soils above the water table, clean-out should be performed dry with an auger.

For undisturbed samples below the water table, or where wash water must be minimized, clean out is usually accomplished with an appropriate diameter clean-out auger. This auger has cutting blades at the bottom to carry loose material up into the auger, and up-turned water jets just above the cutting blades to carry the removed soil to the surface. In this manner there is a minimum of disturbance at the top of the material to be sampled. If any gravel material washes down into the casing and cannot be removed by the cleanout auger, a split-barrel sample can be taken to remove it. Bailers and sandpumps should not be used. For undisturbed samples above the groundwater table, all operations must be performed in a dry manner.

If all of the cuttings created by drilling through the overlying formations are not cleaned from the borehole prior to sampling, some of the problems which may be encountered during sampling include:

- When sampling is attempted through the cuttings remaining in the borehole, all or part of the sampler may become filled with the cuttings. This limits the amount of sample from the underlying formation which can enter and be retained in the sampler, and also raises questions on the validity of the sample.
- If the cuttings remaining in the borehole contain coarse gravel and/or other large particles, these may block the bit of the sampler and prevent any materials from the underlying formation from entering the sampler when the sampler is advanced.
- In cased borings, should sampling be attempted through cuttings which remain in the lower portion of the casing, these cuttings could cause the sampler to become bound into the casing, such that it becomes very difficult to either advance or retract the sampler.
- When sampler blow counts are used to estimate the density or strength of the formation being sampled, the presence of cuttings in the borehole will usually give erroneously high sample blow counts.

To confirm that all cuttings have been removed from the borehole prior to attempting sampling, it is important that the rig geologist measure the "stickup" of the drill string. This is accomplished by

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measuring the assembled length of all drill rods and bits or samplers (the drill string) as they are lowered to the bottom of the hole, below some convenient reference point of the drill string; then to measure the height of this reference point above the ground surface. The difference of these measurements is the depth of the drill string (lower end of the bit or sampler) below the ground surface, which must then be compared with the depth of sampling required (installed depth of casing or depth of borehole drilled). If the length of drill string below grade is more than the drilled or casing depth, the borehole has been cleaned too deeply, and this deeper depth of sampling must be recorded on the log. If the length of drill string below grade is less than the drilled or casing depth, the difference represents the thickness of cuttings which remain in the borehole. In most cases, an inch or two of cuttings may be left in the borehole with little or no problem. However, if more than a few inches for cuttings are encountered, the borehole must be recleaned prior to attempting sampling.

5.5 MATERIALS OF CONSTRUCTION

The effects of monitoring well construction materials on specific chemical analytical parameters are described and/or referenced in FT-7.01. However, there are several materials used during drilling, particularly drilling fluids and lubricants, which must be used with care to avoid compromising the representativeness of soil and ground water samples.

The use of synthetic or organic polymer slurries is not permitted at any location where soil samples for chemical analysis are to be collected. These slurry materials could be used for installation of long term monitoring wells, but the early time data in time series collection of ground water data may then be suspect. If synthetic or organic polymer muds are proposed for use at a given site, a complete written justification including methods and procedures for their use must be provided by the site geologist and approved by the site manager. The specific slurry composition and the concentration of selected chemicals for each site must be known.

For many drilling operations, potable water is an adequate lubricant for drill stem and drilling tool connections. However, there are instances, such as drilling in tight clayey formations or in loose gravels, when threaded couplings must be lubricated to avoid binding. In these instances, to be determined in the field at the judgment of the site geologist and noted in the Site Logbook, and only after approval by the site manager, a vegetable oil or silicone based lubricant should be used. Petroleum based greases, etc. will not be permitted. Samples of lubricants used must be provided and analyzed for chemical parameters appropriate to the given site.

5.6 SUBSURFACE SOIL SAMPLES

Subsurface soil samples are used to characterize subsurface stratigraphy. This characterization can indicate the potential for migration of chemical contaminants in the subsurface. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of the soil samples. Where the remedial activities may include in-situ treatment or the excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

Engineering and physical properties of soil may also be of interest should site construction activities be planned. Soil types, grain size distribution, shear strength, compressibility, permeability, plasticity, unit weight, and moisture content are some of the physical characteristics that may be determined for soil samples.

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Penetration tests are also described in this procedure. The tests can be used to estimate various physical and engineering parameters such as relative density, unconfined compressive strength, and consolidation characteristics of soils.

The procedures described here are representative of a larger number of possible drilling and sampling techniques. The choice of techniques is based on a large number of variables such as cost, local geology, etc. The final choice of methods must be made with the assistance of drilling subcontractors familiar with the local geologic conditions. Alternative techniques must be based upon the underlying principles of quality assurance implicit in the following procedures.

5.6.1 Equipment

The following equipment is used for subsurface soil sampling and test boring:

- Drilling equipment, provided by subcontractor.
- Split-barrel (split-spoon) samplers, O.D. 2 inches, I.D. 1-3/8 inches, either 20-inch or 26 inches long. Larger O.D. samplers are available if a larger volume of sample is needed. A common size is 3-inch O.D. (2-1/2-inch I.D.).
- Thin-walled tubes (Shelby), O.D. 2 to 5 inches, 18 to 54 inches long.
- Drive weight assembly, 140-lb. (± 2 lb.) weight, driving head and guide permitting free fall of 30 inches (± 1 inch).
- Drive weight assembly, 300-lb. (± 2 lb.) weight, driving head and guide permitting free fall of 18 inches (± 1 inch).
- Accessory equipment, including labels, logbook, paraffin, and sample jars.

5.6.2 Split-barrel (Split-Spoon) Sampling (ASTM D1586-84)

The following method will be used for split-barrel sampling:

- Clean out the borehole to the desired sampling depth using equipment that will ensure that the material to be sampled is not disturbed by the operation. In saturated sands and silts, withdraw the drill bit slowly to prevent loosening of the soil around the hole and maintain the water level in the hole at or above groundwater level.
- Side-discharge bits are permissible. A bottom-discharge bit shall not be used. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. Where casing is used, it may not be driven below the sampling elevation.
- Install the split-barrel sampler and sampling rods into the boring to the desired sampling depth. After seating the sampler by means of a single hammer blow, three 6-inch increments shall be marked on the sampling rod so that the progress of the sampler can be monitored.

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- The 2-inch O.D. split-barrel sampler shall be driven with blows from a 140-lb. (± 2 lb.) hammer falling 30 inches (± 1 inch) until either a total of 50 blows have been applied during any one of the three 6-inch increments, a total of 100 blows have been applied, there is no observed advance of the sampler for 10 successive hammer blows, or until the sampler has advanced 18 inches without reaching any of the blow count limitation constraints described herein. This process is referred to as the Standard Penetration Test.
- A 300-lb. weight falling 18 inches is sometimes used to drive a 2-1/2-inch or 3-inch O.D. spoon sampler. This procedure is used where dense materials are encountered or when a large volume of sample is required. However, this method does not conform the ASTM specifications.
- Repeat this operation at intervals not greater than 5 feet in homogeneous strata, or as specified in the sampling plan.
- Record the number of blows required to effect each 6 inches of penetration or fraction thereof. The first 6 inches is considered to be seating drive. The sum of the number of blows required for the second and third 6 inches of penetration is termed the penetration resistance, N. If the sampler is driven less than 18 inches, the penetration resistance is that for the last 1 foot penetrated.
- Bring the sampler to the surface and remove both ends and one-half of the split barrel so that the soil recovered rests in the remaining half of the barrel. Describe carefully the sample interval, recovery (length), composition, structure, consistency, color, condition, etc., of the recovered soil then put a representative portion of each sample into a jar, without ramming. Jars with samples not taken for chemical analysis shall be sealed with wax, or hermetically sealed (using a teflon cap liner) to prevent evaporation of the soil moisture, if the sample is to be later evaluated for moisture content. Affix labels to the jar and complete Chain-of-Custody and other required sample data forms. Protect samples against extreme temperature changes and breakage by placing them in appropriate cartons stored in a protected area. Pertinent data which shall be noted on the label or written on the jar lid for each sample includes the project number, boring number, sample number, depth interval, blow counts, and date of sampling.
- An addition to the sampler mentioned above is an internal liner, which is split longitudinally and has a thin-wall brass, steel, or paper liner inserted inside, which will preserve the sample. However, since the development of the thin-walled samplers (mentioned below) the split-barrel sampler with liner has declined in use.

5.6.3 Thin-Walled Tube (Shelby Tube) Sampling (ASTM D1587-83)

When it is desired to take undisturbed samples of soil, thin-walled seamless tube samplers (Shelby tubes) will be used. The following method will be used:

- Clean out the borehole to the sampling depth, being careful to minimize the chance for disturbance of the material to be sampled. In saturated materials, withdraw the drill bit slowly to prevent loosening of the soil around the borehole and maintain the water level in the hole at or above groundwater level.

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- The use of bottom discharge bits or jetting through an open-tube sampler to clean out the hole shall not be allowed. Any side discharge bits are permitted.
- A stationary piston-type sampler may be required to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used. Prior to inserting the tube sampler in the hole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the sampling rods from pushing the sample out of the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.
- To minimize chemical reaction between the sample and the sampling tube, brass tubes may be required, especially if the tube is stored for an extended time prior to testing. While steel tubes coated with shellac are less expensive than brass, they are more reactive, and shall only be used when the sample will be tested within a few days after sampling or if chemical reaction is not anticipated. With the sampling tube resting on the bottom of the hole and the water level in the boring at the groundwater level or above, push the tube into the soil by a continuous and rapid motion, without impacting or twisting. In no case shall the tube be pushed farther than the length provided for the soil sample. Allow about 3 inches in the tube for cuttings and sludge.
- Upon removal of the sampler tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of soil from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Newspaper or other types of filler must be placed in voids at either end of the sampler prior to sealing with wax. Place plastic caps on the ends of the sampler, tape in the caps place, and dip the ends in wax.
- Affix labels to the tubes as required and record sample number, depth, penetration, and recovery length on the label. Mark the same information and "up" direction on the tube with indelible ink, and mark the end of the sample. Complete Chain-of-Custody and other required forms. Do not allow tubes to freeze and store the samples vertically (with the same orientation they had in the ground, i.e., top of sample is up) in a cool place out of the sun at all times. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.

Thin-walled undisturbed tube samplers are restricted in their usage by the consistency of the soil to be sampled. Often, very loose and/or wet samples cannot be retrieved by the samplers, and soils with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Denison or Pitcher core samplers can be used to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs and therefore their use shall be weighed against the increased cost and the need for an undisturbed sample. In any case, if a sample cannot be obtained with a tube sampler, an attempt shall be made with a split-barrel sampler at the same depth so that at least a sample can be obtained for classification purposes.

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5.6.4 Continuous Core Soil Samples

The CME continuous sample tube system provides a method of sampling soil continuously during hollow-stem augering. The 5-foot sample barrel fits within the lead auger of a hollow-auger column. The sampling system can be used with a wide range of I.D. hollow-stem augers (from 3-1/4-inch to 8-1/4-inch I.D.). This method has been used to sample many different materials such as glacial drift, hard clays and shales, mine tailings, etc. This method is particularly used when SPT samples are not required and a large volume of material is needed. Also, this method is useful when a visual description of the subsurface lithology is required.

5.7 SURFACE SOIL SAMPLES

For loosely packed earth or waste pile samples, stainless steel scoops or trowels can be used to collect representative samples. For densely packed soils or deeper soil samples, a hand or power soil auger may be used.

The following methods are to be used:

- Use a soil auger for deep samples (6 to 24 inches) or a scoop or trowel for surface samples. Remove debris, rocks, twigs, and vegetation before collection of soil. Mark the location with a numbered stake if possible and locate sample points on a sketch of the site.
- Use a new or freshly-decontaminated sampler for each sample taken. Attach a label and identification tag. Record all required information in the field logbook and on the sample log sheet, Chain-of-Custody record, and other required forms.
- Pack and ship accordingly.
- When a representative composited sample is to be prepared (e.g., samples taken from a gridded area or from several different depths), it is best to composite individual samples in the laboratory where they can be more precisely composited on a weight or volume basis. If this is not possible, the individual samples (all of equal volume, i.e., the sample bottles shall be full) shall be placed in a decontaminated stainless steel bucket, mixed thoroughly using a stainless steel spatula or trowel, and a composite sample collected.

5.8 WASTE PILE SAMPLES

The use of stainless steel scoops or trowels to obtain small discrete samples of homogeneous waste piles is usually sufficient for most conditions. Layered (nonhomogeneous) piles require the use of tube samplers to obtain cross-sectional samples.

- Collect small, equal portions of the waste from several points around the pile, penetrating it as far as practical. Use numbered stakes, if possible, to mark the sampling locations and locate sampling points on the site sketch.
- Place the waste sample in a glass container. Attach a label and identification tag. Record all the required information in the field logbook and on the sample log sheet and other required forms.

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For layered, nonhomogeneous piles, grain samplers, sampling triers, or waste pile samplers must be used at several representative locations to acquire a cross section of the pile. The basic steps to obtain each sample are:

- Insert a sampler into the pile at a 0- to 45-degree angle from the horizontal to minimize spillage.
- Rotate the sampler once or twice to cut a core of waste material. Rotate the grain sampler inner tube to the open position and then shake the sampler a few times to allow the material to enter the open slits. Move the sampler into position with slots upward (grain sampler closed) and slowly withdraw from the pile.

5.9 ROCK SAMPLING (CORING) (ASTM D2113-83)

Rock coring enables a detailed assessment of borehole conditions to be made, showing precisely all lithologic changes and characteristics. Because coring is an expensive drilling method, it is commonly used for shallow studies of 500 feet or less, or for specific intervals in the drill hole that require detailed logging and/or analyzing. It can, however, proceed for thousands of feet continuously, depending on the size of the drill rig. It yields better quality data than air rotary drilling, although at a substantially reduced drilling rate. Rate of drilling varies widely, depending on the characteristics of lithologies encountered, drilling methods, depth of drilling, and condition of drilling equipment. Average output in a 10-hour day ranges from 40 to over 200 feet. Downhole geophysical logging or television camera monitoring is sometimes used to complement the data generated by coring.

Borehole diameter can be drilled to various sizes, depending on the information needed. Standard sizes of core barrels (showing core diameter) and casing are shown in Attachment No. 1.

Core drilling is used when formations are too hard to be sampled by soil sampling methods and a continuous solid sample is desired. Usually, soil samples are used for overburden, and coring begins in sound bedrock. Casing is set into bedrock before coring begins to prevent loose material from entering the borehole, to prevent loss of drilling fluid, and to prevent cross contamination of aquifers.

Drilling through bedrock is initiated by using a diamond-tipped core bit threaded to a drill rod (outer core barrel) with a rate of drilling determined by the downward pressure, rotation speed of drill rods, drilling fluid pressure in the borehole, and the characteristics of the rock (mineralogy, cementation, weathering).

5.9.1 Diamond Core Drilling

A penetration of typically less than 6 inches per 50 blows using a 140-lb. hammer dropping 30 inches with a 2-inch split-spoon sampler shall be considered an indication that soil sampling methods may not be applicable and that coring may be necessary to obtain samples.

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When formations are encountered that are too hard to be sampled by soil sampling methods, the following diamond core drilling procedure may be used.

- Firmly seat a casing into the bedrock or the hard material to prevent loose materials from entering the hole and to prevent the loss of drilling fluid return. Level the surface of the rock or hard material when necessary by the use of a fishtail or other bits. If the drill hole can be retained open without the casing and if cross contamination of aquifers in the unconsolidated materials is unlikely, it may be omitted.
- Begin the core drilling using a double-tube swivel-core barrel of the desired size. After drilling no more than 10 feet (3 m), remove the core barrel from the hole, and take out the core. If the core blocks the flow of the drilling fluid during drilling, remove the core barrel immediately. In soft materials, a large starting size may be specified for the coring tools; where local experience indicates satisfactory core recovery or where hard, sound materials are anticipated, a smaller size or the single-tube type may be specified and longer runs may be drilled. NX/NW size coring equipment is the most commonly used size.
- When soft materials are encountered that produce less than 50 percent recovery, stop the core drilling. If soil samples are desired, secure such samples in accordance with the procedures described in ASTM Method D 1586 (Split-barrel Sampling) or in Method D 1587 (Thin-Walled Tube Sampling) for Sampling of Soils (see Section 5.1.1 and 5.1.2). Resume diamond core drilling when refusal materials are again encountered.
- Since rock structures and the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described, take special care to obtain and record these features. If such broken zones or cavities prevent further advance of the boring, one of the following three steps shall be taken: (1) cement the hole; (2) ream and case; or (3) case and advance with the next smaller size core barrel, as the conditions warrant.
- In soft, seamy, or otherwise unsound rock, where core recovery may be difficult, M-design core barrels may be used. In hard, sound rock where a high percentage of core recovery is anticipated, the single-tube core barrel may be employed.

5.9.2 Rock Sample Preparation and Documentation

Once the rock coring has been completed and the core recovered, the rock core shall be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery as well as the rock quality designation (RQD). Each core shall be described, classified, and logged using a uniform system as presented in Procedure GH-1.4. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of clay formations) or oxidation of the core, the core shall be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number, and the footage represented in each sleeve shall be included, as well as the top and bottom of the core run.

After sampling, rock cores shall be placed in the sequence of recovery in well-constructed wooden boxes provided by the drilling contractor. Rock cores from two different borings shall not be placed in the same core box unless accepted by the Site Geologist. The core boxes shall be constructed to accommodate at least 20 linear feet of core in rows of approximately 5 feet each and shall be

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constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened down. Wood partitions shall be placed at the end of each core run and between rows. The depth from the surface of the boring to the top and bottom of the drill run and run number shall be marked on the wooden partitions with indelible ink. A wooden partition (wooden block) shall be placed at the end of each run with the depth of the bottom of the run written on the block. These blocks will serve to separate successive core runs and indicate depth intervals for each run. The order of placing cores shall be the same in all core boxes. Rock core shall be placed in the box so that, when the box is open, with the inside of the lid facing the observer, the top of the cored interval contained within the box is in the upper left corner of the box, and the bottom of the cored interval is in the lower right corner of the box (see Attachment 2). The top and bottom of each core obtained and its true depth shall be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, an empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box.

The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data on the box's contents. At a minimum, the following information shall be included:

- Project name
- Project number
- Boring number
- Run numbers
- Footage (depths)
- Recovery
- RQD (%)
- Box number and total number of boxes for that boring (Example: Box 5 of 7).

For easy retrieval when core boxes are stacked, the sides and ends of the box shall also be labeled and include project number, boring number, top and bottom depths of core and box number. Attachment No. 2 illustrates a typical rock core box.

Prior to final closing of the core box, a photograph of the recovered core and the labeling on the inside cover shall be taken. If moisture content is not critical, the core shall be wetted and wiped clean for the photograph. (This will help to show true colors and bedding features in the cores).

6.0 REFERENCES

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7.0 ATTACHMENTS

Attachment A - Drilling Equipment Sizes.

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ATTACHMENT 1

STANDARD SIZES OF CORE BARRELS AND CASING

Coring Bit Size	Nominal*		Set Size*	
	O.D.	I.D.	O.D.	I.D.
RWT	1 5/32	3/4	1.160	.735
EWT	1 1/2	29/32	1.470	.905
EX, EXL, EWG, EWM	1 1/2	13/16	1.470	.845
AWT	1 7/8	1 9/32	1.875	1.281
AX, AXL, AWG, AWM	1 7/8	1 3/16	1.875	1.185
BWT	2 3/8	1 3/4	2.345	1.750
BX, BXL, BWG, BWM	2 3/8	1 5/8	2.345	1.655
NWT	3	2 5/16	2.965	2.313
NX, NXL, NWG, NWM	3	2 1/8	2.965	2.155
HWT	3 29/32	3 3/16	3.889	3.187
HWG	3 29/32	3	3.889	3.000
2 3/4 x 3 7/8	3 7/8	2 3/4	3.840	2.690
4 x 5 1/2	5 1/2	4	5.435	3.970
6 x 7 3/4	7 3/4	6	7.655	5.970
AX Wire line <u> </u> <u> </u> /	1 7/8	1	1.875	1.000
BX Wire line <u> </u> <u> </u> /	2 3/8	1 7/16	2.345	1.437
NX Wire line <u> </u> <u> </u> /	3	1 15/16	2.965	1.937

* All dimensions are in inches; to convert to millimeters, multiply by 25.4.

 | / Wire line dimensions and designations may vary according to manufacturer.

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**ATTACHMENT 1
STANDARD SIZES OF CORE BARRELS AND CASING
PAGE TWO**

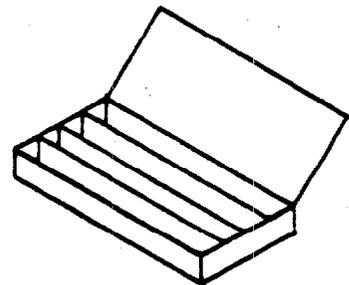
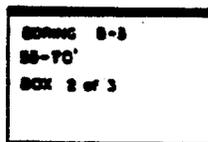
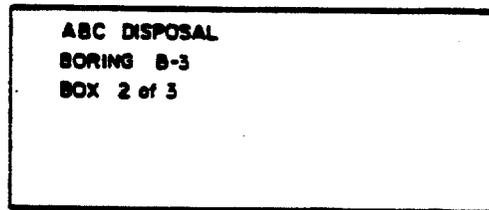
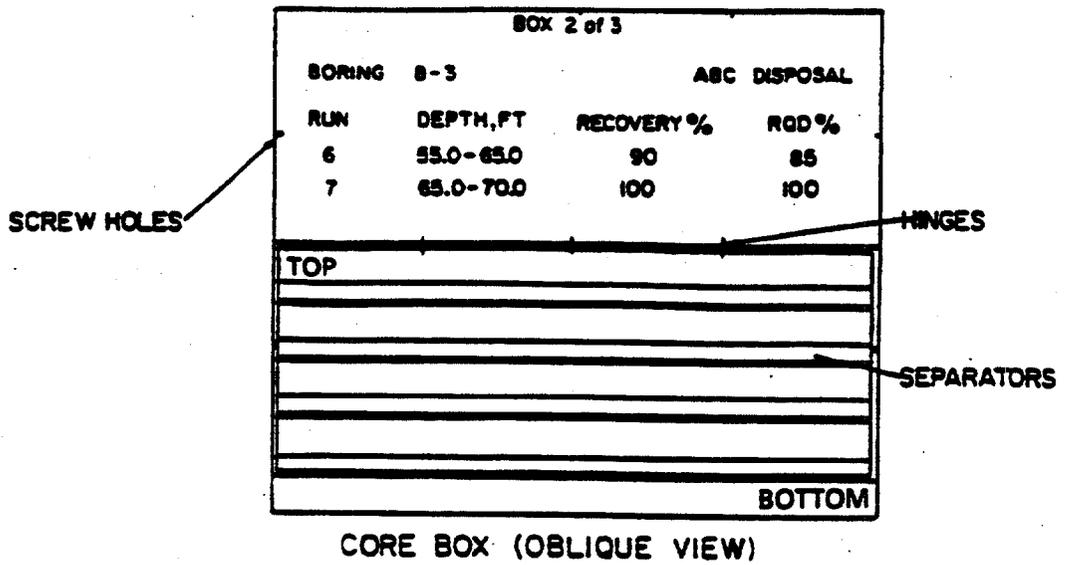
Size Designations		Casing O.D., Inches	Casing Coupling		Casing bit, O.D., Inches	Core barrel bit O.D., Inches*	Drill rod O.D., Inches	Approximate Core Diameter			
Casing; Casing coupling; Casing bits; Core barrel bits	Rod; Rod couplings		O.D., Inches	I.D., Inches				Normal, Inches	Thinwall, Inches		
RX	RW	1.437	1.437	1.188	1.485	1.160	1.094	—	.735		
EX	E	1.812	1.812	1.500	1.875	1.470	1.313	.845	.905		
AX	A	2.250	2.250	1.906	2.345	1.875	1.625	1.185	1.281		
BX	B	2.875	2.875	2.375	2.965	2.345	1.906	1.655	1.750		
NX	N	3.500	3.500	3.000	3.615	2.965	2.375	2.155	2.313		
HX	HW	4.500	4.500	3.938	4.625	3.890	3.500	3.000	3.187		
RW	RW	1.437			1.485	1.160	1.094	—	.735		
EW	EW	1.812			1.875	1.470	1.375	.845	.905		
AW	AW	2.250			2.345	1.875	1.750	1.185	1.281		
BW	BW	2.875			2.965	2.345	2.125	1.655	1.750		
NW	NW	3.500			3.615	2.965	2.625	2.155	2.313		
HW	HW	4.500			4.625	3.890	3.500	3.000	3.187		
PW	—	5.500			5.650	—	—	—	—		
SW	—	6.625			6.790	—	—	—	—		
UW	—	7.625			7.800	—	—	—	—		
ZW	—	8.625			8.810	—	—	—	—		
—	AX <u> </u> /	—			—	—	—	1.875	1.750	1.000	—
—	BX <u> </u> /	—			—	—	—	2.345	2.250	1.437	—
—	NX <u> </u> /	—			—	—	—	2.965	2.813	1.937	—

* For hole diameter approximation, assume 1/32-inch larger than core barrel bit.
 / Wire line designation, drill rod only, serves as both casing and drill rod. Wire line core bit, and core diameters vary slightly according to manufacturer.

NOMINAL DIMENSIONS FOR DRILL CASINGS AND ACCESSORIES. (DIAMOND CORE DRILL MANUFACTURERS ASSOCIATION). 288-D-2889.

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ATTACHMENT 2
TYPICAL ROCK CORE BOX
(NOT TO SCALE)



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ATTACHMENT A

DRILLING EQUIPMENT SIZES

Drilling Component	Designation or Hole Size (Inches)	O.D. (Inches)	I.D. (Inches)	Coupling I.D. (Inches)
Hollow-stem Augers (Ref. 7)	6 1/4	5	2 1/4	
	6 3/4	5 3/4	2 3/4	—
	7 1/4	6 1/4	3 1/4	—
	13 1/4	12	6	—
Thin Wall Tube Samplers (Ref. 7)	—	2	1 7/8	—
	—	2 1/2	2 3/8	—
	—	3	2 7/8	—
	—	3 1/2	3 3/8	—
	—	4 1/2	4 3/8	—
	—	5	4 3/4	—
Drill Rods (Ref. 7)	RW	1 3/32	23/32	13/32
	EW	1 3/8	15/16	7/16
	AW	1 3/4	1 1/4	5/8
	BW	2 1/8	1 3/4	3/4
	NW	2 5/8	2 1/4	1 3/8
	HW	3 1/2	3 1/16	2 3/8
	E	1 5/16	7/8	7/16
	A	1 5/8	1 1/8	9/16
	B	1 7/8	1 1/4	5/8
	N	2 3/8	2	1
				Wall Thickness (Inches)
Driven External Coupled Extra Strong Steel* Casing (Ref. 8)	2 1/2	2.875	2.323	0.276
	3	3.5	2.9	0.300
	3 1/2	4.0	3.364	0.318
	4	4.5	3.826	0.337
	5	5.63	4.813	0.375
	6	6.625	5.761	0.432
	8	8.625	7.625	0.500
	10	10.750	9.750	0.500
	12	12.750	11.750	0.500

* Add twice the casing wall thickness to casing O.D. to obtain the approximate O.D. of the external pipe couplings.

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**ATTACHMENT A
DRILLING EQUIPMENT SIZES
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Drilling Component	Designation or Hole Size (Inches)	O.D. (Inches)	I.D. (Inches)	Coupling I.D. (Inches)
Flush Coupled Casing (Ref. 7)	RX	1 7/16	1 3/16	1 3/16
	EX	1 13/16	1 5/8	1 1/2
	AX	2 1/4	2	1 29/32
	BX	2 7/8	2 9/16	2 3/8
	NX	3 1/2	3 3/16	3
	HX	4 1/2	4 1/8	3 15/16
Flush Joint Casing (Ref. 7)	RW	1 7/16	1 3/16	
	EW	1 13/16	1 1/2	
	AW	2 1/4	1 29/32	
	BW	2 7/8	2 3/8	
	NW	3 1/2	3	
	HW	4 1/2	4	
	PW	5 1/2	5	
	SW	6 5/8	6	
	UW	7 5/8	7	
	ZW	8 5/8	8	
Diamond Core Barrels (Ref. 7)	EWM	1 1/2	7/8**	
	AWM	1 7/8	1 1/8**	
	BWM	2 3/8	1 5/8**	
	NWM	3	2 1/8	
	HWG	3 7/8	3	
	2 3/4 x 3 7/8	3 7/8	2 11/16	
	4 x 5 1/2	5 1/2	3 15/16	
	6 x 7 3/4	7 3/4	5 15/16	
	AQ (wireline)	1 57/64	1 1/16**	
	BQ (wireline)	2 23/64	1 7/16**	
	NQ (wireline)	2 63/64	1 7/8	
	HQ (wireline)	3 25/32	2 1/2	

** Because of the fragile nature of the core and the difficulty to identify rock details, use of small-diameter core (1 3/8") is not recommended.



HALLIBURTON NUS
Environmental Corporation

**ENVIRONMENTAL
TECHNOLOGIES GROUP**

**STANDARD
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PROCEDURES**

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Revision
2

Applicability
ETG

Prepared
Earth Sciences

Approved
D. Senovich

Subject
BOREHOLE AND SAMPLE LOGGING

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1.0 PURPOSE

The purpose of this document is to establish standard procedures and technical guidance on borehole and sample logging.

2.0 SCOPE

These procedures provide descriptions of the standard techniques for borehole and sample logging. These techniques shall be used for each boring logged to provide consistent descriptions of subsurface lithology. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist/engineer can do a good job of classification by careful, thoughtful observation and by being consistent throughout the classification procedure.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Site Geologist. Responsible for supervising all boring activities and assuring that each borehole is completely logged. If more than one rig is being used onsite the Site Geologist must make sure that each field geologist is properly trained in logging procedures. A brief review or training session may be necessary prior to the start up of the field program and/or upon completion of the first boring.

5.0 PROCEDURES

The classification of soil and rocks is one of the most important jobs of the field geologist/engineer. To maintain a consistent flow of information, it is imperative that the field geologist/engineer understand and accurately use the field classification system described in this SOP. This identification is based on visual examination and manual tests.

5.1 MATERIALS NEEDED

When logging soil and rock samples, the geologist or engineer may be equipped with the following:

- Rock hammer
- Knife
- Camera
- Dilute HCl
- Ruler (marked in tenths and hundredths of feet)
- Hand Lens

5.2 CLASSIFICATION OF SOILS

All data shall be written directly on the boring log (Exhibit 4-1) or in a field notebook if more space is needed. Details on filling out the boring log are discussed in Section 5.5.

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5.2.1 USCS Classification

Soils are to be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in Exhibit 4-2. This method of classification identifies soil types on the basis of grain size and cohesiveness.

Fine-grained soils, or fines, are smaller than the No. 200 sieve and are of two types: silt (M) and clay (C). Some classification systems define size ranges for these soil particles, but for field classification purposes, they are identified by their respective behaviors. Organic material (O) is a common component of soil but has no size range; it is recognized by its composition. The careful study of the USCS will aid in developing the competence and consistency necessary for the classification of soils.

Coarse-grained soils shall be divided into rock fragments, sand, or gravel. The terms sand and gravel not only refer to the size of the soil particles but also to their depositional history. To insure accuracy in description, the term rock fragments shall be used to indicate angular granular materials resulting from the breakup of rock. The sharp edges typically observed indicate little or no transport from their source area, and therefore the term provides additional information in reconstructing the depositional environment of the soils encountered. When the term "rock fragments" is used it shall be followed by a size designation such as "(1/4 inch ϕ -1/2 inch ϕ)" or "coarse-sand size" either immediately after the entry or in the remarks column. The USCS classification would not be affected by this variation in terms.

5.2.2 Color

Soil colors shall be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light gray" or "blue-gray." Since color can be utilized in correlating units between sampling locations, it is important for color descriptions to be consistent from one boring to another.

Colors must be described while the sample is still moist. Soil samples shall be broken or split vertically to describe colors. Samplers tend to smear the sample surface creating color variations between the sample interior and exterior.

The term "mottled" shall be used to indicate soils irregularly marked with spots of different colors. Mottling in soils usually indicates poor aeration and lack of good drainage.

Soil Color Charts shall not be used unless specified by the project manager.

5.2.3 Relative Density and Consistency

To classify the relative density and/or consistency of a soil, the geologist is to first identify the soil type. Granular soils contain predominantly sands and gravels. They are noncohesive (particles do not adhere well when compressed). Finer-grained soils (silts and clays) are cohesive (particles will adhere together when compressed).

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The density of noncohesive, granular soils is classified according to standard penetration resistances obtained from split barrel sampling performed according to the methods detailed in Standard Operating Procedures GH-1.3 and SA-1.2. Those designations are:

Designation	Standard Penetration Resistance (Blows per Foot)
Very loose	0 to 4
Loose	5 to 10
Medium dense	11 to 30
Dense	31 to 50
Very dense	Over 50

Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a 2-inch outside diameter 12 inches into the material using a 140-pound hammer falling freely through 30 inches. The sampler is driven through an 18-inch sample interval, and the number of blows is recorded for each 6-inch increment. The density designation of granular soils is obtained by adding the number of blows required to penetrate the last 12 inches of each sample interval. It is important to note that if gravel or rock fragments are broken by the sampler or if rock fragments are lodged in the tip, the resulting blow count will be erroneously high, reflecting a higher density than actually exists. This shall be noted on the log and referenced to the sample number. Granular soils are given the USCS classifications GW, GP, GM, SW, SP, SM, GC, and SC (see Exhibit 4-2).

The consistency of cohesive soils is determined by performing field tests and identifying the consistency as shown in Exhibit 4-3. Cohesive soils are given the USCS classifications ML, MH, CL, CH, OL, or OH (see Exhibit 4-2).

The consistency of cohesive soils is determined either by blow counts, a pocket penetrometer (values listed in the table as Unconfined Compressive Strength) or by hand by determining the resistance to penetration by the thumb. The pocket penetrometer and thumb determination methods are conducted on a selected sample of the soil, preferably the lowest 0.5 foot of the sample in the split-barrel sampler. The sample shall be broken in half and the thumb or penetrometer pushed into the end of the sample to determine the consistency. Do not determine consistency by attempting to penetrate a rock fragment. If the sample is decomposed rock, it is classified as a soft decomposed rock rather than a hard soil. Consistency shall not be determined solely by blow counts. One of the other methods shall be used in conjunction with it. The designations used to describe the consistency of cohesive soils are as follows:

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Consistency	Unc. Compressive Str. Tons/Sq. Foot	Standard Penetration Resistance (Blows per Foot)	Field Identification Methods
Very soft	Less than 0.25	0 to 2	Easily penetrated several inches by fist
Soft	0.25 to 0.50	2 to 4	Easily penetrated several inches by thumb
Medium stiff	0.50 to 1.0	4 to 8	Can be penetrated several inches by thumb
Very stiff	1.0 to 2.0	8 to 15	Readily indented by thumb
Hard	2.0 to 4.0	15 to 30	Readily indented by thumbnail
Hard	More than 4.0	Over 30	Indented with difficulty by thumbnail

5.2.4 Weight Percentages

In nature, soils are comprised of particles of varying size and shape, and are combinations of the various grain types. The following terms are useful in the description of soil:

Terms of Identifying Proportion of the Component	Defining Range of Percentages by Weight
trace	0 - 10 percent
some	11 - 30 percent
and or adjective form of the soil type (e.g., "sandy")	31 - 50 percent

Examples:

- Silty fine sand: 50 to 69 percent fine sand, 31 to 50 percent silt.
- Medium to coarse sand, some silt: 70 to 80 percent medium to coarse sand, 11 to 30 percent silt.
- Fine sandy silt, trace clay: 50 to 68 percent silt, 31 to 49 percent fine sand, 1 to 10 percent clay.
- Clayey silt, some coarse sand: 70 to 89 percent clayey silt, 11 to 30 percent coarse sand.

5.2.5 Moisture

Moisture content is estimated in the field according to four categories: dry, moist, wet, and saturated. In dry soil, there appears to be little or no water. Saturated samples obviously have all the water they can hold. Moist and wet classifications are somewhat subjective and often are determined by the individual's judgment. A suggested parameter for this would be calling a soil wet if rolling it in the hand or on a porous surface liberates water, i.e., dirties or muddies the surface. Whatever method is adopted for describing moisture, it is important that the method used by an individual remains consistent throughout an entire drilling job.

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Laboratory tests for water content shall be performed if the natural water content is important.

5.2.6 Stratification

Stratification can only be determined after the sample barrel is opened. The stratification or bedding thickness for soil and rock is depending on grain size and composition. The classification to be used for stratification description is shown in Exhibit 4-4.

5.2.7 Texture/Fabric/Bedding

The texture/fabric/bedding of the soil shall be described. Texture is described as the relative angularity of the particles: rounded, subrounded, subangular, and angular. Fabric shall be noted as to whether the particles are flat or bulky and whether there is a particular relation between particles (i.e., all the flat particles are parallel or there is some cementation). The bedding or structure shall also be noted (e.g., stratified, lensed, nonstratified, heterogeneous varved).

5.2.8 Summary of Soil Classification

In summary, soils shall be classified in a similar manner by each geologist/engineer at a project site. The hierarchy of classification is as follows:

- Density and/or consistency
- Color
- Plasticity (Optional)
- Soil types
- Moisture content
- Stratification
- Texture, fabric, bedding
- Other distinguishing features

5.3 CLASSIFICATION OF ROCKS

Rocks are grouped into three main divisions, including sedimentary, igneous and metamorphic rocks. Sedimentary rocks are by far the predominant type exposed at the earth's surface. The following basic names are applied to the types of rocks found in sedimentary sequences:

- Sandstone - Made up predominantly of granular materials ranging between 1/16 to 2 mm in diameter.
- Siltstone - Made up of granular materials less than 1/16 to 1/256 mm in diameter. Fractures irregularly. Medium thick to thick bedded.
- Claystone - Very fine-grained rock made up of clay and silt-size materials. Fractures irregularly. Very smooth to touch. Generally has irregularly spaced pitting on surface of drilled cores.
- Shale - A fissile very fine-grained rock. Fractures along bedding planes.

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- Limestone - Rock made up predominantly of calcite (CaCO_3). Effervesces strongly upon the application of dilute hydrochloric acid.
- Coal - Rock consisting mainly of organic remains.
- Others - Numerous other sedimentary rock types are present in lesser amounts in the stratigraphic record. The local abundance of any of these rock types is dependent upon the depositional history of the area. These include conglomerate, halite, gypsum, dolomite, anhydrite, lignite, etc. are some of the rock types found in lesser amounts.

In classifying a sedimentary rock the following hierarchy shall be noted:

- Rock type
- Color
- Bedding thickness
- Hardness
- Fracturing
- Weathering
- Other characteristics

5.3.1 Rock Type

As described above, there are numerous names of sedimentary rocks. In most cases a rock will be a combination of several grain types, therefore, a modifier such as a sandy siltstone, or a silty sandstone can be used. The modifier indicates that a significant portion of the rock type is composed of the modifier. Other modifiers can include carbonaceous, calcareous, siliceous, etc.

Grain size is the basis for the classification of clastic sedimentary rocks. Exhibit 4-5 is the Udden-Wentworth classification that will be assigned to sedimentary rocks. The individual boundaries are slightly different than the USCS subdivision for soil classification. For field determination of grain sizes, a scale can be used for the coarse grained rocks. For example, the division between siltstone and claystone may not be measurable in the field. The boundary shall be determined by use of a hand lens. If the grains cannot be seen with the naked eye but are distinguishable with a hand lens, the rock is a siltstone. If the grains are not distinguishable with a hand lens, the rock is a claystone.

5.3.2 Color

The color of a rock can be determined in a similar manner as for soil samples. Rock core samples shall be classified while wet, when possible, and air cored samples shall be scraped clean of cuttings prior to color classifications.

Rock Color Charts shall not be used unless specified by the project manager.

5.3.3 Bedding Thickness

The bedding thickness designations applied to soil classification will also be used for rock classification.

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5.3.4 Hardness

The hardness of a rock is a function of the compaction, cementation, and mineralogical composition of the rock. A relative scale for sedimentary rock hardness is as follows:

- Soft - Weathered, considerable erosion of core, easily gouged by screwdriver, scratched by fingernail. Soft rock crushes or deforms under pressure of a pressed hammer. This term is always used for the hardness of the saprolite (decomposed rock which occupies the zone between the lowest soil horizon and firm bedrock).
- Medium soft - Slight erosion of core, slightly gouged by screwdriver, or breaks with crumbly edges from single hammer blow.
- Medium hard - No core erosion, easily scratched by screwdriver, or breaks with sharp edges from single hammer blow.
- Hard - Requires several hammer blows to break and has sharp conchoidal breaks. Cannot be scratched with screwdriver.

Note the difference in usage here of the words "scratch" and "gouge." A scratch shall be considered a slight depression in the rock (do not mistake the scraping off of rock flour from drilling with a scratch in the rock itself), while a gouge is much deeper.

5.3.5 Fracturing

The degree of fracturing or brokenness of a rock is described by measuring the fractures or joint spacing. After eliminating drilling breaks, the average spacing is calculated and the fracturing is described by the following terms:

- Very broken (V. BR.) - Less than 2-inch spacing between fractures
- Broken (BR.) - 2-inch to 1-foot spacing between fractures
- Blocky (BL.) - 1- to 3-foot spacing between fractures
- Massive (M.) - 3 to 10-foot spacing between fractures

The structural integrity of the rock can be approximated by calculating the Rock Quality Designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding 4 inches and dividing by the total length of the coring run, to obtain a percentage.

Method of Calculating RQD
(After Deere, 1964)

$$RQD \% = r/l \times 100$$

r = Total length of all pieces of the lithologic unit being measured, which are greater than 4 inches length, and have resulted from natural breaks. Natural breaks include slickensides, joints, compaction slicks, bedding plane partings (not caused by drilling), friable zones, etc.

l = Total length of the coring run.

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5.3.6 Weathering

The degree of weathering is a significant parameter that is important in determining weathering profiles and is also useful in engineering designs. The following terms can be applied to distinguish the degree of weathering:

- Fresh - Rock shows little or no weathering effect. Fractures or joints have little or no staining and rock has a bright appearance.
- Slight - Rock has some staining which may penetrate several centimeters into the rock. Clay filling of joints may occur. Feldspar grains may show some alteration.
- Moderate - Most of the rock, with exception of quartz grains, is stained. Rock is weakened due to weathering and can be easily broken with hammer.
- Severe - All rock including quartz grains is stained. Some of the rock is weathered to the extent of becoming a soil. Rock is very weak.

5.3.7 Other Characteristics

The following items shall be included in the rock description:

- Description of contact between two rock units. These can be sharp or gradational.
- Stratification (parallel, cross stratified)
- Description of any filled cavities or vugs.
- Cementation (calcareous, siliceous, hematitic)
- Description of any joints or open fractures.
- Observation of the presence of fossils.
- Notation of joints with depth, approximate angle to horizontal, any mineral filling or coating, and degree of weathering.

All information shown on the boring logs shall be neat to the point where it can be reproduced on a copy machine for report presentation. The data shall be kept current to provide control of the drilling program and to indicate various areas requiring special consideration and sampling.

5.3.8 Additional Terms Used in the Description of Rock

The following terms are used to further identify rocks:

- Seam - Thin (12 inch or less), probably continuous layer.
- Some - Indicates significant (15 to 40 percent) amounts of the accessory material. For example, rock composed of seams of sandstone (70 percent) and shale (30 percent) would be "sandstone - some shale seams."
- Few - Indicates insignificant (0 to 15 percent) amounts of the accessory material. For example, rock composed of seam of sandstone (90 percent) and shale (10 percent) would be "sandstone - few shale seams."

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- **Interbedded** - Used to indicate thin or very thin alternating seams of material occurring in approximately equal amounts. For example, rock composed of thin alternating seams of sandstone (50 percent) and shale (50 percent) would be "interbedded sandstone and shale."
- **Interlayered** - Used to indicate thick alternating seams of material occurring in approximately equal amounts.

The preceding sections describe the classification of sedimentary rocks. The following are some basic names that are applied to igneous rocks:

- **Basalt** - A fine-grained extrusive rock composed primarily of calcic plagioclase and pyroxene.
- **Rhyolite** - A fine-grained volcanic rock containing abundant quartz and orthoclase. The fine-grained equivalent of a granite.
- **Granite** - A coarse-grained plutonic rock consisting essentially of alkali feldspar and quartz.
- **Diorite** - A coarse-grained plutonic rock consisting essentially of sodic plagioclase and hornblende.
- **Gabbro** - A coarse-grained plutonic rock consisting of calcic plagioclase and clinopyroxene. Loosely used for any coarse grained dark igneous rock.

The following are some basic names that are applied to metamorphic rocks:

- **Slate** - A very fine-grained foliated rock possessing a well developed slaty cleavage. Contains predominantly chlorite, mica, quartz, and sericite.
- **Phyllite** - A fine-grained foliated rock that splits into thin flaky sheets with a silky sheen on cleavage surface.
- **Schist** - A medium to coarse-grained foliated rock with subparallel arrangement of the micaceous minerals which dominate its composition.
- **Gneiss** - A coarse-grained foliated rock with bands rich in granular and platy minerals.
- **Quartzite** - A fine- to coarse-grained nonfoliated rock breaking across grains, consisting essentially of quartz sand with silica cement.

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5.4 ABBREVIATIONS

Abbreviations may be used in the description of a rock or soil. However, they shall be kept at a minimum. Following are some of the abbreviations that may be used:

C - Coarse	Lt - Light	Yl - Yellow
Med - Medium	BR - Broken	Or - Orange
F - Fine	BL - Blocky	SS - Sandstone
V - Very	M - Massive	Sh - Shale
Sl - Slight	Br - Brown	LS - Limestone
Occ - Occasional	Bl - Black	Fgr - Fine grained
Tr - Trace		

5.5 BORING LOGS AND DOCUMENTATION

This section describes in more detail the procedures to be used in completing boring logs in the field. Information obtained from the preceding sections shall be used to complete the logs. A sample boring log has been provided as Exhibit 4-6. The field geologist/engineer shall use this example as a guide in completing each borings log. Each boring log shall be fully described by the geologist/engineer as the boring is being drilled. Every sheet contains space for 25 feet of log. Information regarding classification details is provided on the back of the boring log, for field use.

5.5.1 Soil Classification

- Identify site name, boring number, job number, etc. Elevations and water level data to be entered when surveyed data is available.
- Enter sample number (from SPT) under appropriate column. Enter depth sample was taken from (1 block = 1 foot). Fractional footages, i.e., change of lithology a 13.7 feet, shall be lined off at the proportional location between the 13- and 14-foot marks. Enter blow counts (Standard Penetration Resistance) diagonally (as shown). Standard penetration resistance is covered in Section 5.2.3.
- Determine sample recovery/sample length as shown. Measure the total length of sample recovered from the split spoon sampler, including material in the drive shoe. Do not include cuttings or wash material that may be in the upper portion of the sample tube.
- Indicate any change in lithology by drawing a line at the appropriate depth. For example, if clayey silt was encountered from 0 to 5.5 feet and shale from 5.5 to 6.0 feet, a line shall be drawn at this increment. This information is helpful in the construction of cross-sections. As an alternative, symbols may be used to identify each change in lithology.
- The density of granular soils is obtained by adding the number of blows for the last two increments. Refer to Density of Granular Soils Chart of back of log sheet. For consistency of cohesive soils refer also to the back of log sheet - Consistency of Cohesive Soils. Enter this information under the appropriate column. Refer to Section 5.2.3.

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- Enter color of the material in the appropriate column.
- Describe material using the USCS. Limit this column for sample description only. The predominate material is described last. If the primary soil is silt but has fines (clay) - use clayey silt. Limit soil descriptors to the following:
 - Trace 0 - 10 percent
 - Some 11 - 30 percent
 - And 31 - 50 percent
- Also indicate under Material Classification if the material is fill or natural soils. Indicate roots, organic material, etc.
- Enter USCS symbol - use chart on back of boring log as a guide. If the soils fall into one of two basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example ML/CL or SM/SP.
- The following information shall be entered under the Remarks Column and shall include, but is not limited by the following:
 - Moisture - estimate moisture content using the following terms - dry, moist, wet and saturated. These terms are determined by the individual. Whatever method is used to determine moisture, be consistent throughout the log.
 - Angularity - describe angularity of coarse grained particles using Angular, Subangular, Subrounded, Rounded. Refer to ASTM D 2488 or Earth Manual for criteria for these terms.
 - Particle shape - flat, elongated, or flat and elongated.
 - Maximum particle size or dimension.
 - Water level observations.
 - Reaction with HCl - none, weak or strong.
- Additional comments:
 - Indicate presence of mica, caving of hole, when water was encountered, difficulty in drilling, loss or gain of water.
 - Indicate odor and HNu or OVA reading if applicable.
 - Indicate any change in lithology by drawing in line through the lithology change column and indicate the depth. This will help later on when cross-sections are constructed.
 - At the bottom of the page indicate type of rig, drilling method, hammer size and drop and any other useful information (i.e., borehole size, casing set, changes in drilling method).

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- Vertical lines shall be drawn (as shown in Exhibit 4.6) in columns 5 to 8 from the bottom of each sample to the top of the next sample to indicate consistency of material from sample to sample, if the material is consistent. Horizontal lines shall be drawn if there is a change in lithology, then vertical lines drawn to that point.
- Indicate screened interval of well, as needed, in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.2 Rock Classification

- Indicate depth at which coring began by drawing a line at the appropriate depth. Indicate core run depths by drawing coring run lines (as shown) under the first and fourth columns on the log sheet. Indicate RQD, core run number, RQD percent and core recovery under the appropriate columns.
- Indicate lithology change by drawing a line at the appropriate depth as explained in Section 5.5.1.
- Rock hardness is entered under designated column using terms as described on the back of the log or as explained earlier in this section.
- Enter color as determined while the core sample is wet; if the sample is cored by air, the core shall be scraped clean prior to describing color.
- Enter rock type based on sedimentary, igneous or metamorphic. For sedimentary rocks use terms as described in Section 5.3. Again, be consistent in classification. Use modifiers and additional terms as needed. For igneous and metamorphic rock types use terms as described in Sections 5.3.8.
- Enter brokenness of rock or degree of fracturing under the appropriate column using symbols VBR, BR, BL, or M as explained in Section 5.3.5 and as noted on the back of the Boring Log.
- The following information shall be entered under the remarks column. Items shall include but are not limited to the following:
 - Indicate depths of joints, fractures and breaks and also approximate to horizontal angle (such as high, low), i.e., 70° angle from horizontal, high angle.
 - Indicate calcareous zones, description of any cavities or vugs.
 - Indicate any loss or gain of drill water.
 - Indicate drop of drill tools or change in color of drill water.
- Remarks at the bottom of Boring Log shall include:
 - Type and size of core obtained.
 - Depth casing was set.
 - Type of Rig used.

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- As a final check the boring log shall include the following:
 - Vertical lines shall be drawn as explained for soil classification to indicate consistency of bedrock material.
 - If applicable, indicate screened interval in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.3 Classification of Soil and Rock from Drill Cuttings

The previous sections describe procedures for classifying soil and rock samples when cores are obtained. However, some drilling methods (air/mud rotary) may require classification and borehole logging based on identifying drill cuttings removed from the borehole. Such cuttings provide only general information on subsurface lithology. Some procedures that shall be followed when logging cuttings are:

- Obtain cutting samples at approximately 5-foot intervals, sieve the cuttings (if mud rotary drilling) to obtain a cleaner sample, place the sample into a small sample bottle or "zip lock" bag for future reference, and label the jar or bag (i.e. hole number, depth, date, etc.). Cuttings shall be closely examined to determine general lithology.
- Note any change in color of drilling fluid or cuttings, to estimate changes in lithology.
- Note drop or chattering of drilling tools or a change in the rate of drilling, to determine fracture locations or lithologic changes.
- Observe loss or gain of drilling fluids or air (if air rotary methods are used), to identify potential fracture zones.
- Record this and any other useful information onto the boring log as provided in Exhibit 4-1.

This logging provides a general description of subsurface lithology and adequate information can be obtained through careful observation of the drilling process. It is recommended that split barrel and rock core sampling methods be used at selected boring locations during the field investigation to provide detailed information to supplement the less detailed data generated through borings drilled using air/mud rotary methods.

5.6 REVIEW

Upon completion of the borings logs, copies shall be made and reviewed. Items to be reviewed include:

- Checking for consistency of all logs
- Checking for conformance to the guideline
- Checking to see that all information is entered in their respective columns and spaces

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6.0 REFERENCES

Unified Soil Classification System (USCS)

ASTM D2488, 1985

Earth Manual, U.S. Department of the Interior, 1974

7.0 RECORDS

Originals of the boring logs shall be retained in the project files.

SOIL TERMS

UNIFIED SOIL CLASSIFICATION (USCS)									
COARSE-GRAINED SOILS More Than Half of Material is LARGER Than No. 200 Sieve Size				FINE-GRAINED SOILS More Than Half of Material is SMALLER Than No. 200 Sieve Size					
FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)			GROUP SYMBOL	TYPICAL NAMES	FIELD IDENTIFICATION PROCEDURES (Excluding Particles Larger Than 3 Inches and Basing Fractions on Estimated Weights)				
GRAVELS 50% (+) > 1/4" @	CLEAN GRAVELS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes. Predominantly one size or a range of sizes with some intermediate sizes missing.			FIELD IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN NO. 40 SIEVE SIZE				
	GRAVELS WITH FINES (High % Fines)	Non plastic fines (for identification procedures see ML)	GP	SILTS AND CLAYS Liquid Limit < 50	DAY STRENGTH (Crushing Characteristics)	DILATANCY (Reaction to Shaking)	TOUGHNESS (Consistency Near Plastic Limit)	GROUP SYMBOL	TYPICAL NAMES
Plastic fines (for identification procedures see CL)		GM	None to Slight						
SANDS 50% (+) < 1/4" @	CLEAN SANDS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes. Predominantly one size or a range of sizes with some intermediate sizes missing.	SW	SILTS AND CLAYS Liquid Limit > 50	Slight to Medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity
	SANDS WITH FINES (High % Fines)	Non plastic fines (for identification procedures see MC)	SP						
			SM	HIGHLY ORGANIC SOILS	None to Very High	None to Very Slow	Slight to Medium	OH	Organic clays of medium to high plasticity
			SC						
			Readily identified by color, odor, sponge feel and frequently by fibrous texture.						
			Peat and other organic soils						

Boundary classifications: Soils possessing characteristics of two groups are designated by combining group symbols. For example GW-GC, well graded gravel sand mixture with clay binder. All pore sizes on this chart are U.S. Standard.

DENSITY OF GRANULAR SOILS	
DESIGNATION	STANDARD PENETRATION RESISTANCE - BLOW/FOOT
Very Loose	0-4
Loose	5-10
Medium Dense	11-30
Dense	31-50
Very Dense	Over 50

CONSISTENCY OF COHESIVE SOILS			
CONSISTENCY	UNE COMPRESSIVE STRENGTH (TONS/SQ FT.)	STANDARD PENETRATION RESISTANCE - BLOW/FOOT	FIELD IDENTIFICATION METHODS
Very Soft	Less than 0.25	0 to 2	Easily penetrated several inches by fist.
Soft	0.25 to 0.50	2 to 4	Easily penetrated several inches by thumb
Medium Stiff	0.50 to 1.0	4 to 8	Can be penetrated several inches by thumb
Stiff	1.0 to 2.0	8 to 15	Readily indented by thumb
Very Stiff	2.0 to 4.0	15 to 30	Readily indented by thumbnail
Hard	More than 4.0	Over 30	Indented with difficulty by thumbnail

ROCK TERMS

ROCK HARDNESS (FROM CORE SAMPLES)			ROCK BROKENNESS		
Descriptive Terms	Screwdriver or Knife Effects	Hammer Effects	Descriptive Terms	Abbreviation	Spacing
Soft	Easily gouged	Crushes when pressed with hammer	Very Broken	(V. Br.)	0-2"
Medium Soft	Can be gouged	Breaks (some blow), crumbly edges	Broken	(Br.)	2"-1'
Medium Hard	Can be scratched	Breaks (some blow), sharp edges	Blocky	(Blk.)	1'-2'
Hard	Cannot be scratched	Breaks (some blow), sharp edges	Massive	(M)	2'-10'

LEGEND:

SOIL SAMPLES - TYPES
 S-2" O.D. Split-Barrel Sample
 ST-3" O.D. Undisturbed Sample
 O - Other Samples, Specify in Remarks

ROCK SAMPLES - TYPES
 X-NX (Conventional) Core (-3-1/8" O.D.)
 Q-NQ (Wireline) Core (-1-7/8" O.D.)
 Z - Other Core Sizes, Specify in Remarks

WATER LEVELS
 12/10
 ▽ 12.6' Initial Level w/Date & Depth
 12/10
 ▽ 12.6' Stabilized Level w/Date & Depth

Subject

BOREHOLE AND SAMPLE LOGGING

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EXHIBIT 4-3

CONSISTENCY FOR COHESIVE SOILS

Consistency	(Blows per Foot)	Unconfined Compressive Strength (tons/square foot by pocket penetration)	Field Identification
Very soft	0 to 2	Less than 0.25	Easily penetrated several inches by fist
Soft	2 to 4	0.25 to 0.50	Easily penetrated several inches by thumb
Medium stiff	4 to 8	0.50 to 1.0	Can be penetrated several inches by thumb with moderate effort
Stiff	8 to 15	1.0 to 2.0	Readily indented by thumb but penetrated only with great effort
Very stiff	15 to 30	2.0 to 4.0	Readily indented by thumbnail
Hard	Over 30	More than 4.0	Indented by thumbnail

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EXHIBIT 4-4

BEDDING THICKNESS CLASSIFICATION

Thickness (Metric)	Thickness (Approximate English Equivalent)	Classification
> 1.0 meter	> 3.3'	Massive
30 cm - 1 meter	1.0' - 3.3'	Thick Bedded
10 cm - 30 cm	4" - 1.0'	Medium Bedded
3 cm - 10 cm	1" - 4"	Thin Bedded
1 cm - 3 cm	2/5" - 1"	Very Thin Bedded
3 mm - 1 cm	1/8" - 2/5"	Laminated
1 mm - 3 mm	1/32" - 1/8"	Thinly Laminated
< 1 mm	< 1/32"	Micro Laminated

(Weir, 1973 and Ingram, 1954)

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EXHIBIT 4-5

GRAIN SIZE CLASSIFICATION FOR ROCKS

Particle Name	Grain Size Diameter
Cobbles	> 64 mm
Pebbles	4-64 mm
Granules	2-4 mm
Very Coarse Sand	1-2 mm
Coarse Sand	0.5-1 mm
Medium Sand	0.25-0.5 mm
Fine Sand	0.125-0.25 mm
Very Fine Sand	0.0625-0.125 mm
Silt	0.0039-0.0625 mm

After Wentworth, 1922

BORING LOG **NUS CORPORATION**

PROJECT: **HEBELKA SITE** BORING NO.: **MW 3A**
 PROJECT NO.: **619Y** DATE: **9-21-87** DRILLER: **B. GOLLIGUE**
 ELEVATION: **510.07** FIELD GEOLOGIST: **SJ CONT.**
 WATER LEVEL DATA: **WL 26.35 - TPVC 10-16-87**
 (Date, Time & Conditions):

SAMPLE NO. & TYPE	DEPTH (FT) / RUN NO.	ELEV. (FT) ON ROD	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (MATERIALS) OR SAMPLES	MATERIAL DESCRIPTION*			REMARKS
					SOIL BEHAVIOR CONSISTENCY OR ROCK CHARACTER	COLOR	MATERIAL CLASSIFICATION	
S-1	0.0 1.5	510.07 508.57	1.5 1.5		STIFF	BEN	CLAYEY SILT-TR SHALE	ML 0-6" TOP SOIL MOIST ORPM
							FRG-TR ORG.	RESIDUAL SOIL
	5.0							
S-2	6.0	507.07	0.3 1.0	5.5 6.0	M.SOFT	GRAY BEN	DEC SHALE AND SILT	VER DAMP ORPM
					TO			REFILL @ 6' 5.5 TOP OF DEC ROCK
					M.HARD			ADDED TO 15' 11" SOLID STEM AUG. CUTTING MOIST @ 28' WATER @ 11' 2
								WL @ 12:10 PM WAS 29' FROM GS.
								SET 4" PVC CAS. @ 13.0'
9-21	15.0							
9-22					M.HARD	GRAY	SILTY SHALE - FEW QUARTZ PCS	VER SEVERAL Fe STAINED JOINTS ON CORE THROUGHOUT RUN. JOINTS AND BREAKS ARE HORIZ TO LO & W/ VEGS ON LOWER PORTION 23 TO 25 OF CORE
	20.0	504.07	0.3 1.0	7.9 10.0				
	25.0							

REMARKS: ACCESS AD IT RIG - SOLID STEM AUGERS USED TO ADVANCE BORING - 140 LB WTE @ 30" DEEP - TO TAKE 2" Ø SP. SPOON SAMPLES - SET UP OVER HOLE @ 11:10 AM. WILL SAMPLE.
 * See Legend on back THIS HOLE - SET 4" CASING THEN DO SHALLOW WELL.
 STARTED TO CORE 9-22-87 USING THE WIRE-LINE CORING METHOD.

BORING LOG	NUS CORPORATION
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PROJECT: HEBELKA SITE **BORING NO.:** MW 3A
PROJECT NO.: 619Y **DATE:** 9-22-87 **DRILLER:** B. GOLLHUE
ELEVATION: **FIELD GEOLOGIST:** SJ CONTI
WATER LEVEL DATA: _____
 (Date, Time & Conditions) _____

SAMPLE NO. & TYPE	DEPTH (ft)	BLOW COUNT (ft)	SAMPLE RECOVERY (%)	LITHOLOGY CHANGE (ft)	MATERIAL DESCRIPTION*			REMARKS
					SOIL CONSISTENCY OR ROCK HARDNESS	COLOR	MATERIAL CLASSIFICATION	
9-22	25.0				M.HARD	GRAY	SILTY SHALE (SILTSTONE)	VBR SHALE IS VBR W/ HORIZ TO 1.0 & INTS 2-26 TO 27 2" VERT JOINTS. IRON STAINS ON INTS. ROCK BECOMES AND BREAKS MORE LIKE A SILTSTONE WITH DEPTH.
	27.0	22	87	0.0				
	35.0							BR 23 TO 23 FEW QUARTZ PIECES W/ VEGS. VBR SI. MICALCED. VERT QUARTZ GRAINS IN MATRIX - 30X MAG. 234 TO 35 - 2 VERT JOINTS
	35.0				M.HARD	GRAY	SILTY SHALE (SILTSTONE)	VBR 35.0-35.5 QUARTZ PIECES
								ER - FEW QUARTZ SEAMS VBR BECOMES SI. CALC. @ 37.1 THIN CALCITE LAMINATIONS. WATER STAINED INTS THROUGHOUT RUN
	37.0	108	93	0.0				BR MORE SO 35-37 ± 39.5 → 42.0
	45.0							VBR 42.7 → 43.0 HI & JNT 42.4 → 42.7 VERT JNT
								VBR 43.3 → 45.5 VERT JNT & VBR 47.5 VERT JOINT ER 48. HI & JNT SLIGHTLY CALCAREOUS MORE CALCITE PRESENT

REMARKS _____

BORING MW 3A
 PAGE 2 OF 3

* See Legend on Back

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BORING LOG **NUS CORPORATION**

PROJECT: **HEBELKA STE** BORING NO: **MW 3A**
 PROJECT NO.: **619Y** DATE: **9-22-87** DRILLER: **B. GOLLWIE**
 ELEVATION: FIELD GEOLOGIST: **SJ. CONT. 1**
 WATER LEVEL DATA:
 (Date, Time & Conditions)

SAMPLE NO & TYPE	DEPTH (ft.)	BLOWS 5" OR 10" ROD (%)	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (BOOK NO.)	MATERIAL DESCRIPTION*		VICI	REMARKS
					SOIL DENSITY CONSISTENCY OR ROCK HARDNESS	COLOR		
1-9/10.0 (4)	19.9/10.0	10.0/10.0			M. HARD GRAY	SILTY SHALE (SILTSTONE)	VBR	50.5 - 51.0 VBR
						SL. CALCAREOUS	BR	51.5 - 54.0 BR w/ sev LD & JOINTS
	55.0							VBR POOR RECOVERY w/ SOFT ZONES.
0/10 (5)	0/10	1.8/10.0						
	65.0							
								68.0 - DRILLER NOTED SOFT AREA - LOSS OF 1/3 OF WATER - CHANGE IN COLOR OF DRILL WATER TO YELLOW BROWN
0/10 (6)	0/10	1.3/10.0						POOR RECOVERY FEW CALCAREOUS ZONES.
	75.0							

REMARKS AT 75' @ 1:45 PM - PULLING TOOLS - TO REAM HOLE
 AT 1:50 PM. CORED HOLE TO 75' REAMER TUCKE
 DUE TO RUNNING SAND (FRACTURE) AT 68'. REAMED
 2ND TIME TO 81'. SET WELL 66-76.

BORING **MW 3A**
 PAGE **3** OF **3**

Subject

BOREHOLE AND SAMPLE LOGGING

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EXHIBIT 4-6

BORING LOG				NUS CORPORATION			
PROJECT: WESTLINE SITE		BORING NO.: MW 013		PROJECT NO.: 473 Y		DATE: 7-7-87	
ELEVATION: 1462.37		FIELD GEOLOGIST: S. CONTI		DRILLER: B. ERICSON		PERM - DRILL	
WATER LEVEL DATA: 5.54' @ 9:50 AM 7-23-87 T-PVC		ACKER AD-11		(Date, Time & Conditions)			
SAMPLE NO. & TYPE OR R.O.B.	DEPTH (FT) OR RUN IN.	DEPTH (FT) OR R.O.B.	SAMPLE RECOVERY (%)	LITHOLOGY CHANGE (SHAPE) OR SLUGS	MATERIAL DESCRIPTION		REMARKS (HWS) (HEAD SP)
					SOIL DENSITY (G/CC) OR MOISTURE (%)	COLOR	
S-1	0.0	3	14/1.3		LOOSE	BLK BRN	SLT. SILT AND CLAY. ML MOIST (OPPM)
							TR. COLL. FRAGS - 3/4" FRAGS - NEAR OLD RR. LINE.
							TR. CO. FRAG (FIL)
S-2	5.0	1	13/1.5	6.0	V. LOOSE	RED BRN TO GRAY	SANDY SILT - TR. FRAGS TO SILTY CLAY - TR. GRAVEL. GM MOIST TO WET (OPPM)
	6.5	3					GRAY SAND @ 6' ± MICACEOUS 1.0% ± NATURAL
							DRILLER NOTE H2O @ 10'
S-3	10.0	11	12/1.5		DENSE	BRN	SILTY CLAY AND S.S. GM WET (OPPM)
	11.5	27					FRAGS. (GRV.) 1" Ø SIZE MAX SIZE SUBANGULAR TO SUBROUND GRAVEL
S-4	15.0	9	10/1.5		V. DENSE	BRN	SILTY FINE TO C. SAND AND GRAVEL. GM WET (OPPM)
	16.5	47					1" Ø SIZE MAX SIZE SUBANGULAR TO SUBROUND GRAVEL
		43					
S-5	20.0	17	9/1.9		V. DENSE	DRY BRN	SILTY CLAY - SOME GRAVEL AND S.S. FRAGS. GM WET (OPPM)
	20.9	37					MOIST BECOMES MORE LIKE SANDY SILT AT BOTTOM OF SAMPLE

REMARKS: START @ 1:15 PM - 7-7-87 USING 4 1/4" ID HOLLOW DRILLS TO LOCATE THE FORMERS. USING S-4 @ 3:30 PM. S-5 @ 4:30 PM. ACKER DRILL - MONITOR ON FOPU BOO TRUCK. SAMPLES TAKEN USING 140 lb wt AND 30 INCH DROP.

BORING MW 013
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BORING LOG **NUS CORPORATION**

PROJECT: WESTLINE SITE BORING NO.: 14WD13
 PROJECT NO.: 473Y DATE: 7-7-87 DRILLER: Y. EPSON
 ELEVATION: _____ FIELD GEOLOGIST: S.J. CONTI
 WATER LEVEL DATA: _____
 (Date, Time & Conditions) _____

SAMPLE NO. & TYPE OR REQ	DEPTH (FT) OR RUN NO	BLOW 1' OR ROD (")	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (NORMAL) OR GREAT EXT	MATERIAL DESCRIPTION		REMARKS			
					SOIL DENSITY, CONSISTENCY OR ROCK HARDNESS	MATERIAL CLASSIFICATION				
S-6	25.0	17	1.5		NENSE	CLIVE BLUE GRAY	SILTY SILT - CLAY	GM	11WET	OPPM
	26.5	20					GRAVEL - TR CLAY			2.5' IS FEASIBLE FIRST 2' IN COLOR. NOT ENOUGH CLAY TO BE CONFINING
							TR. SS. FRAG.			NOTE: MAY BE ZONE 2 CASING = 88'
7/7	30.0									
S-7	31.5	17	1.5		V.DENSE	BLU GRAY	SILTY SAND - SILTY GRAVEL	EM/	11WET	(OPPM)
	33.0	27					TR CLAY			2.5' IS FEASIBLE. SILTY SAND SILTY NOT FINE CLAY - BUT MAY BE SEMI-CONFINING.
	35.0									
S-8	35.9	20	0.9		V.DENSE	BLUE GRAY	SILTY F TO C. SAND -	SM/	11WET	(OPPM)
							SOME GRAVEL	GM		V. SL. TR CLAY - LESS
							TR. SS. FRAG.			1" FRAG - MORE SAND THAN ABOVE
	40.0									POSSIBLE STONS SCREEN LOC. SUFF'D
S-9	41.5	21	1.5		V.DENSE	BLU GRAY	SILTY SAND (FINE TO M.)	SM	11WET	(OPPM)
	43.0	34					SOME GRAVEL - TR CLAY	GM		LITTLE MORE CLAY THAN 5-B SUBSAMPLER GRAVEL
	45.0									VERY SLOW PENETRATION 40-45 (RIG STALLS) LESS CLAY LAST 3" OF SAMPLE
S-10	46.5	13	1.5		V.DENSE	BLU GRAY	SILTY SAND (FINE TO M.)	SM/	11WET	(OPPM)
		34					SOME GRAVEL - TR CLAY	GM		1" ST. - HOLD TO - GETTER WHEN SUFF'D BUT NOT COMESIVE CLASSIFICATION
										LOW PENETRATION TO 50'

REMARKS S-6 @ 4:40 PM
S-8 @ 8:36 AM 7-8-87
S-10 @ 10:40 AM 5-11-87

BORING MWO13
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BORING LOG **NUS CORPORATION**

PROJECT: WESTLINE SITE BORING NO.: MW013
 PROJECT NO.: 437Y DATE: 7-13-87 / 7-14-87 DRILLER: E. ERICSON
 ELEVATION: _____ FIELD GEOLOGIST: SJ. COATE
 WATER LEVEL DATA: _____
 (Date, Time & Conditions) _____

SAMPLE NO. & TYPE OR RSD	DEPTH (FLI & RAN NO)	BLOWS (F' OR RSD 1')	SAMPLE RECOVERY SAMPLE LENGTH	LITHOLOGY CHANGE (GENERAL) OR S.S. TAG	MATERIAL DESCRIPTION		REMARKS (HNU)		
					SOIL DENSITY, CONSISTENCY OR ROCK HARDNESS	COLOR			
S-16	75.0	57	0.9/1.0	75	V. DENSE	GRAY ORANG	FINE TO C. CLAYEY SAND - SOME	3C	WET (OPPM)
	76.0	55	1.5				BRN	GRAVEL - TR ROCK FRAG (S.S.)	
	80.0								NO SAMPLE @ 80' - DECIDED TO GO TO 85'
S-17	85.0	50	0.4/0.4	85	V. DENSE	GRAY ORANG	SILTY F. TO C. SAND - SOME	6W	WET (OPPM)
	85.4	4					BRN	GRAVEL - TR S.S. FRAG - TR CLAY	
							BOTM OF HOLE @ 85.0'		

REMARKS S-17 @ 2:20 PM 7-14-87 - METEORIC HEAVY 6" CASINGS
SPIN 4" Ø - 5 3/4" ØD. STAIN TO BOTM. USING WATER AS
DRILLING FLUID. BORING MW 013
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HALLIBURTON NUS
Environmental Corporation

**ENVIRONMENTAL
TECHNOLOGIES GROUP**

**STANDARD
OPERATING
PROCEDURES**

Number
SA-1.1

Page
1 of 14

Effective Date
01/02/91

Revision
2

Applicability
ETG

Prepared
Earth Sciences

Subject
GROUNDWATER SAMPLE ACQUISITION

Approved
D. Senovich

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1.0 PURPOSE

The purpose of this procedure is to provide general reference information on the sampling of groundwater wells. The methods and equipment described are for the collection of water samples from the saturated zone of the subsurface.

2.0 SCOPE

This procedure provides information on proper sampling equipment and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described shall be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methodology.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Site Hydrogeologist or Geochemist - responsible for selecting and detailing the specific groundwater sampling techniques and equipment to be used, documenting these in the Project Operations Plan (POP), and properly briefing the site sampling personnel.

Site Geologist - The Site Geologist is primarily responsible for the proper acquisition of the groundwater samples. When appropriate, such responsibilities may be performed by other qualified personnel (engineers, field technicians).

Site Manager - The Site Manager is responsible for reviewing the sampling procedures used by the field crew and for performing in-field spot checks for proper sampling procedures.

5.0 PROCEDURES

5.1 GENERAL

To be useful and accurate, a groundwater sample must be representative of the particular zone of the water being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of testing in order to keep any changes in water quality parameters to a minimum.

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach shall be followed prior to sample acquisition:

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1. All monitoring wells shall be purged prior to obtaining a sample. Evacuation of three to five volumes is recommended for a representative sample. In a high-yielding groundwater formation and where there is no stagnant water in the well above the screened section, evacuation prior to sample withdrawal is not as critical.
2. For wells that can be purged to dryness with the sampling equipment being used, the well shall be evacuated and allowed to recover prior to sample acquisition. If the recovery rate is fairly rapid, evacuation of more than one volume of water is preferred.
3. For high-yielding monitoring wells which cannot be evacuated to dryness, there is no absolute safeguard against contaminating the sample with stagnant water. One of the following techniques shall be used to minimize this possibility:
 - A submersible pump, intake line of a surface pump or bailer shall be placed just below the water surface when removing the stagnant water and lowered as the water level decreases. Three to five volumes of water shall be removed to provide reasonable assurance that all stagnant water has been evacuated. Once this is accomplished a bailer may be used to collect the sample for chemical analysis.
 - The inlet line of the sampling pump (or the submersible pump itself) shall be placed near the bottom of the screened section, and approximately one casing volume of water shall be pumped from the well at a rate equal to the well's recovery rate.

Stratification of contaminants may exist in the aquifer formation, both in terms of a concentration gradients due to mixing and dispersion processes in a homogeneous layer, and in layers of variable permeability into which a greater or lesser amount of the contaminant plume has flowed. Excessive pumping can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column at that point, and thus result in the collection of a non-representative sample.

5.2 SAMPLING, MONITORING, AND EVACUATION EQUIPMENT

Sample containers shall conform with EPA regulations for the appropriate contaminants.

The following equipment shall be on hand when sampling ground water wells:

- Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, appropriate packing containers and filler, ice, labels and chain-of-custody documents.
- Field tools and instrumentation - Thermometer; pH paper/meter; camera and film; tags; appropriate keys (for locked wells); engineers rule; water-level indicator; where applicable, specific-conductivity meter.

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- Pumps
 - Shallow-well pumps—Centrifugal, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing) where applicable.
 - Deep-well pumps—submersible pump and electrical power generating unit, or air-lift apparatus where applicable.
- Other sampling equipment - Bailers and monofilament line with tripod-pulley assembly (if necessary). Bailers shall be used to obtain samples for volatile organics from shallow and deep groundwater wells.
- Pails - Plastic, graduated.
- Decontamination solutions - Distilled water, Alconox, methanol, acetone.

Ideally, sample withdrawal equipment shall be completely inert, economical, easily cleaned, sterilized, and reused, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well flushing and sample collection.

5.3 CALCULATIONS OF WELL VOLUME

To insure that the proper volume of water has been removed from the well prior to sampling it is first necessary to know the volume of standing water in the well pipe. This volume can be easily calculated by the following method. Calculations shall be entered in the field logbook and on the field data form (Attachment A):

- Obtain all available information on well construction (location, casing, screens, etc.).
- Determine well or casing diameter.
- Measure and record static water level (depth below ground level or top of casing reference point).
- Determine depth of well (if not known from past records) by sounding using a clean, decontaminated weighted tape measure.
- Calculate number of linear feet of static water (total depth or length of well pipe minus the depth to static water level).

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- Calculate one static well volume in gallons ($V = 0.163Tr^2$).

where:

- V = Static volume of well in gallons.
- T = Thickness of water table in the well measured in feet, i.e., linear feet of static water.
- r = Inside radius of well casing in inches.
- 0.163 = A constant conversion factor which compensates for the conversion of the casing radius from inches to feet, the conversion of cubic feet to gallons, and pi.

- Determine the minimum amount to be evacuated before sampling.

5.4 EVACUATION OF STATIC WATER (PURGING)

5.4.1 General

The amount of flushing a well shall receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer. Alternately the well can be pumped until the parameters such as temperature, electrical conductance, and pH have stabilized. Onsite measurements of these parameters shall be recorded on the field data form.

For defining a contaminant plume, a representative sample of only a small volume of the aquifer is required. These circumstances require that the well be pumped enough to remove the stagnant water but not enough to induce significant groundwater flow from other areas. Generally three to five well volumes are considered effective for purging a well.

The site hydrogeologist, geochemist and risk assessment personnel shall define the objectives of the groundwater sampling program in the Work Plan, and provide appropriate criteria and guidance to the sampling personnel on the proper methods and volumes of well purging.

5.4.2 Evacuation Devices

The following discussion is limited to those devices commonly used at hazardous waste sites. Attachment B provides guidance on the proper evacuation device to use for given sampling situations. Note that all of these techniques involve equipment which is portable and readily available.

5.4.2.1 Bailers

Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line is used to lower the bailer and retrieve the sample.

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Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Bailers are inexpensive, and can be dedicated and hung in a well to reduce the chances of cross-contamination.
- There is minimal outgassing of volatile organics while the sample is in the bailer.
- Bailers are relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- It is time consuming to remove stagnant water using a bailer.
- Transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.

5.4.2.2 Suction Pumps

There are many different types of inexpensive suction pumps including centrifugal, diaphragm, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump (therefore not suitable for well purging) that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 20 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps can cause significant loss of dissolved gases and volatile organics. In addition, the complex internal components of these pumps may be difficult to decontaminate.

5.4.2.3 Gas-Lift Samplers

This group of samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Gas lift samplers are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation or loss of volatile organics.

5.4.2.4 Submersible Pumps

Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed gas or electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for 2-inch-diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

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Limitations of this class of pumps include:

- They may have low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components is difficult and time-consuming.

5.5 SAMPLING

5.5.1 Sampling Plan

The sampling approach consisting of the following, shall be developed as part of the POP prior to the field work:

- Background and objectives of sampling.
- Brief description of area and waste characterization.
- Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
- Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these shall be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.
- Sample preservation requirements.
- Working schedule.
- List of team members.
- List of observers and contacts.
- Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

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5.5.2 Sampling Methods

The collection of a groundwater sample is made up of the following steps:

1. HSO or designee will first open the well cap and use volatile organic detection equipment (HNU or OVA) on the escaping gases at the well head to determine the need for respiratory protection.
2. When proper respiratory protection has been donned, sound the well for total depth and water level (using clean equipment) and record these data in a well sampling data sheet (Attachment A); then calculate the fluid volume in the well pipe.
3. Calculate well volume to be removed as stated in Section 5.3.
4. Select appropriate purging equipment (see Attachment B). If an electric submersible pump with packer is chosen, go to Step 10.
5. Lower purging equipment or intake into the well to a short distance below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner. Lower the purging device, as required, to maintain submergence.
6. Measure rate of discharge frequently. A bucket and stopwatch are most commonly used; other techniques include using pipe trajectory methods, weir boxes or flow meters.
7. Observe peristaltic pump intake for degassing "bubbles." If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. Never collect volatile organics samples using a vacuum pump.
8. Purge a minimum of three-to-five casing volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice.
9. If sampling using a pump, lower the pump intake to midscreen or the middle of the open section in uncased wells and collect the sample. If sampling with a bailer, lower the bailer to sampling level before filling (this requires use of other than a 'bucket-type' bailer). Purged water shall be collected in a designated container and disposed of in an acceptable manner.
10. (For pump and packer assembly only). Lower assembly into well so that packer is positioned just above the screen or open section and inflate. Purge a volume equal to at least twice the screened interval or unscreened open section volume below the packer before sampling. Packers shall always be tested in a casing section above ground to determine proper inflation pressures for good sealing.
11. In the event that recovery time of the well is very slow (e.g., 24 hours), sample collection can be delayed until the following day. If the well has been bailed early in the morning, sufficient water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record in the logbook.
12. Add preservative if required. Label, tag, and number the sample bottle(s).

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13. Replace the well cap. Make sure the well is readily identifiable as the source of the samples.
14. Pack the samples for shipping. Attach a custody seal to the front and back of the shipping package. Make sure that traffic reports and chain-of-custody forms are properly filled out and enclosed or attached.
15. Decontaminate all equipment

5.5.3 Sample Containers

For most samples and analytical parameters, either glass or plastic containers are satisfactory.

5.5.4 Preservation of Samples and Sample Volume Requirements

Sample preservation techniques and volume requirements depend on the type and concentration of the contaminant and on the type of analysis to be performed. Procedure SF-1.2 describes the sample preservation and volume requirements for most of the chemicals that will be encountered during hazardous waste site investigations. Procedure SA-4.3 describes the preservation requirement for microbial samples.

5.5.5 Handling and Transporting Samples

After collection, samples shall be handled as little as possible. It is preferable to use self-contained "chemical" ice (e.g., "blue ice") to reduce the risk of contamination. If water ice is used, it shall be bagged and steps taken to ensure that the melted ice does not cause sample containers to be submerged and thus possibly become cross-contaminated. All sample containers shall be enclosed in plastic bags or cans to prevent cross-contamination. Samples shall be secured in the ice chest to prevent movement of sample containers and possible breakage. Sample packing and transportation requirements are described in SA-6.2.

5.5.6 Sample Holding Times

Holding times (i.e. allowed time between sample collection and analysis) for routine samples are given in Procedure SF-1.2.

5.6 RECORDS

Records will be maintained for each sample that is taken. The sample log sheet will be used to record the following information:

- Sample identification (site name, location, project number; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Sample source and source description.
- Purge data - prior to removal of each casing volume and before sampling, pH, electrical conductance, temperature, color, and turbidity shall be measured and recorded.

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- Field observations and measurements (appearance; volatile screening; field chemistry; sampling method).
- Sample disposition (preservatives added; lab sent to, date and time; lab sample number, EPA Traffic Report or Special Analytical Services number, chain-of-custody number.
- Additional remarks - (e.g., sampled in conjunction with state, county, local regulatory authorities; samples for specific conductance value only; sampled for key indicator analysis; etc.).

5.7 CHAIN-OF-CUSTODY

Proper chain-of-custody procedures play a crucial role in data gathering. Procedure SA-6.1 describes the requirements for a correct chain-of-custody.

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7.0 ATTACHMENTS

Attachment A - Well Sampling Data Sheet
Attachment B - Purging Equipment Selection

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ATTACHMENT A

SAMPLE LOG SHEET

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- Monitoring Well Data
- Domestic Well Data
- Other

Case # _____

By _____

Project Site Name _____

Project Site Number _____

HALLIBURTON NUS Source No. _____

Source Location _____

Total Well Depth:	Purge Data				
	Volume	pH	S.C.	Temp. (°C)	Color & Turbidity
Well Casing Size and Depth:					
Static Water Level:					
One Casing Volume:					
Start Purge (hrs.):					
End Purge (hrs.):					
Total Purge Time (min.):					
Total Amount Purged (gal.):					
Monitor Reading:					
Purge Method:					
Sample Method:					
Depth Sampled:					
Sample Date and Time:	Sample Data				
	pH	S.C.	Temp. (°C)	Color & Turbidity	
Sampled By:					
Signature(s):	Observations/Notes:				
<input type="checkbox"/> Type of Sample <input type="checkbox"/> Low Concentration <input type="checkbox"/> High Concentration <input type="checkbox"/> Grab <input type="checkbox"/> Composite <input type="checkbox"/> Grab - Composite					
Analysis:	Preservative:		Organic	Inorganic	
		Traffic Report #			
		Tag #			
		AB #			
		Date Shipped			
		Time Shipped			
		Lab			
		Volume			

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**ATTACHMENT B
PURGING EQUIPMENT SELECTION**

Diameter Casing		Bailer	Peristaltic Pump	Vacuum pump	Airlift	Diaphragm "Trash" Pump	Submersible Diaphragm Pump	Submersible Electric Pump	Submersible Electric Pump w/Packer
1.25-inch	Water Level <25 feet)		X	X	X	X			
	Water Level >25 feet				X				
2-inch	Water Level <25 feet)	X	X	X	X	X	X		
	Water Level >25 feet	X			X		X		
4-inch	Water Level <25 feet)	X	X	X	X	X	X	X	X
	Water Level >25 feet	X			X		X	X	X
6-inch	Water Level <25 feet)				X	X		X	X
	Water Level >25 feet				X			X	X
8-inch	Water Level <25 feet)				X	X		X	X
	Water Level >25 feet				X			X	X

Manufacturer	Model name/ number	Principle of operation	Maximum outside diameter/length (inches)	Construction materials (w/lines & tubing)	Lift range (ft)	Delivery rates or volumes	1982 price (dollars)	Comments
BarCad Systems, Inc.	BarCad Sampler	dedicated; gas drive (positive displacement)	1.5/18	PE, brass, nylon, aluminum oxide	0-150 with std. tubing	1 liter for each 10-15 ft of submergence	220-350	requires compressed gas; custom sizes and materials available; acts as piezometer
Cole-Parmer Inst. Co.	Master Flex 7578 Portable Sampling Pump	portable; peristaltic (suction)	<1.0/NA	(not submersible) Tygon® silicone Viton®	0-30	570 mL/min with 7018- 20 pump head	500-800	AC/DC; variable speed control available; other models may have different flow rates
ECO Pump Corp.	SAMPLNier	portable; venturi	<1.5 or <2.0/NA	PP, PE, PVC, SS, Teflon®, Tefzel®	0-100	0-500 mL/min depending on lift	400-700	AC, DC, or gasline driven motors avail- able; must be primed other sizes available
Gettek Corp.	Bailer 2184	portable; grab (positive dis- placement)	1.66/38	Teflon®	no limit	1078 mL	120-135	
GeoEngineering, Inc.	GEO-MONITOR	dedicated; gas drive (positive displacement)	1.5/18	PE, PP, PVC, Viton®	probably 0-150	app. 1 liter for each 10 ft of submergence	185	acts as piezometer; requires compressed gas
Industrial and Environmental Analytcs, Inc. (IEA)	Aquarius	portable; bladder (positive dis- placement)	1.75/43	SS, Teflon®, Viton®	0-200	0-2000 mL/min	1500-3000	requires compressed gas; other models available; AC, DC, manual operation possible
IEA	Syringe Sampler	portable; grab (positive dis- placement)	1.75/43	SS, Teflon®	no limit	550 mL sample vol.	1100	requires vacuum and/or pressure from hand pump
Instrument Special- ties Co. (ISCO)	Model 2000 Well Sampler	portable; bladder (positive dis- placement)	1.75/50	PC, silicone, Teflon®, PP, PE, Dextrin® acetel	0-120	0-7500 mL/min	990	requires compressed gas (40 psi minimum)
Kech Geophysical Instruments, Inc.	SP-81 Submer- sible Sampling Pump	portable; helical rotor (positive displacement)	1.75/25	SS, Teflon®, PP, EPDM, Viton®	0-100	0-4500 mL/min	3800	DC operated
Leonard Mold and Die Works, Inc.	GasFilter Small Dia. Well Pump (#0600)	portable; bladder (positive dis- placement)	1.75/38	SS, Teflon®, PC, Neoprene®	0-400	0-3500 mL/min	1400-1800	requires compressed gas (55 PSI minimum); pneumatic or AC/DC control module
OH Recovery Systems, Inc.	Surface Sampler	portable; grab (positive dis- placement)	1.75/12	acrylic, Dextrin®	no limit	app. 200 mL	125-180	other materials and models available; for measuring thick- ness of "floating" contaminants
O.E.D. Environmental Systems, Inc.	Well Wizard® Monitoring System (P-100)	dedicated; bladder (positive dis- placement)	1.66/38	PVC	0-230	0-7000 mL/min	300-400	requires compressed gas; piezometric level indi- cator; other materials available

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Manufacturer	Model name/ number	Principle of operation	Maximum outside diameter/length (inches)	Construction materials (w/lines & tubing)	Lift range (ft)	Delivery rates or volumes	1982 price (dollars)	Comments
Randolph Austin Co.	Model 500 Vari-Flow Pump	portable; peri- staltic (suction)	<0.5/NA	(not submersible) rubber, Tygon® or Neoprene®	0-30	see comments	1200-1300	flow rate dependent on motor and tubing selec- ted, AC operated; other models available
Robert Bennett Co.	Model 180	portable; piston (positive dis- placement)	1.8/22	SS, Teflon®, Del- rin®, PP, Vicon® acrylic, PE	0-500	0-1800 mL/min	2600-2700	requires compressed gas; water level indicator and flow meter; custom models available
Steps Indicator Co. (EMCO)	Model S14124 Pneumatic Water Sampler	portable; gas drive (positive displacement)	1.8/18	PVC, nylon	0-1100	250 mL/flush- ing cycle	250-350	requires compressed gas; SS available; piezometer model available; dedi- cated model available
Selinet Canada Ltd.	SN Water Sampler	portable; grab (positive dis- placement)	1.8/27	PVC, brass, nylon, Neoprene®	0-330	500 mL	1300-1800	requires compressed gas; custom models available
TIMCO Mfg. Co., Inc.	Std. Boiler	portable; grab (positive dis- placement)	1.88/ custom	PVC, PP	no limit	250 mL/ft of boiler	20-60	other sizes, materials, models available; op- tional bottom-emptying device available; no solvents used
TIMCO	Air or Gas Lift Sampler	portable; gas drive (positive displacement)	1.88/30	PVC, Tygon®, Teflon®	0-150	350 mL/flush- ing cycle	100-200	requires compressed gas; other sizes, materials, models available; no solvents used
Telo Devices Co.	Sampling Pump	portable; bladder (positive dis- placement)	1.38/48	SS, silicone, Delrin®, Tygon®	0-125	0-4000 mL/min	800-1000	compressed gas re- quired; DC control module; custom built

Construction Materials Abbreviations

PE	Polyethylene
PP	Polypropylene
PVC	Polyvinyl Chloride
SS	Stainless Steel
PC	Polycarbonate
EPDM	Ethylene-Propylene Diene (synthetic rubber)

Other Abbreviations

NA	Not Applicable
AC	Alternating Current
DC	Direct Current

NOTE: Other manufacturers market pumping devices which could be used for ground-water sampling, though not expressly designed for this purpose. The list is not meant to be all-inclusive and listing does not constitute endorsement for use. Information in the table is from sales literature and/or personal communication. No skimmer, scavenger-type, or high-capacity pumps are included.

Source: Barcelona et al., 1983



HALLIBURTON NUS
Environmental Corporation

**ENVIRONMENTAL
TECHNOLOGIES GROUP**

**STANDARD
OPERATING
PROCEDURES**

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Applicability ETG	
Prepared Earth Sciences	
Approved D. Senovich	

Subject
SURFACE WATER AND SEDIMENT SAMPLING

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1.0 PURPOSE

This procedure describes methods and equipment commonly used for collecting environmental samples of surface water and aquatic sediment for either on-site examination and chemical testing or for laboratory analysis.

2.0 SCOPE

The information presented in this guideline is generally applicable to all environmental sampling of surface waters (Section 5.3) and aquatic sediments (Section 5.4), except where the analyte(s) may interact with the sampling equipment. The collection of concentrated sludges or hazardous waste samples from disposal or process lagoons often requires methods, precautions and equipment different from those described herein.

3.0 GLOSSARY

Environmental Sample - low concentration sample typically collected offsite and not requiring DOT hazardous waste labeling or CLP handling as a high concentration sample.

Hazardous Waste Sample - medium- to high-concentration sample (e.g., source material, sludge, leachate) requiring DOT labeling and CLP handling as a high concentration sample.

4.0 RESPONSIBILITIES

Field Operations Leader - has overall responsibility for the correct implementation of surface water and sediment sampling activities, including review of the sampling plan with, and any necessary training of, the sampling technician(s). The actual collection, packaging, documentation (sample label and log sheet, chain-of-custody record, CLP traffic reports, etc.) and initial custody of samples will be the responsibility of the sampling technician(s).

5.0 PROCEDURES

5.1 INTRODUCTION

Collecting a representative sample from surface water or sediments is difficult because of water movement, stratification or patchiness. To collect representative samples, one must standardize sampling bias related to site selection; sampling frequency; sample collection; sampling devices; and sample handling, preservation, and identification.

Representativeness is a qualitative description of the degree to which an individual sample accurately reflects population characteristics or parameter variations at a sampling point. It is therefore an important quality not only of assessment and quantification of environmental threats posed by the site, but also for providing information for engineering design and construction. Proper sample location selection and proper sample collection methods are important to ensure that a truly representative sample has been taken. Regardless of scrutiny and quality control applied during laboratory analyses, reported data are not better than the confidence that can be placed in the representativeness of the samples.

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5.2 DEFINING THE SAMPLING PROGRAM

Many factors must be considered in developing a sampling program for surface water or sediments including study objectives; accessibility; site topography; flow, mixing and other physical characteristics of the water body; point and diffuse sources of contamination; and personnel and equipment available to conduct the study. For waterborne constituents, dispersion depends on the vertical and lateral mixing within the body of water. For sediments, dispersion depends on bottom current or flow characteristics, sediment characteristics (density, size) and geochemical properties (which affect an adsorption/desorption). The hydrologist developing the sampling plan must therefore, know not only the mixing characteristics of streams and lakes, but also must understand the role of fluvial-sediment transport, deposition, and chemical sorption.

5.2.1 Sampling Program Objectives

The objective of surface water sampling is to determine the surface water quality entering, leaving or remaining within the site. The scope of the sampling program must consider the sources and potential pathways for transport of contamination to or in a surface water body. Sources may include point sources (leaky tanks, outfalls, etc.) or nonpoint sources (e.g., spills). The major pathways for surface water contamination (not including airborne deposition are: (a) overland runoff; (b) leachate influx to the waterbody; (c) direct waste disposal (solid or liquid) into the water body; and groundwater flow influx from upgradient. The relative importance of these pathways, and therefore the design of the sampling program, is controlled by the physiographic and hydrologic features of the site, the drainage basin(s) which encompass the site, and the history of site activities.

Physiographic and hydrologic features to be considered include slopes and runoff direction, areas of temporary flooding or pooling, tidal effects, artificial surface runoff controls such as berms or drainage ditches (and when they were constructed relative to site operation), and locations of springs, seeps, marshes, etc. In addition, the obvious considerations such as the location of man-made discharge points to the nearest stream (intermittent or flowing), pond, lake, estuary, etc., shall be considered.

A more subtle consideration in designing the sampling program is the potential for dispersion of dissolved or sediment-associated contaminants away from the source. The dispersion could lead to a more homogeneous distribution of contamination at low or possibly non-detectable concentrations. Such dispersion does not, however, always readily occur. For example, obtaining a representative sample of contamination from a main stream immediately below an outfall or a tributary is difficult because the inflow frequently follows a stream bank with little lateral mixing for some distance. Sampling alternatives to overcome this situation are: (1) move the site far enough downstream to allow for adequate mixing, or (2) collect integrated samples in a cross section. Also, nonhomogeneous distribution is a particular problem with regard to sediment-associated contaminants, which may accumulate in low-energy environments (coves, river bends, deep spots, or even behind boulders) near or distant from the source while higher-energy areas (main stream channels) near the source may show no contaminant accumulation.

The distribution of particulates within a sample itself is an important consideration. Many organic compounds are only slightly water soluble and tend to be absorbed by particulate matter. Nitrogen, phosphorus, and the heavy metals may also be transported by particulates. Samples will be collected with a representative amount of suspended material; transfer from the sampling device shall include transferring a proportionate amount of the suspended material.

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5.2.2 Location of Sampling Stations

Accessibility is the primary factor affecting sampling costs. The desirability and utility of a sample for analysis and description of site conditions must be balanced against the costs of collection as controlled by accessibility. Bridges or piers are the first choice for locating a sampling station on a stream because bridges provide ready access and also permit the sampling technician to sample any point across the stream. A boat or pontoon (with an associated increase in cost) may be needed to sample locations on lakes and reservoirs, as well as those on larger rivers. Frequently, however, a boat will take longer to cross a water body and will hinder manipulation of the sampling equipment. Wading for samples is not recommended unless it is known that contaminant levels are low so that skin contact will not produce adverse health effects. This provides a built in margin of safety in the event that wading boots or other protective equipment should fail to function properly. If it is necessary to wade into the water body to obtain a sample, the sampler shall be careful to minimize disturbance of bottom sediments and must enter the water body downstream of the sampling location. If necessary, the sampling technician shall wait for the sediments to settle before taking a sample.

Sampling in marshes or tidal areas may require the use of an all-terrain vehicle (ATV). The same precautions mentioned above with regard to sediment disturbance will apply.

Under ideal and uniform contaminant dispersion conditions in a flowing stream, the same concentrations of each would occur at all points along the cross section. This situation is most likely downstream of areas of high turbulence. Careful site selection is needed in order to ensure, as nearly as possible, that samples are taken where uniform flow or deposition and good mixing conditions exist.

The availability of streamflow and sediment discharge records can be an important consideration in choosing sampling sites in streams. Streamflow data in association with contaminant concentration data are essential for estimating the total contaminant loads carried by the stream. If a gaging station is not conveniently located on a selected stream, the project hydrologist shall explore the possibility of obtaining streamflow data by direct or indirect methods.

5.2.3 Frequency of Sampling

The sampling frequency and the objectives of the sampling event will be defined by the work plan. For single-event site- or area-characterization sampling, both bottom material and overlying water samples shall be collected at the specified sampling stations. If valid data are available on the distribution of the contaminant between the solid and aqueous phases it may be appropriate to sample only one phase, although this is not often recommended. If samples are collected primarily for monitoring purposes, consisting of repetitive, continuing measurements to define variations and trends at a given location, water samples shall be collected at a pre-established and constant interval as specified in the work plan (often monthly or quarterly) and during droughts and floods. Samples of bottom material shall be collected from fresh deposits at least yearly, and preferably during both spring and fall seasons.

The variability in available water-quality data shall be evaluated before deciding on the number and collection frequency of samples required to maintain an effective monitoring program.

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5.3 SURFACE WATER SAMPLE COLLECTION

5.3.1 Streams, Rivers, Outfalls and Drainage Features (Ditches, Culverts)

Methods for sampling streams, rivers, outfalls and drainage features at a single point vary from the simplest of hand sampling procedures to the more sophisticated multipoint sampling techniques known as the equal-width-increment (EWI) method or the equal-discharge-increment (EDI) methods (see below).

Samples from different depths or cross-sectional locations in the water course taken during the same sampling episode shall be composited. However, samples collected along the length of the watercourse or at different times may reflect differing inputs or dilutions and therefore shall not be composited. Generally, the number and type of samples to be taken depend on the river's width, depth, discharge and on the suspended sediment the river's transports. The greater number of individual points that are sampled, the more likely that the composite sample will truly represent the overall characteristics of the water.

In small streams less than about 20 feet wide, a sampling site can generally be found where the water is well mixed. In such cases, a single grab sample taken at mid-depth in the center of the channel is adequate to represent the entire cross section.

For larger streams, at least one vertical composite shall be taken with one sample each from just below the surface, at mid-depth, and just above the bottom. The measurement of DO, pH, temperature, conductivity, etc., shall be made on each aliquot of the vertical composite and on the composite itself. For rivers, several vertical composites shall be collected.

5.3.2 Lakes, Ponds and Reservoirs

Lakes, ponds, and reservoirs have as much greater tendency to stratify than rivers and streams. The relative lack of mixing requires that more samples be obtained.

The number of water sampling sites on a lake, pond, or impoundment will vary with the size and shape of the basin. In ponds and small lakes, a single vertical composite at the deepest point may be sufficient. Similarly, the measurement of DO, pH, temperature, etc., is to be conducted on each aliquot of the vertical composite. In naturally-formed ponds, the deepest point may have to be determined empirically; in impoundments, the deepest point is usually near the dam.

In lakes and larger reservoirs, several vertical composites shall be composited to form a single sample. These verticals are often taken along a transect or grid. In some cases, it may be of interest to form separate composites of epilimnetic and hypolimnetic zones. In a stratified lake, the epilimnion is the thermocline which is exposed to the atmosphere. The hypolimnion is the lower, "confined" layer which is only mixed with the epilimnion and vented to the atmosphere during seasonal "overturn" (when density stratification disappears). These two zones may thus have very different concentrations of contaminants if input is only to one zone, if the contaminants are volatile (and therefore vented from the epilimnion but not the hypolimnion), or if the epilimnion only is involved in short-term flushing (i.e., inflow from or outflow to shallow streams). Normally, however, a composite consists of several verticals with samples collected at various depths.

In lakes with irregular shape and with bays and coves that are protected from the wind, separate composite samples may be needed to adequately represent water quality since it is likely that only

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poor mixing will occur. Similarly, additional samples are recommended where discharges, tributaries, land use characteristics, and other such factors are suspected of influencing water quality.

Many lake measurements are now made in-situ using sensors and automatic readout or recording devices. Single and multiparameter instruments are available for measuring temperature, depth, pH, oxidation-reduction potential (ORP), specific conductance, dissolved oxygen, some cations and anions, and light penetration.

5.3.3 Estuaries

Estuarine areas are by definition zones where inland freshwaters (both surface and ground) mix with oceanic saline waters. Estuaries are generally categorized into three types dependent upon freshwater inflow and mixing properties. Knowledge of the estuary type is necessary to determine sampling locations:

- **Mixed estuary** - characterized by the absence of a vertical halocline (gradual or no marked increase in salinity in the water column) and a gradual increase in salinity seaward. Typically this type of estuary is shallow and is found in major freshwater sheetflow areas. Being well mixed, the sampling locations are not critical in this type of estuary.
- **Salt wedge estuary** - characterized by a sharp vertical increase in salinity and stratified freshwater flow along the surface. In these estuaries the vertical mixing forces cannot override the density differential between fresh and saline waters. In effect, a salt wedge tapering inland moves horizontally, back and forth, with the tidal phase. If contamination is being introduced into the estuary from upstream, water sampling from the salt wedge may miss it entirely.
- **Oceanic estuary** - characterized by salinities approaching full-strength oceanic waters. Seasonally, freshwater inflow is small with the preponderance of the fresh-saline water mixing occurring near, or at, the shore line.

Sampling in estuarine areas is normally based upon the tidal phases, with samples collected on successive slack tides (i.e. when the tide turns). Estuarine sampling programs shall include vertical salinity measurements at 1- to 5-foot increments coupled with vertical dissolved oxygen and temperature profiles.

5.3.4 Surface Water Sampling Equipment

The selection of sampling equipment depends on the site conditions and sample type required. The most frequently used samplers are:

- Open tube
- Dip sampler
- Hand pump
- Kemmerer
- Depth-Integrating Sampler

The dip sampler and the weighted bottle sampler are used most often.

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The criteria for selecting a sampler include:

- Disposable and/or easily decontaminated
- Inexpensive (if the item is to be disposed of)
- Ease of operation
- Nonreactive/noncontaminating - Teflon-coating, glass, stainless steel or PVC sample chambers are preferred (in that order)

Each sample (grab or each aliquot collected for compositing) shall be measured for:

- Specific conductance
- Temperature
- pH (optional)
- Dissolved oxygen (optional)

as soon as it is recovered. These analyses will provide information on water mixing/stratification and potential contamination.

5.3.4.1 Dip Sampling

Water is often sampled by filling a container either attached to a pole or held directly, from just beneath the surface of the water (a dip or grab sample). Constituents measured in grab samples are only indicative of conditions near the surface of the water and may not be a true representation of the total concentration that is distributed throughout the water column and in the cross section. Therefore, whenever possible it is recommended to augment dip samples with samples that represent both dissolved and suspended constituents and both vertical and horizontal distributions.

5.3.4.2 Weighted Bottle Sampling

A grab sample can also be taken using a weighted holder that allows a sample to be lowered to any desired depth, opened for filling, closed, and returned to the surface. This allows discrete sampling with depth. Several of these samples can be combined to provide a vertical composite. Alternatively, an open bottle can be lowered to the bottom and raised to the surface at a uniform rate so that the bottle collects sample throughout the total depth and is just filled on reaching the surface. The resulting sample using either method will roughly approach what is known as a depth-integrated sample.

A closed weighted bottle sampler consists of a stopped glass or plastic bottle, a weight and/or holding device, and lines to open the stopper and lower or raise the bottle. The procedure for sampling is:

- Gently lower the sampler to the desired depth so as not to remove the stopper prematurely (watch for bubbles).
- Pull out the stopper with a sharp jerk of the sampler line.
- Allow the bottle to fill completely, as evidenced by the absence of air bubbles.

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- Raise the sampler and cap the bottle.
- Decontaminate the outside of the bottle. The bottle can be used as the sample container (as long as original bottle is an approved container).

5.3.4.3 Kemmerer

If samples are desired at a specific depth, and the parameters to be measured do not require a Teflon coated sampler, a standard Kemmerer sampler may be used. The Kemmerer sampler is a brass, stainless steel or acrylic cylinder with rubber stoppers that leave the ends open while being lowered in a vertical position to allow free passage of water through the cylinder. "Messenger" is sent down the line when the sampler is at the designated depth, to cause the stoppers to close the cylinder, which is then raised. Water is removed through a valve to fill sample bottles.

5.3.5 Surface Water Sampling Techniques

Most samples taken during site investigations are grab samples. Typically, surface water sampling involves immersing the sample container in the body of water; however, the following suggestions are made to help ensure that the samples obtained are representative of site conditions:

- The most representative samples are obtained from mid-channel at 0.6 stream depth in a well-mixed stream.
- Even though the containers used to obtain the samples are previously laboratory cleaned, it is suggested that the sample container be rinsed at least once with the water to be sampled before the sample is taken.
- For sampling running water, it is suggested that the farthest downstream sample be obtained first and that subsequent samples be taken as one works upstream. Work from zones suspected of low contamination to zones of high contamination.
- To sample a pond or other standing body of water, the surface area may be divided into grids. A series of samples taken from each grid is combined into one sample, or several grids are selected at random.
- Care should be taken to avoid excessive agitation of the water that results in the loss of volatile constituents.
- When obtaining samples in 40 mL septum vials for volatile organics, analysis, it is important to exclude any air space in the top of the bottle and to be sure that the Teflon liner faces in after the bottle is filled and capped. The bottle can be turned upside down to check for air bubbles.
- Do not sample at the surface, unless sampling specifically for a known constituent which is immiscible and on top of the water. Instead, the sample container should be inverted, lowered to the approximate depth, and held at about a 45-degree angle with the mouth of the bottle facing upstream.

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5.4 SEDIMENT SAMPLING

5.4.1 General

Sediment samples are usually collected at the same verticals at which water samples were collected. If only one sediment sample is to be collected, the site shall be approximately at the center of water body. Generally, the coarser grained sediments are deposited near the headwaters of the reservoir. Bed sediments near the center will be composed of fine-grained materials which may, because of their lower porosity and greater surface area available for adsorption, contain greater concentrations of contaminants. The shape, flow pattern, bathymetry (depth distribution), and water circulation patterns must all be considered when selecting sediment sampling sites. In streams, areas likely to have sediment accumulation (bends, behind islands or boulders, quiet shallow areas or very deep, low-velocity areas) shall be sampled while areas likely to show net erosion (high-velocity, turbulent areas) and suspension of fine solid materials shall be avoided.

Chemical constituents associated with bottom material may reflect an integration of chemical and biological processes. Bottom samples reflect the historical input to streams, lakes, and estuaries with respect to time, application of chemicals, and land use. Bottom sediments (especially fine-grained material) may act as a sink or reservoir for adsorbed heavy metals and organic contaminants (even if water column concentrations are below detection limits). It is therefore important to minimize the loss of low-density "fines" during any sampling process.

5.4.2 Sampling Equipment and Techniques

A bottom-material sample may consist of a single scoop or core or may be a composite of several individual samples in the cross section. Sediment samples may be obtained using on-shore or off-shore techniques.

When boats are used for sampling, life preservers must be provided and two individuals must undertake the sampling. An additional person shall remain on-shore in visual contact at all times.

The following samplers may be used to collect bottom materials:

- Scoop sampler
- Dredge samplers

5.4.2.1 Scoop Sampler

A scoop sampler consists of a pole to which a jar or scoop is attached. The pole may be made of bamboo, wood or aluminum and be either telescoping or of fixed length. The scoop or jar at the end of the pole is usually attached using a clamp.

If the water body can be sampled from the shore or if it can be waded, the easiest and "cleanest" way to collect a sediment sample is to use a scoop sampler. This reduces the potential for cross-contamination. This method is accomplished by reaching over or wading into the water body and, while facing upstream (into the current), scooping in the sample along the bottom in the upstream direction. It is very difficult not to disturb fine-grained materials of the sediment-water interface when using this method.

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5.4.2.2 Dredges

Dredges are generally used to sample sediments which cannot easily be obtained using coring devices (i.e., coarse-grained or partially-cemented materials) or when large quantities of materials are required. Dredges generally consist of a clam shell arrangement of two buckets. The buckets may either close upon impact or be activated by use of a messenger. Most dredges are heavy (up to several hundred pounds) and require use of a winch and crane assembly for sample retrieval. There are three major types of dredges: Peterson, Eckman and Ponar dredges.

The Peterson dredge is used when the bottom is rocky, in very deep water, or when the flow velocity is high. The dredge shall be lowered very slowly as it approaches bottom, because it can force out and miss lighter materials if allowed to drop freely.

The Eckman dredge has only limited usefulness. It performs well where bottom material is unusually soft, as when covered with organic sludge or light mud. It is unsuitable, however, for sandy, rocky, and hard bottoms and is too light for use in streams with high flow velocities.

The Ponar dredge is a Peterson dredge modified by the addition of side plates and a screen on the top of the sample compartment. The screen over the sample compartment permits water to pass through the sampler as it descends thus reducing the "shock wave" and permitting direct access to the secured sample without opening the closed jaws. The Ponar dredge is easily operated by one person in the same fashion as the Peterson dredge. The Ponar dredge is one of the most effective samplers for general use on all types of substrates. Access to the secured sample through the covering screens permits subsampling of the secured material with coring tubes or Teflon scoops, thus minimizing the change of metal contamination from the frame of the device.

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7.0 ATTACHMENTS

None.



HALLIBURTON NUS
Environmental Corporation

**ENVIRONMENTAL
TECHNOLOGIES GROUP**

**STANDARD
OPERATING
PROCEDURES**

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Applicability ETG	
Prepared Earth Sciences	
Approved D. Senovich	

Subject
SAMPLE HANDLING

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1.0 PURPOSE

This purpose of this procedure is to provide information on chain-of-custody, sample preservation, packaging and shipping procedures to be used under the HALLIBURTON NUS Program.

2.0 SCOPE

This procedure:

- Describes the steps necessary for transferring samples through the use of Chain-of-Custody Records.
- Describes the appropriate containers to be used for samples depending on the analyses to be performed, and the steps necessary to preserve the samples when shipped offsite for chemical analysis.
- Provides instruction for sample packaging and shipping in accordance with U.S. Department of Transportation (DOT) regulations.

3.0 GLOSSARY

Chain-of-Custody Record Form - A Chain-of-Custody Record Form is a printed two-part form that accompanies a sample or group of samples as custody of the sample(s) is transferred from one custodian to another custodian.

The chain-of-custody form is a two-page carbon copy-type form. The original form accompanies the samples during shipment, and the carbon-copy is retained in the project file.

Custodian - The person responsible for the custody of samples at a particular time, until custody is transferred to another person (and so documented), who then becomes custodian. A sample is under your custody if:

- It is in your actual possession.
- It is in your view, after being in your physical possession.
- It was in your physical possession and then you locked it up to prevent tampering.
- It is in a designated and identified secure area.

Hazardous Material - A substance or material in a quantity and form which may pose an unreasonable risk to health and safety or property when transported in commerce ("commerce" here to include any traffic or transportation). Defined and regulated by DOT (49 CFR 173.2) and listed in Attachment A of this guideline.

Hazardous Waste - Any substance listed in 40 CFR Subpart D (y261.20 et seq.) or otherwise characterized as ignitable, corrosive, reactive, or EP toxic as specified under 40 CFR Subpart C (y261.20 et seq) that would be subject to manifest requirements specified in 40 CFR 262. Defined and regulated by EPA.

Marking - Applying the descriptive name, instruction, cautions, weight, or specification marks or combination thereof required to be placed outside containers of hazardous materials.

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n.o.i - Not otherwise indicated.

n.o.s. - Not otherwise specified.

ORM - Other regulated material.

Packaging - The assembly of one or more containers and any other components necessary to assure compliance with the minimum packaging requirements of 49 CFR 174, including containers (other than freight containers or overpacks), portable tanks, cargo tanks, tank cars, multi-unit tank car tanks.

Placard - Color-coded, pictorial sign depicting the hazard class symbol and name to be placed on all four sides of a vehicle transporting certain hazardous materials.

Preservatives:

- HCl - Hydrochloric Acid
- H₂SO₄ - Sulfuric Acid
- HNO₃ - Nitric Acid
- NaOH - Sodium Hydroxide

Normality (N) - Concentration of a solution expressed as equivalent per liter, an equivalent being the amount of a substance containing 1 gram-atom of replaceable hydrogen or its equivalent. Thus, a one-molar solution of HCl, containing 1 gram-atom of H, is "one normal," while a one-molar solution of H₂SO₄ containing 2 gram-atoms of H, is "two normal."

Reportable Quantity (RQ) - A parenthetical note of the form "(RQ-1000/454)" following an entry in the DOT Hazardous Materials table (49 CFR 172.101) indicates the reportable quantity of the substance in pounds and kilograms. If a spill of that amount or more of the substance occurs during transit or storage, a report must be filed with DOT according to y171.15-15 concerning hazardous materials incidents reports. If the material spilled is a hazardous waste, a report must always be filed, regardless of the amount, and must include a copy of the manifest. If the RQ notation appears, it must be shown either immediately before or after the proper shipping name on the shipping paper (or manifest). Most shipping papers and manifests will have a column designated "HM" which may be used for this purpose.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the point and time that it was collected.

4.0 RESPONSIBILITIES

Field Operations Leader - Directly responsible for the bottling, preservation, labeling, packaging, shipping, and custody of the samples up to and including release to the shipper.

Field Samplers - Responsible for initiating the Chain-of-Custody Record, implementing the packaging and shipping requirements, and maintaining custody of samples until they are relinquished to another custodian or to the common carrier.

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5.0 PROCEDURES

5.1 SAMPLE IDENTIFICATION AND CHAIN-OF-CUSTODY

5.1.1 OVERVIEW

A Chain-of-Custody Record is required, without exception, for the tracking and recording of all samples collected for onsite or offsite analysis (chemical or geotechnical) during program activities. Use of the Chain-of-Custody Record form creates an accurate written record that can be used to trace the possession and handling of the sample from the moment of its collection through analysis.

5.1.2 Sample Identification

The method of identification of a sample depends on the type of measurement or analysis performed. When in-situ measurements are made, the data are recorded directly in bound logbooks or other field data records, with identifying information.

Samples, other than in-situ measurements, are removed and transported from the sample location to a laboratory or other location for analysis. Before removal, however, a sample is often divided into portions, depending upon the analyses to be performed. Each portion is preserved in accordance with the Sampling Plan. Each sample container is identified by a sample label (see Attachment B). Sample labels are provided by the PMO. The information recorded on the sample label includes:

- **Project:** Site name or project number (obtained from the Site Manager).
- **Station Location:** The unique sample number identifying this sample (can be obtained from the Sampling Plan).
- **Date:** A six-digit number indicating the day, month, and year of sample collection; e.g., 12/21/85.
- **Time:** A four-digit number indicating the 24-hour time of collection (for example: 0954 is 9:54 a.m., and 1629 is 4:29 p.m.).
- **Medium:** Water, soil, sediment, sludge, waste, etc.
- **Concentration:** The expected concentration (i.e., low, medium, high).
- **Sample Type:** Grab or composite.
- **Preservation:** Type of preservation added and pH levels.
- **Analysis:** VOA, BNAs, PCBs, pesticides, metals, cyanide, other.
- **Sampled By:** Sampler's initials.
- **Remarks:** Any pertinent additional information.

Using just the project number of the sample label maintains the anonymity of sites. This may be necessary, even to the extent of preventing the laboratory performing analysis from knowing the

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identity of the site (e.g., if the laboratory is part of an organization that has performed previous work on the site).

5.1.3 Chain-of-Custody Procedures

After collection, separation, identification, and preservation, the sample is maintained under chain-of-custody procedures until it is in the custody of the analytical laboratory and has been stored or disposed of.

5.1.3.1 Field Custody Procedures

- Samples are collected as described in the site-specific Sampling Plan. Care must be taken to record precisely the sample location and to ensure that the sample number on the label matches the sample log sheet and Chain-of-Custody Record exactly.
- The person undertaking the actual sampling in the field is responsible for the care and custody of the samples collected until they are properly transferred or dispatched.
- When photographs are taken of the sampling as part of the documentation procedure, the name of the photographer, date, time, site location, and site description are entered sequentially in the site logbook as photos are taken. Once developed, the photographic prints shall be serially numbered, corresponding to the logbook descriptions.
- Sample labels shall be completed for each sample, using waterproof ink unless prohibited by weather conditions, e.g., a logbook notation would explain that a pencil was used to fill out the sample label because a ballpoint pen would not function in freezing weather.

5.1.3.2 Transfer of Custody and Shipment

Samples are accompanied by a Chain-of-Custody Record Form. Chain-of-Custody Record Forms used are shown in Attachments B. The appropriate form shall be obtained from the EPA Regional Office. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the Record. This Record documents sample custody transfer from the sampler, often through another person, to the analyst in the laboratory. The Chain-of-Custody Record is filled out as follows:

- Enter header information (project number, samplers, and project name – project name if approved by SM).
- Sign, date, and enter the time under "Relinquished by" entry.
- Enter station number.
- Check composite or grab sample.
- Enter station location number (the same number as the station location on the).
- Enter the total number of containers per station number and the type of each bottle.

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- Make sure that the person receiving the sample signs the "Received by" entry, or enter the name of the carrier (e.g., UPS, Federal Express) under "Received by." Receiving laboratory will sign "Received for Laboratory by" on the lower line and enter the date and time.
- Enter the bill-of-lading or Federal Express airbill number under "Remarks," in the bottom right corner, if appropriate.
- Place the original (top, signed copy) of the Chain-of-Custody Record Form in the appropriate sample shipping package. Retain the carbon copy with field records.
- Sign and date the custody seal, a 1- by 3-inch white paper label with black lettering and an adhesive backing. Attachment F is an example of a custody seal. The custody seal is part of the chain-of-custody process and is used to detect tampering with samples after they have been collected in the field. Custody seals are provided by the Sample Coordinator on an as-needed basis.
- Place the seal across the shipping container opening so that it would be broken if the container is opened.
- Complete other carrier-required shipping papers.

The custody record is completed using black waterproof ink. Any corrections are made by drawing a line through and initialing and dating the change, then entering the correct information. Erasures are not permitted.

Common carriers will usually not accept responsibility for handling Chain-of-Custody Record Forms; this necessitates packing the record in the sample container (enclosed with other documentation in a plastic zip-lock bag). As long as custody forms are sealed inside the sample container and the custody seals are intact, commercial carriers are not required to sign off on the custody form.

If sent by mail, the package will be registered with return receipt requested. If sent by common carrier or air freight, proper documentation must be maintained.

The laboratory representative who accepts the incoming sample shipment signs and dates the Chain-of-Custody Record, completing the sample transfer process. It is then the laboratory's responsibility to maintain internal logbooks and custody records throughout sample preparation and analysis.

5.2 SAMPLE PRESERVATION

5.2.1 Overview

Different types of chemicals react differently with sample containers made of various materials. For example, trace metals adsorb more strongly to glass than to plastic, while many organic chemicals may dissolve various types of plastic containers. It is therefore critical to select the correct container in order to maintain the quality of the sample prior to analysis.

Many water and soil samples are unstable, and therefore require preservation when the time interval between field collection and laboratory analysis is long enough to produce changes in either the concentration or the physical condition of the constituent(s) requiring analysis. While complete and

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irreversible preservation of samples is not possible, preservation does retard the chemical and biological changes that inevitably take place after the sample is collected.

Preservation techniques are usually limited to pH control, chemical addition(s) and refrigeration/freezing. Their purpose is to (1) retard biological activity, (2) retard hydrolysis of chemical compound/complexes, (3) reduce constituent volatility, and (4) reduce adsorption effects.

5.2.2 Sample Containers

For most samples and analytical parameters either glass or plastic containers are satisfactory. In general, if the analyte(s) to be determined is organic in nature, the container shall be made of glass. If the analyte(s) is inorganic, then the container shall be plastic. Since container specification will depend on the analyte and sample matrix types (as indicated in Attachment D) duplicate samples shall be taken when both organic and inorganic analyses are required. Containers shall be kept in the dark (to minimize biological or photooxidation/photolysis breakdown of constituent) until they reach the analytical laboratory. The sample container shall allow approximately 5-10 percent air space ("ullage") to allow for expansion/vaporization if the sample is heated during transport (1 liter of water at 4°C expands by 15 mL if heated to 130°F/55°C), however, head space for volatile organic analyses shall be omitted.

Generally, the analytical laboratory shall provide containers that have been cleaned according to U.S. EPA procedures. Sufficient lead time shall be allowed for a final delivery of all bottle orders.

Once opened, the container must be used at once for storage of a particular sample. Unused but opened containers are to be considered contaminated and must be discarded; because of the potential for introduction of contamination, they cannot be reclosed and saved for later use. Likewise, any unused containers which appear contaminated upon receipt, or which are found to have loose caps or missing Teflon liner (if required for the container) shall be discarded.

General sample container and sample volume requirements are listed in Attachment D. Specific container requirements are listed in Attachment E.

5.2.3 Preservation Techniques

The preservation techniques to be used for various analytes are listed in Attachments D and E. Reagents required for sample preservation will either be added to the sample containers by the laboratory prior to their shipment to the Field or added in the Field. In general, aqueous samples of low concentration organics (or soil samples of low or medium concentration organics) are cooled to 4°C. Medium concentration aqueous samples and high hazard organics sample are not preserved. Low concentration aqueous samples for metals are acidified with HNO₃, while medium concentration and high hazard aqueous metal samples are not preserved. Low or medium concentration soil samples for metals are cooled to 4°C while high hazard samples are not preserved.

The following subsections describe the procedures for preparing and adding chemical preservatives. Attachments D and E indicate the specific analytes which require these preservatives.

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5.2.3.1 Addition of Acid (H₂SO₄, HCl, or HNO₃) or Base

Addition of the following acids or bases may be specified for sample preservation; these reagents shall be analytical reagent (AR) grade and shall be diluted to the required concentration with double-distilled, deionized water in the laboratory, before Field sampling commences:

Acid Base	Concentration	Normality	Amount for Acidification*
HCl	1:1 dilution of concentrated HCl	6N	5-10 mL
H ₂ SO ₄	1:1 dilution of concentrated H ₂ SO ₄	18N	2-5 mL
HNO ₃	Undiluted concentrated HNO ₃	16N	2-5 mL
NaOH	400 grams solid NaOH in 870 mL water	10N	2 mL**

* Amount of acid to add (at the specified strength) per liter of water to reduce the sample pH to less than 2, assuming that the water is initially at pH 7, and is poorly buffered and does not contain particulate matter.

** To raise pH of 1 liter of water to 12.

The approximate volumes needed to acidify one liter of neutral water to a pH of less than 2 (or raise the pH to 12) are shown in the last column of the above table. These volumes are only approximate; if the water is more alkaline, contains inorganic or organic buffers, or contains suspended particles, more acid may be required. The final pH must be checked using narrow-range pH paper.

Sample acidification or base addition shall proceed as follows:

- Check initial pH of sample with wide range (0-14) pH paper.
- Fill sample bottle to within 5-10 mL of final desired volume and add about 1/2 of estimated acid or base required, stir gently and check pH with medium range pH paper (pH 0-6 or pH 7.5-14, respectively).
- Add acid or base a few drops at a time while stirring gently. Check for final pH using narrow range (0-2.5 or 11-13, respectively) pH paper; when desired pH is reached, cap sample bottle and seal.

Never dip pH paper into the sample; apply a drop of sample to the pH paper using the stirring rod.

5.2.3.2 Cyanide Preservation

Pre-sample preservation is required if oxidizing agents such as chlorine are suspected to be present. To test for oxidizing agents, place a drop of the sample on KI-starch paper; a blue color indicates the need for treatment. Add ascorbic acid to the sample, a few crystals at a time, until a drop of sample produces no color on the KI-starch paper. Then add an additional 0.6 g of ascorbic acid for each liter of sample volume. Add NaOH solution to raise pH to greater than 12 as described in 5.2.3.1. If oxidizing agents are not suspected, add NaOH as directed.

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5.2.3.3 Sulfide Preservation

Samples for sulfide analysis must be preserved by addition of 4 drops (0.2 mL) of 2N zinc acetate solution per 100 mL sample. The sample pH is then raised to 9 using NaOH. The 2N zinc acetate solution is made by dissolving 220 g of zinc acetate in 870 mL of distilled water to make 1 liter of solution.

5.2.3.4 Preservation of Organic Samples Containing Residual Chlorine

Some organic samples containing residual chlorine must be treated to remove this chlorine upon collection (see Attachment A). Test the samples for residual chlorine using EPA Methods 330.4 or 330.5 (Field Test Kits are available for this purpose). If residual chlorine is present, add 0.008% sodium thiosulfate (80 mg per liter of sample).

5.2.3.5 Field Filtration

When the objective is to determine concentration of dissolved inorganic constituents in a water system, the sample must be filtered through a non-metallic 0.45-micron membrane filter immediately after collection. A filtration system is recommended if large quantities of samples must be filtered in the field. The filtration system shall consist of a Büchner funnel inserted into a single-hole rubber stopper, sized to form a seal when inserted into the top of a vacuum filter flask equipped with a single side arm. Heavy-wall Tygon tubing shall be attached to the single side arm of the vacuum filter flask and the suction port of a vacuum pump. The stem of the Büchner funnel shall extend below the level of the side arm of the vacuum filter flask to prevent any solvent from entering the tubing leading to the vacuum pump. Before filtration, the filter paper, which shall be of a size to lay flat on the funnel plate, shall be wetted with the solvent in order to "seal" it to the funnel. Slowly pour the solvent into the funnel and monitor the amount of solvent entering the vacuum filter flask. When the rate of solvent entering the flask is reduced to intermittent dripping and the added aliquot of solvent in the funnel has passed through the filter, the used filter paper shall be replaced with new filter paper. If the solvent contains a high percentage of suspended solids, a coarser-sized nonmetallic membrane filter may be used prior to usage of the 0.45-micron membrane filter. This "prefiltering" step may be necessary to expedite the filtration procedure. Discard the first 20 to 50 mL of filtrate from each sample to rinse the filter and filtration apparatus to minimize the risk of altering the composition of the samples by the filtering operation. For analysis of dissolved metals, the filtrate is collected in a suitable bottle (see Section 5.2.2) and is immediately acidified to pH 2.0 or less with nitric acid whose purity is consistent with the measurement to be made. Inorganic anionic constituents may be determined using a portion of the filtrate that has not been acidified.

Samples used for determining temperature, dissolved oxygen, Eh, and pH should not be filtered. Do not use vacuum filtering prior to determining carbonate and bicarbonate concentration because it removes dissolved carbon dioxide and exposes the sample to the atmosphere. Pressure filtration can be done using water pressure from the well. If gas pressure is required, use an inert gas such as argon or nitrogen.

Do not filter samples for analysis of volatile organic compounds. If samples are to be filtered for analyzing other dissolved organic constituents, use a glass-fiber or metal-membrane filter and collect the samples in a suitable container (see Section 5.2.2). Because most organic analyses require extraction of the entire sample, do not discard any of it. After filtering, the membrane containing the suspended fraction can be sealed in a glass container and analyzed separately as soon as practicable.

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Total recoverable inorganic constituents may be determined using a second, unfiltered sample collected at the same time as the sample for dissolved constituents.

5.3 **SAMPLE PACKAGING AND SHIPPING**

5.3.1 Introduction

Samples collected for shipment from a site shall be classified as either environmental or hazardous material (or waste) samples. In general, environmental samples are collected off-site (for example from streams, ponds, or wells) and are not expected to be grossly contaminated with high levels of hazardous materials. On-site samples (for example, soil, water, and materials from drums or bulk storage tanks, obviously contaminated ponds, lagoons, pools, and leachates from waste sites) are considered hazardous. A distinction must be made between the two types of samples in order to:

- Determine appropriate procedures for transportation of samples. If there is any doubt, a sample shall be considered hazardous and shipped accordingly.
- Protect the health and safety of transport and laboratory personnel receiving the samples. Special precautions are used by the shipper and at laboratories when hazardous materials are received.

5.3.2 Environmental Samples

5.3.2.1 **Packaging**

Environmental samples are packaged as follows:

- Place sample container, properly identified and with a sealed lid, in a polyethylene bag, and seal the bag.
- Place sample in a cooler constructed of sturdy material which has been lined with a large polyethylene bag.
- Pack with enough noncombustible, absorbent, cushioning materials (bottle shoulders if ice is required) to minimize the possibility of the container breaking.
- If cooling is required (see Attachments D and E), place ice in zip-lock bags, on container lids (minimum of 8 pounds of ice for a medium size cooler).
- Seal large bag.
- Seal or close outside container.

5.3.2.2 **Marking/Labeling**

Sample containers must have a completed sample identification tag and the outside container must be marked "Environmental Sample." The appropriate side of the container must be marked "This End Up" and arrows placed appropriately. No DOT marking or labeling are required.

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5.3.2.3 Shipping Papers

No DOT shipping papers are required. However, the appropriate chain-of-custody forms must be included with the shipment.

5.3.2.4 Transportation

There are no DOT restrictions on mode of transportation.

5.2.3 Determination of Shipping Classification for Hazardous Material Samples

Samples not determined to be environmental samples, or samples known or expected to contain hazardous materials, must be considered hazardous material samples and transported according to the requirements listed below.

5.3.3.1 Known Substances

If the substance in the sample is known or can be identified, package, mark, label and ship according to the specific instructions for that material (if it is listed) in the DOT Hazardous Materials Table, 49 CFR 172.101.

Unz and Company have published the following steps to help in locating a proper shipping name from the Hazardous Materials Table, 49 CFR 172.101.

1. Look first for the chemical or technical name of the material, for example, ethyl alcohol. Note that many chemicals have more than one technical name, for example, perchloroethylene (not listed in 172.101) is also called tetrachloroethylene (listed 172.101). It may be useful to consult a chemist for all possible technical names a material can have. If your material is not listed by its technical name then.
2. Look for the chemical family name. For example, pentyl alcohol is not listed but the chemical family name is: alcohol, n.o.s. (not otherwise specified). If the chemical family name is not listed then.
3. Look for a generic name based on end use. For example, Paint, n.o.s or Fireworks, n.o.s. If a generic name based on end use is not listed then.
4. Look for a generic family name based on end use, for example, drugs, n.o.s. or cosmetics, n.o.s. Finally, if your material is not listed by a generic family name but you suspect or know the material is hazardous because it meets the definition of one or more hazardous classes, then.
5. You will have to go the the general hazard class for a proper shipping name. For example, Flammable Liquid, n.o.s, or Oxidizer, n.o.s.

5.3.3.2 Unknown Substances

For samples of hazardous substances of unknown content, select the appropriate transportation category according to the DOT Hazardous Materials Classification (Attachment F), a priority system of transportation categories.

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The correct shipping classification for an unknown sample is selected through a process of elimination, utilizing Attachment F. Unless known or demonstrated otherwise (through the use of radiation survey instruments), the sample is considered radioactive and appropriate shipping regulations for "radioactive material" followed.

If a radioactive material is eliminated, the sample is considered to contain "Poison A" materials (Attachment G), the next classification on the list. DOT defines "Poison A" as extremely dangerous poisonous gases or liquids of such a nature that a very small amount of gas, or vapor of the liquids, mixed with air is dangerous to life. Most Poison A materials are gases or compressed gases and would not be found in drum-type containers. Liquid Poison A would be found only in closed containers; however, all samples taken from closed drums do not have to be shipped as Poison A, which provides for a "worst case" situation. Based upon information available, a judgment must be made whether a sample from a closed container is a Poison A.

If Poison A is eliminated as a shipment category, the next two classifications are "flammable" or "nonflammable" gases. Since few gas samples are collected, "flammable liquid" would be the next applicable category. With the elimination of radioactive material, Poison A, flammable gas, and nonflammable gas, the sample can be classified as flammable liquid (or solid) and shipped accordingly. These procedures would also suffice for shipping any other samples classified below flammable liquids in the DOT classification table (Attachment F). For samples containing unknown materials, categories listed below flammable liquids/solids on Attachment F are generally not used because showing that these materials are not flammable liquids (or solids) requires flashpoint testing, which may be impractical and possibly dangerous at a site. Thus, unless the sample is known to consist of materials listed as less hazardous than flammable liquid (or solid) on Attachment F, it is considered a flammable liquid (or solid) and shipped as such.

For any hazardous material shipment, utilize the shipping checklist (Attachment H) as a guideline to ensure that all sample-handling requirements are satisfied.

5.3.4 PACKAGING AND SHIPPING OF SAMPLES CLASSIFIED AS FLAMMABLE LIQUID (OR SOLID)

5.3.4.1 Packaging

Applying the word "flammable" to a sample does not imply that it is in fact flammable. The word prescribes the class of packaging according to DOT regulations.

1. Collect sample in the prescribed container with a nonmetallic, Teflon-lined screw cap. To prevent leakage, fill container no more than 90 percent full.
2. Complete sample label tag and attach securely to sample container.
3. Seal container and place in 2-mil-thick (or thicker) polyethylene bag, one sample per bag. Position sample identification label so that it can be read through bag. Seal bag.
4. Place sealed bag inside metal can and cushion it with enough noncombustible, absorbent material (for example, vermiculite or diatomaceous earth) between the bottom and sides of the can and bag to prevent breakage and absorb leakage. Pack one bag per can. Use clips, tape, or other positive means to hold can lid securely, tightly and permanently. Mark can as indicated in Paragraph 1 of Section 5.3.4.2, below.

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5. Place one or more metal cans (or single 1-gallon bottle) into a strong outside container, such as a metal picnic cooler or a DOT-approved fiberboard box. Surround cans with noncombustible, absorbent cushioning materials for stability during transport. Mark container as indicated in Paragraph 2 of Section 5.3.4.2.

5.3.4.2 Marking/Labeling

1. Use abbreviations only where specified. Place the following information, either hand-printed or in label form, on the metal can (or 1-gallon bottle):
 - Laboratory name and address.
 - "Flammable Liquid, n.o.s. UN1993" or "Flammable Solid, n.o.s. UN1325."

Not otherwise specified (n.o.s) is not used if the flammable liquid (or solid) is identified. Then the name of the specific material is listed before the category (for example, Acetone, Flammable Liquid), followed by its appropriate UN number found in the DOT Hazardous Materials table (49 CFR 172.101).

2. Place all information on outside shipping container as on can (or bottle), specifically:
 - Proper shipping name.
 - UN or NA number.
 - Proper label(s).
 - Addressee and sender.

Place the following labels on the outside shipping container: "Cargo Aircraft Only" and "Flammable Liquid" (or "Flammable Solid"). "Dangerous When Wet" label shall be used if the solid has not been exposed to a wet environment. "Laboratory Samples" and "THIS SIDE UP" or "THIS END UP" shall also be marked on the top of the outside container, and upward-pointing arrows shall be placed on all four sides of the container.

5.3.4.3 Shipping Papers

1. Use abbreviations only where specified. Complete the carrier-provided bill of lading and sign certification statement. Provide the following information in the order listed (one form may be used for more than one exterior container).
 - "Flammable Liquid, n.o.s. UN1993" or "Flammable Solid, n.o.s. UN1325."
 - "Limited Quantity" (or "Ltd. Qty.").
 - "Cargo Aircraft Only."
 - Net weight (wt) or net volume (vol), just before or just after "Flammable Liquid, n.o.s." or "Flammable Solid, n.o.s.," by item, if more than one metal can is inside an exterior container.
 - "Laboratory Samples" (if applicable).

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2. Include Chain-of-Custody Record, properly executed in outside container.
3. "Limited Quantity" of "Flammable Liquid, n.o.s." is limited to one pint per inner container. For "Flammable Solid, n.o.s.," net weight of inner container plus sample shall not exceed one pound; total package weight shall not exceed 25 pounds.

5.3.4.4 Transportation

1. Transport unknown hazardous substance samples classified as flammable liquids by rented or common carrier truck, railroad, or express overnight package services. Do not transport by any passenger-carrying air transport system, even if they have cargo-only aircraft. DOT regulations permit regular airline cargo-only aircraft, but difficulties with most suggest avoiding them. Instead, ship by airline carriers that only carry cargo.
2. For transport by government-owned vehicle, including aircraft, DOT regulations do not apply. However, procedures described above, with the exception of execution of the bill of lading with certification, shall still be used.

6.0 REFERENCES

American Public Health Association, 1981. Standard Methods for the Examination of Water and Wastewater. 15th Edition. APHA, Washington, D.C.

U. S. Department of Transportation, 1983. Hazardous Materials Regulations, 49 CFR 171-177.

U.S. EPA, 1984. "Guidelines Establishing Test Procedures for the Analysis of Pollutants under Clean Water Act." Federal Register, Volume 49 (209), October 26, 1984, p. 43234.

U.S. EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. U.S. EPA-EMSL, Cincinnati, Ohio.

7.0 ATTACHMENTS

- Attachment A - Sample Label
- Attachment B - Chain-of-Custody Record Form
- Attachment C - Chain-of-Custody Seal
- Attachment D - General Sample Container and Preservation Requirements CERCLA/RCRA Samples
- Attachment E - Required Containers, Preservation Techniques, and Holding Times (sheets)
- Attachment F - DOT Hazardous Material Classification (49 CFR 173.2)
- Attachment G - DOT List of Class "A" Poisons (40 CFR 172.101)
- Attachment H - Hazardous Materials Shipping Checklist

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ATTACHMENT A

SAMPLE LABEL

PROJECT: _____	
STATION LOCATION: _____	
DATE: ____/____/____	TIME: _____ hrs.
MEDIA: WATER <input type="checkbox"/> SOIL <input type="checkbox"/> SEDIMENT <input type="checkbox"/>	<input type="checkbox"/>
CONCENTRATION: LOW <input type="checkbox"/> MEDIUM <input type="checkbox"/> HIGH <input type="checkbox"/>	
TYPE: GRAB <input type="checkbox"/> COMPOSITE <input type="checkbox"/>	
ANALYSIS	PRESERVATION
VOA <input type="checkbox"/> BNAs <input type="checkbox"/>	Cool to 4°C <input type="checkbox"/>
PCBs <input type="checkbox"/> PESTICIDES <input type="checkbox"/>	HNO ₃ to pH <2 <input type="checkbox"/>
METALS: TOTAL <input type="checkbox"/> DISSOLVED <input type="checkbox"/>	NaOH to pH>12 <input type="checkbox"/>
CYANIDE <input type="checkbox"/>	_____ <input type="checkbox"/>
_____ <input type="checkbox"/>	
Sampled by: _____	
Case No. _____	Traffic Report No.: _____
Remarks:	

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ATTACHMENT C

CHAIN-OF-CUSTODY SEAL

Signature <hr/>		<hr/>		CUSTODY SEAL <hr/>
Date <hr/>				Date <hr/>
CUSTODY SEAL <hr/>				Signature <hr/>

ATTACHMENT D

GENERAL SAMPLE CONTAINER AND PRESERVATION REQUIREMENTS
CERCLA/RCRA SAMPLES

Sample Type and Concentration		Container ⁽¹⁾	Sample Size	Preservation ⁽²⁾	Holding Time ⁽²⁾		
WATER	Organics (GC & GC/MS)	VOA	Borosilicate glass	2 x 40 mL	Cool to 4°C	7 days	
		Extractables	Low Medium	Amber glass	2 x 2 L or 4 x 1 L 4 x 32 oz.	Cool to 4°C None	5 days after extraction; 40 days after extraction
	Inorganics	Metals	Low Medium	High-density polyethylene Wide-mouth glass	1 L 16 oz.	HNO ₃ to pH ≤ 2 None	6 months (Hg-30 days) 6 months
		Cyanide	Low Medium	High-density polyethylene Wide-mouth glass	1 L 16 oz.	NaOH to pH > 12 None	4 days
	Organic/Inorganic	High Hazard	8-oz. wide-mouth glass	6 oz.	None	14 days	
	COD	----	High-density polyethylene	0.5 L	H ₂ SO ₄ to pH < 2	28 days	
	TOC	----	High-density polyethylene	0.5 L	HCl to pH < 2	28 days	
	Oil & Grease	----	Glass	1.0 L	H ₂ SO ₄ to pH < 2	28 days	
	Phenols	----	High-density polyethylene	1.0 L	H ₂ SO ₄ to pH < 2	28 days	
	General Chemistry	----	High-density polyethylene	1.0 L	None	----	
SOIL	Organics (GC & GC/MS)	VOA	2 x 120 mL (4 oz.) wide-mouth glass	240 mL	Cool to 4°C	10 days	
		Extractables	Low Medium	8-oz. or 2 x 4-oz. (120 mL) wide-mouth glass	6 oz.	Cool to 4°C	10 days to extraction; 40 days after extraction
	Inorganics	Low/Medium	8-oz. or 2 x 4-oz. (120 mL) wide-mouth glass	6 oz.	Cool to 4°C	NA	
	Organic/Inorganic	High Hazard	8-oz. (120 mL) wide-mouth glass	6 oz.	None	NA	
	Dioxin	All	4-oz. (120 mL) wide-mouth glass	4 oz.	None	NA	
	EP Toxicity	All	250 mL high-density polyethylene	200 grams	None	NA	
AIR	Volatile Organics	Low Medium	Charcoal Tube 7 cm long, 6 mm OD, 4 mm ID	100 L air	Cool to 4°C	NA	

(1) All glass containers should have Teflon cap liners or septa.

(2) See Attachment B.

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ATTACHMENT E

REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter Number/Name	Container ⁽¹⁾	Preservation ⁽²⁾⁽³⁾	Maximum Holding Time ⁽⁴⁾
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INORGANIC TESTS:

Acidity	P, G	Cool, 4°C	14 days
Alkalinity	P, G	Cool, 4°C	14 days
Ammonia	P, G	Cool, 4°C, H ₂ SO ₄ to pH 2	28 days
Biochemical Oxygen Demand	P, G	Cool, 4°C	48 hours
Bromide	P, G	None required	28 days
Biochemical Oxygen Demand, Carbonaceous	P, G	Cool, 4°C	48 hours
Chemical Oxygen Demand	P, G	Cool, 4°C, H ₂ SO ₄ to pH 2	28 days
Chloride	P, G	None required	28 days
Chlorine, Total Residual	P, G	None required	Analyze immediately
Color	P, G	Cool, 4°C	48 hours
Cyanide, Total and Amenable to Chlorination	P, G	Cool, 4°C, NaOH to pH 12, 0.6 g ascorbic acid ⁽⁵⁾	14 days ⁽⁶⁾
Fluoride	P	None required	28 days
Hardness	P, G	HNO ₃ to pH 2, H ₂ SO ₄ to pH 2	6 months
Hydrogen Ion (pH)	P, G	None required	Analyze immediately
Kjeldahl and Organic Nitrogen	P, G	Cool, 4°C, H ₂ SO ₄ to pH 2	28 days
Nitrate	P, G	None required	48 hours
Nitrate-Nitrite	P, G	Cool, 4°C, H ₂ SO ₄ to pH 2	28 days
Nitrite	P, G	Cool, 4°C	48 hours
Oil & Grease	G	Cool, 4°C, H ₂ SO ₄ to pH 2	28 days
Organic Carbon	P, G	Cool, 4°C, HCl or H ₂ SO ₄ to pH 2	428 days
Orthophosphate	P, G	Filter immediately, Cool 4°C	48 hours
Oxygen, Dissolved-Probe	G Bottle and top	None required	Analyze immediately
Oxygen, Dissolved-Winkler	G Bottle and top	Fix on site and store in dark	8 hours
Phenols	G	Cool, 4°C, H ₂ SO ₄ to pH 2	28 days
Phosphorus (elemental)	G	Cool, 4°C	48 hours
Phosphorus, Total	P, G	Cool, 4°C, H ₂ SO ₄ to pH 2	28 days
Residue, Total	P, G	Cool, 4°C	7 days
Residue, Filterable	P, G	Cool, 4°C	48 hours
Residue, Nonfilterable (TSS)	P, G	Cool, 4°C	7 days
Residue, Settleable	P, G	Cool, 4°C	48 hours
Residue, Volatile	P, G	Cool, 4°C	7 days
Silica	P	Cool, 4°C	28 days
Specific Conductance	P, G	Cool, 4°C	28 days

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**ATTACHMENT E
REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
PAGE TWO**

Parameter Number/Name	Container ⁽¹⁾	Preservation ⁽²⁾⁽³⁾	Maximum Holding Time ⁽⁴⁾
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INORGANIC TESTS (Cont'd):

Sulfate	P, G	Cool, 4°C	28 days
Sulfide	P, G	Cool, 4°C, add zinc acetate plus sodium hydroxide to pH 9	7 days
Sulfite	P, G	None required	Analyze immediately
Surfactants	P, G	Cool, 4°C	48 hours
Temperature	P, G	None required	Analyze immediately
Turbidity	P, G	Cool, 4°C	48 hours

METALS:(7)

Chromium VI	P, G	Cool, 4°C	24 hours
Mercury	P, G	HNO ₃ to pH 2	28 days
Metals, except Chromium VI and Mercury	P, G	HNO ₃ to pH 2	6 months

ORGANIC TESTS:(8)

Purgeable Halocarbons	G, Teflon-lined septum	Cool, 4°C, 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾	14 days
Purgeable Aromatic Hydrocarbons	G, Teflon-lined septum	Cool, 4°C, 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾ HCl to pH 2 ⁽⁹⁾	14 days
Acrolein and Acrylonitrile	G, Teflon-lined septum	Cool, 4°C, 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾ adjust pH to 4-5 ⁽¹⁰⁾	14 days
Phenols ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C, 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾	7 days until extraction, 40 days after extraction
Benzidines ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C, 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾	7 days until extraction ⁽¹³⁾
Phthalate Esters ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C	7 days until extraction, 40 days after extraction
Nitrosamines	G, Teflon-lined cap	Cool, 4°C, store in dark, 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾	7 days until extraction, 40 days after extraction
PCBs ⁽¹¹⁾ Acrylonitrile	G, Teflon-lined cap	Cool, 4°C	7 days until extraction, 40 days after extraction
Nitroaromatics & Isophorone ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C, 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾ , store in dark	7 days until extraction, 40 days after extraction
Polynuclear Aromatic Hydrocarbons ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C, 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾ , store in dark	7 days until extraction, 40 days after extraction
Haloethers ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C, 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾	7 days until extraction, 40 days after extraction
Chlorinated Hydrocarbons ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C	7 days until extraction, 40 days after extraction
TCDD ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C, 0.008% Na ₂ S ₂ O ₃ ⁽⁵⁾	7 days until extraction, 40 days after extraction

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**ATTACHMENT E
REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
PAGE THREE**

Parameter Number/Name	Container ⁽¹⁾	Preservation ⁽²⁾⁽³⁾	Maximum Holding Time ⁽⁴⁾
-----------------------	--------------------------	--------------------------------	-------------------------------------

PESTICIDES TESTS:

Pesticides ⁽¹¹⁾	G, Teflon-lined cap	Cool, 4°C, pH 5-9 ⁽¹⁵⁾	7 days until extraction; 40 days after extraction
----------------------------	---------------------	-----------------------------------	------------------------------------------------------

RADIOLOGICAL TESTS:

1-5 Alpha, beta and radium	P, G	HNO ₃ to pH 2	6 months
----------------------------	------	--------------------------	----------

- (1) Polyethylene (P) or Glass (G)
- (2) Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the _____ of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at _____ until compositing and sample splitting is completed.
- (3) When any sample is to be shipped by common carrier or sent through the United States mails, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR Part 172).
- (4) Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis _____ still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that the specific types of samples under study are stable for the longer time, and has received a variance from the Regional Administrator.
- (5) Should only be used in the presence of residual chlorine.
- (6) Maximum holding time is 24 hours when sulfide is present. Optionally, all samples may be tested with lead acetate paper before pH adjustments is _____ order to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. the sample is filtered and then NaOH is added to pH 12.
- (7) Samples should be filtered immediately on site before adding preservative for dissolved metals.
- (8) Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.
- (9) Sample receiving no pH adjustment must be analyzed within 7 days of sampling.
- (10) the pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.
- (11) When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4°C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6-9; samples preserved in this manner may be held for 7 days before extraction and for 40 days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re: the requirement for thiosulfate reduction of residual chlorine) and footnotes 12, 13 (re: the analysis of benzidine).
- (12) If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0 ± 0.2 to prevent rearrangement to benzidine.
- (13) Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.
- (14) For the analysis of diphenylnitrosamine add 0.008% Na₂S₂O₃ and adjust pH to 7-10 with NaOH within 24 hours of sampling.
- (15) The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% Na₂S₂O₃.

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ATTACHMENT F

**DOT HAZARDOUS MATERIAL CLASSIFICATION
(49 CFR 173.2)**

1. Radioactive material (except a limited quantity)
2. Poison A
3. Flammable gas
4. Nonflammable gas
5. Flammable liquid
6. Oxidizer
7. Flammable Solid
8. Corrosive material (liquid)
9. Poison B
10. Corrosive material (solid)
11. Irritating material
12. Combustible liquid (in containers having capacities exceeding 110 gallons [416 liters])
13. ORM-B
14. ORM-A
15. Combustible liquid (in containers having capacities of 110 gallons [416 liters] or less)
16. ORM-E

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ATTACHMENT G

DOT LIST OF CLASS "A" POISON (49 CFR 172.101)

Material	Physical State at Standard Temperature
Arsine	Gas
Bromoacetone	Liquid
Chloropicrin and methyl chloride mixture	Gas
Chloropicrin and nonflammable, nonliquefied compressed gas mixture	Gas
Cyanogen chloride	Gas (> 13.1°C)
Cyanogen gas	Gas
Gas identification set	Gas
Gelatin dynamite (H. E. Germaine)	—
Grenade (with Poison "A" gas charge)	—
Hexaethyl tetraphosphate/compressed gas mixture	Gas
Hydrocyanic (prussic) acid solution	Liquid
Hydrocyanic acid, liquefied	Gas
Insecticide (liquefied) gas containing Poison "A" or Poison "B" material	Gas
Methyldichloroarsine	Liquid
Nitric oxide	Gas
Nitrogen peroxide	Gas
Nitrogen tetroxide	Gas
Nitrogen dioxide, liquid	Gas
Parathion/compressed gas mixture	Gas
Phosgene (diphosgene)	Liquid

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ATTACHMENT H

HAZARDOUS MATERIALS SHIPPING CHECKLIST

PACKAGING

1. Check DOT 172.500 table for appropriate type of package for hazardous substance.
2. Check for container integrity, especially the closure.
3. Check for sufficient absorbent material in package.
4. Check for sample tags and log sheets for each sample, and chain-of-custody record.

SHIPPING PAPERS

1. Check that entries contain only approved DOT abbreviations.
2. Check that entries are in English.
3. Check that hazardous material entries are specially marked to differentiate them from any nonhazardous materials being sent using same shipping paper.
4. Be careful all hazardous classes are shown for multiclass materials.
5. Check total amounts by weight, quantity, or other measures used.
6. Check that any limited-quantity exemptions are so designated on the shipping paper.
7. Offer driver proper placards for transporting vehicle.
8. Check that certification is signed by shipper.
9. Make certain driver signs for shipment.

RCRA MANIFEST

1. Check that approved state/federal manifests are prepared.
2. Check that transporter has the following: valid EPA identification number, valid driver's license, valid vehicle registration, insurance protection, and proper DOT labels for materials being shipped.
3. Check that destination address is correct.
4. Check that driver knows where shipment is going.
5. Check that the driver is aware of emergency procedures for spills and accidents.
6. Make certain driver signs for shipment.
7. Make certain one copy of executed manifest and shipping document is retained by shipper.



HALLIBURTON NUS
Environmental Corporation

**ENVIRONMENTAL
TECHNOLOGIES GROUP**

**STANDARD
OPERATING
PROCEDURES**

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Applicability ETG	
Prepared Earth Sciences	
Approved D. Senovich	

Subject
FIELD DOCUMENTATION

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1.0 PURPOSE

The purpose of this standard operating procedure is to delineate the field data record forms, logs and reports generally initiated and maintained for documenting ETG field activities.

2.0 SCOPE

Documents presented within this procedure shall be used for all ETG field projects, as applicable. Exceptions may include other additional documents required specifically by contract.

3.0 GLOSSARY

None

4.0 RESPONSIBILITIES

Site Manager - The Site Manager releases the site logbook to the Field Operations Leader or other person responsible for the direction of on-site activities (e.g., Reconnaissance Survey Team Leader, Sampling Team Leader). Also, responsible for placing all forms used in site activities, field reports, and upon the completion of field work the site logbook in the permanent site file.

Field Operations Leader - The Field Operations Leader is responsible for ensuring that the site logbook and the appropriate forms and field reports illustrated in this guideline are correctly used, accurately filled out, and completed in the required time-frame.

5.0 PROCEDURES

5.1 SITE LOGBOOK

5.1.1 General

The site logbook is a controlled document which records all major on-site activities. At a minimum, the following activities/events shall be recorded in the site logbook:

- Arrival/departure of site visitors
- Arrival/departure of equipment
- Sample pickup (chain-of-custody form numbers, carrier, time)
- Sampling activities/sample logsheet numbers
- Start or completion of borehole/trench/monitoring well installation or sampling activities
- Health and Safety issues

The site logbook is initiated at the start of the first on-site activity (e.g., initial reconnaissance survey). Entries are made for every day that on-site activities take place which involve HALLIBURTON NUS or subcontractor personnel. One current site logbook is maintained per site. The site logbook becomes part of the permanent site file.

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The cover of each site logbook contains the following information:

- Project Name
- HALLIBURTON NUS Project Number
- Site Manager's Name
- Sequential Book Number
- Start Date
- End Date

Daily entries into the logbook may contain a variety of information. At the beginning of each day the following information must be recorded:

- Date
- Start time
- Weather
- All field personnel present
- Any visitors present

During the day, a summary of all site activities and level of personal protection shall be recorded in the logbook. The information need not duplicate that recorded in other field notebooks (e.g., sample logbook, Site Geologist's notebook, Health and Safety Officer's notebook, etc.), but shall summarize the contents of these other notebooks and refer to the page locations in these notebooks for detailed information. An example of a site logbook page is shown in Attachment A.

The sample logsheet for each sample collected (see Procedure _____) must be referenced. If measurements are made at any location, the measurements and equipment used must either be recorded in the site logbook or reference must be made to the notebook and page number(s) on which they are recorded (see Attachment A).

All entries shall be made in black pen. No erasures are permitted. If an incorrect entry is made, the data shall be crossed out with a single strike mark, and initialed and dated. At the completion of entries by any individual, the logbook must be signed. It must also be signed by the Field Operations Leader or responsible site leader at the end of each day.

5.1.2 Photographs

When movies, slides, or photographs are taken of a site or any monitoring location, they are numbered to correspond to logbook entries. The name of the photographer, date, time, site location, site description, and weather conditions are entered in the logbook as the photographs are taken. A series entry may be used for rapid-sequence photographs. The photographer is not required to record the aperture settings and shutter speeds for photographs taken within the normal automatic exposure range. However, special lenses, films, filters, and other image-enhancement techniques must be noted in the logbook. If possible, such techniques shall be avoided, since they can adversely affect the admissibility of photographs as evidence. Chain-of-custody procedures depend upon the subject matter, type of film, and the processing it requires. Film used for aerial photography, confidential information, or criminal investigation require chain-of-custody procedures. Adequate logbook notation and receipts may be used to account for routine film processing. Once processed, the slides of photographic prints shall be serially numbered and labeled according to the logbook descriptions.

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5.2 FORMS USED IN RI ACTIVITIES

Table 1 lists the forms illustrated in this procedure. Forms may be altered or revised for project-specific needs, with proper client notification.

5.2.1 Sample Collection, Labeling, Shipment and Request for Analysis

5.2.1.1 Sample Label

The sample label is a 2-by 4-inch white label with black lettering and an adhesive backing. Attachment B-1 is an example of a sample label. These labels are required on every sample but are not controlled documents. Guidelines for filling out sample labels are contained in _____.

5.2.1.2 Chain-of-Custody Record Form

The Chain-of-Custody Record Form accompanies a sample (or group of samples) as it is transferred from person to person. This form must be used for any samples collected for chemical or geotechnical analysis, whether on-site or off-site. Attachment B-2 illustrates a Chain-of-Custody Record form used by HALLIBURTON NUS.

5.2.1.3 Chain-of-Custody Seal

Attachment B-3 is an example of a custody seal. The Custody seal is a 1-by 3-inch adhesive-backed label. It is part of a chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field. It is used whenever samples are shipped with an accompanying Chain-of-Custody Record form. Procedure _____ describes the procedures for using chain-of-custody seals.

5.2.1.4 Sample Log Sheet

A Sample Log Sheet is a notebook (3-ring binder) page that is used to record specified types of data while sampling. Attachments B-4 to B-7 are examples of Sample Log Sheets. The data recorded on these sheets are useful in describing the waste source and sample as well as pointing out any problems encountered during sampling. Guidelines for filling out the Sample Log Sheet are contained in _____.

5.2.2 Geohydrological and Geotechnical Forms

5.2.2.1 Groundwater Level Measurement Sheet

A groundwater level measurement sheet, shown in Attachment C-1 should be filled out for each round of water level measurements at a site.

5.2.2.2 Data Sheet for Pumping Test (Pumping Well)

During the performance of a pumping test, a large amount of data must be recorded, often within a short time period. The pumping test data sheet (Attachment C-2) facilitates this task by standardizing the data collection format, and allowing the time interval for collection to be laid out in advance.

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TABLE 1

TECHNICAL FORMS IN CURRENT USE FOR REMEDIAL INVESTIGATIONS

Attachment Number/Description	Form Usage Described in SOP Number
B-1 Sample Label	SA-6.1
B-2 Chain-of-Custody Record	SA-6.1
B-3 Chain-of-Custody Seal	SA-6.6
B-4 Groundwater Sample Log Sheet	SA-6.6
B-5 Soil Sample Log Sheet	SA-6.6
B-6 Surface Water Sample Log Sheet	SA-6.6
B-7 Container Sample Log Sheet	SA-6.6
C-1 Groundwater Level Measurement Sheet	GH-2.5
C-2 Pumping Test Data Sheet	GH-2.3
C-3 Hydraulic Conductivity Testing Data Sheet	GH-2.4
C-4 Packer Testing Report Form	GH-2.2
C-5 Summary Log of Boring	GH-1.5
C-6 Overburden Monitoring Well Construction Sheet	GH-1.5
C-7 Confining Layer Monitoring Well Construction Sheet	GH-1.5
C-8 Bedrock (Open Hole) Monitoring Well Construction Sheet	GH-1.5
C-9 Bedrock (Well Installed) Monitoring Well Construction Sheet	GH-1.5
C-10 Bedrock (Well Installed) Monitoring Well Construction Sheet	GH-1.5
C-11 Test Pit Log	GH-1.8
D-1 Equipment Calibration Log	---

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5.2.2.3 Data Sheet for Pumping Test (Observation Well) or In-Situ Hydraulic Conductivity Test

This data sheet (Attachment C-3) is similar to that described in Section 5.2.2.2. However, somewhat different data must be recorded for pumping test observation wells and in-situ hydraulic conductivity tests, as shown on this sheet.

5.2.2.4 Packer Test Reporting Forms

A packer test reporting form shown in Attachment C-4 is used for collecting data when conducting packer tests during monitoring well drilling.

5.2.2.5 Summary Log of Boring

During the progress of each boring, a log of the materials encountered, operation and driving of casing, and location of samples must be kept. The Summary Log of Boring (Attachment C-5) is used for this purpose. In addition, if volatile organics are monitored on cores, samples or cuttings from the borehole (using HNU or OVA detectors), the results are entered on the boring log at the appropriate depth. The boring log also provides space for entry of the laboratory sample number and the concentration of a few key analytical results. This feature allows direct comparison of contaminant concentrations with soil characteristics.

5.2.2.6 Monitoring Well Construction Details Form

A Monitoring Well Construction Details Form must be completed for every monitoring well installed. This form contains specific information on length and type of well riser pipe and screen, backfill, filter sand and grout characteristics, and surface seal characteristics. This information is important in evaluating the performance of the monitoring well, particularly in areas where water levels show temporal variation, or where there are multiple (immiscible) phases of contaminants. Depending on the type of monitoring well (in overburden or bedrock), different forms are used (see Attachments C-6 through C-10). The Monitoring Well Construction Details Form is not a controlled document. Guidelines on completing this form are contained in _____.

5.2.2.7 Test Pit Log

When a test pit or trench is constructed for investigative or sampling purposes, a Test Pit Log (Attachment C-11) must be filled out by the responsible field geologist or sampling technician.

5.2.3 Equipment Calibration and Maintenance Forms

5.2.3.1 Equipment Calibration Log

The calibration or standardization of monitoring, measuring or test equipment is necessary to assure the proper operation and response of the equipment, to document the accuracy, precision or sensitivity of the measurement, and determine if correction should be applied to the readings. Some items of equipment require frequent calibration, other infrequent. Some are calibrated by the manufacturer, other by the user.

Each instrument requiring calibration has its own Equipment Calibration Log (Attachment D-1) which documents that the manufacturer's instructions were followed for calibration of the equipment, including frequency and type of standard or calibration device.

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5.3 FIELD REPORTS

The reports described herein are to be used during field investigations, but do not replace or take precedence over project-specific or subcontractor-specific required reports.

These reports serve several purposes:

- To maintain a written record of major events/accomplishments/problems related to the field work.
- To allow ongoing monitoring of the actual progress of field tasks in comparison to the planned schedule, and to allow timely corrective action (if required).
- To inform Site Managers of progress/accomplishments for inclusion in The Monthly Project Tracking System.

5.3.1 Program Design

The primary means of recording onsite activities is the site logbook (see Procedure _____) and other field logbooks (e.g. geologists notebook, health and safety officer's logbook, sample logbooks). However, these logbooks and notebooks usually contain extremely detailed information which is required for data interpretation or documentation, but not for tracking and reporting of progress. Furthermore, the field logbooks remain onsite for extended periods of time and are thus not accessible for review by project management. The reports described in this procedure are, in essence, simplified summaries of the logbooks, which are designed to provide only the information needed by project management to keep informed of the progress of field activities.

5.3.2 Daily Activities Report

5.3.2.1 Description

The Daily Activities Report documents the activities and progress for each day's field work. This report is filled out on a daily basis whenever there are drilling, test pitting, well construction, or other related activities occurring which involve subcontractor personnel. These sheets summarize the work performed and form the basis of payment to subcontractors (Attachment E is an example of a Daily Activities Report).

5.3.2.2 Responsibilities

It is the responsibility of the rig geologist to complete the report and obtain the driller's signature acknowledging that the times and quantities of material entered are correct.

5.3.2.3 Submittal and Approval

At the end of the shift, the rig geologist submits the Daily Activities Report to the Field Operations Leader (FOL) for review and filing. The Daily Activities Report is not a formal report and thus requires no further approval. The reports are retained by the FOL for use in preparing the site logbook and weekly Field Summaries, and are submitted to the Site Manager weekly along with the Weekly Field Summary.

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5.3.3 Field Trip Summary

5.3.3.1 Description

The Field Trip Summary is an abstract of the Site Logbook, summarizing the major activities onsite for a particular week or field cycle (e.g., 10 days). It should be organized on a day-by-day basis, and contain the following information at a minimum (see Attachment B):

- Date (week ending)
- Personnel onsite (contractor, subcontractors, visitors)
- Weather conditions encountered during the week
- Site activities
- Number and type of samples collected (including C.O.C. form numbers)
- Issues impacting progress of the project.

5.3.3.2 Responsibilities

The Field Operations Leader or responsible individual onsite if not the FOL (e.g., geophysics team leader, sampling team leader) is responsible for completing the Weekly Field Summary at the end of each week of ongoing site activity, or at the completion of an activity (if no further activity will take place during that week).

5.3.3.3 Submittal and Approval

The summary, along with Daily Activities Reports, Health & Safety Officer's Reports, and any other documentation, must be delivered or sent to the Site Manager at the end of each week.

The Field Trip Summary is an internal informational document and is not subject to project management review or approval.

6.0 REFERENCES

None.

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7.0 ATTACHMENTS

- Attachment A - Typical Site Logbook Entry**
- Attachment B-1 - Sample Label**
- Attachment B-2 - Chain-of-Custody Record From, Region III**
- Attachment B-3 - Chain-of-Custody Seal**
- Attachment B-4 - Groundwater Sample Log Sheet Form**
- Attachment B-5 - Soil Sample Log Sheet Form**
- Attachment B-6 - Surface Water Sample Log Sheet Form**
- Attachment B-7 - Container Sample Log Sheet Form**
- Attachment C-1 - Groundwater Level Measurement Sheet**
- Attachment C-2 - Pumping Test Data Sheet**
- Attachment C-3 - Hydraulic Conductivity Testing Data Sheet**
- Attachment C-4 - Packer Testing Report Form**
- Attachment C-5 - Summary Log of Boring**
- Attachment C-6 - Overburden Monitoring Well Construction Sheet**
- Attachment C-7 - Confining Layer Monitoring Well Construction Sheet**
- Attachment C-8 - Bedrock (Open Hole) Monitoring Well Construction Sheet**
- Attachment C-9 - Bedrock (Well Installed) Monitoring Well Construction Sheet**
- Attachment C-10 - Bedrock (Well Installed) Monitoring Well Construction Sheet**
- Attachment C-11 - Test Pit Log Form**
- Attachment D-1 - Equipment Calibration Log**
- Attachment E - Rig Shift Report**
- Attachment F - Field Trip Summary Report (2 pages)**

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**ATTACHMENT A
TYPICAL SITE LOGBOOK ENTRY**

START TIME: _____ DATE: _____

SITE LEADER: _____

PERSONNEL:

HALLIBURTON NUS	DRILLER	EPA
_____	_____	_____
_____	_____	_____
_____	_____	_____

WEATHER: Clear, 68°F, 2-5 mph wind from SE

ACTIVITIES:

1. Steam jenny and fire hoses were set up.
2. Drilling activities at well _____ resumes. Rig geologist was _____ See Geologist's Notebook, No. 1, page 29-30, for details of drilling activity. Sample No. 123-21-54 collected; see sample logbook, page 42. Drilling activities completed at 11:50 and a 4 inch stainless steel well installed. See Geologist's Notebook, No. 1, page 31, and well construction details for well _____.
3. Drilling rig No. 2 steam-cleaned at decontamination pit. Then set up at location of well _____.
4. Well _____ drilled. Rig geologist was _____. See Geologist's Notebook, No. 2, page _____ for details of drilling activities. Sample numbers 123-22-S1, 123-22-S2, and 123-22-S3 collected; see sample logbook, pages 43, 44, and 45.
5. Well _____ was developed. Seven 55-gallon drums were filled in the flushing stage. The well was then pumped using the pitcher pump for 1 hour. At the end of the hour, water pumped from well was "sand free."
6. EPA remedial project manger arrives on-site at 14:25 hours.
7. Large dump truck arrives at 14:45 and is steam-cleaned. Backhoe and dump truck set up over test pit _____.
8. Test pit _____ dug with cuttings placed in dump truck. Rig geologist was _____. See Geologist's Notebook, No. 1, page 32, for details of test pit activities. Test pit subsequently filled. No samples taken for chemical analysis. Due to shallow groundwater table, filling in of test pit _____ resulted in a very soft and wet area. A mound was developed and the area roped off.
9. Express carrier picked up samples (see Sample Logbook, pages 42 through 45) at 17:50 hours. Site activities terminated at 18:22 hours. All personnel offsite, gate locked.

Field Operations Leader

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ATTACHMENT B-1

SAMPLE LABEL

PROJECT: _____

STATION LOCATION: _____

DATE: ____/____/____ TIME: _____ hrs.

MEDIA: WATER SOIL SEDIMENT _____

CONCENTRATION: LOW MEDIUM HIGH

TYPE: GRAB COMPOSITE

ANALYSIS		PRESERVATION
VOA <input type="checkbox"/>	BNAs <input type="checkbox"/>	Cool to 4°C <input type="checkbox"/>
PCBs <input type="checkbox"/>	PESTICIDES <input type="checkbox"/>	HNO ₃ to pH <2 <input type="checkbox"/>
METALS: TOTAL <input type="checkbox"/>	DISSOLVED <input type="checkbox"/>	NaOH to pH>12 <input type="checkbox"/>
CYANIDE <input type="checkbox"/>		_____ <input type="checkbox"/>

Sampled by: _____

Case No. _____ Traffic Report No.: _____

Remarks:

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**ATTACHMENT B-3
CHAIN-OF-CUSTODY SEAL**

Signature <hr/>	 HALLIBURTON NUS <small>International Corporation</small>	CUSTODY SEAL <hr/>
<hr/> Date		<hr/> Date
<hr/> CUSTODY SEAL	 HALLIBURTON NUS <small>International Corporation</small>	<hr/> Signature

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ATTACHMENT B-4

SAMPLE LOG SHEET

Page _____ of _____



- Monitoring Well Data
- Domestic Well Data
- Other _____

Case # _____

By _____

Project Site Name _____

Project Site Number _____

HALLIBURTON NUS Source No. _____

Source Location _____

Total Well Depth:	Purge Data				
Well Casing Size and Depth:	Volume	pH	S.C.	Temp. (°C)	Color & Turbidity
Static Water Level:					
One Casing Volume:					
Start Purge (hrs.):					
End Purge (hrs.):					
Total Purge Time (min.):					
Total Amount Purged (gal.):					
Monitor Reading:					
Purge Method:					
Sample Method:					
Depth Sampled:					
Sample Date and Time:	Sample Data				
	pH	S.C.	Temp. (°C)	Color & Turbidity	
Sampled By:					
Signature(s):	Observations/Notes:				
Type of Sample <input type="checkbox"/> Low Concentration <input type="checkbox"/> High Concentration <input type="checkbox"/> Grab <input type="checkbox"/> Composite <input type="checkbox"/> Grab - Composite					
Analysis:	Preservative:		Organic	Inorganic	
		Traffic Report #			
		Tag #			
		AS #			
		Date Shipped			
		Time Shipped			
		Lab			
		Volume			

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ATTACHMENT B-5

SAMPLE LOG SHEET

Page _____ of _____



- Surface Soil
- Subsurface Soil
- Sediment
- Lagoon/Pond
- Other _____

Case # _____

By _____

Project Site Name _____

Project Site Number _____

HALLIBURTON NUS Source No. _____

Source Location _____

Sample Method:	Composite Sample Data		
	Sample	Time	Color/Description
Depth Sampled:			
Sample Date & Time:			
Sampled By:			
Signature(s):			
Type of Sample <input type="checkbox"/> High Concentration <input type="checkbox"/> Low Concentration <input type="checkbox"/> Grab <input type="checkbox"/> Composite <input type="checkbox"/> Grab - Composite			
	Sample Data		
	Color	Description: (Sand, Clay, Dry, Moist, Wet, etc.)	
Analysis:	Observations/Notes:		
		Organic	Inorganic
	Traffic Report #		
	Tag #		
	AB #		
	Date Shipped		
	Time Shipped		
	Lab		
	Volume		

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ATTACHMENT B-7

SAMPLE LOG SHEET



Container Data

Page _____ of _____

Case # _____

By _____

Project Site Name _____

Project Site Number _____

HALLIBURTON NUS Source No. _____

Source Location _____

Container Source		Container Description																										
<input type="checkbox"/> Drum <input type="checkbox"/> Bung Top <input type="checkbox"/> Lever Lock <input type="checkbox"/> Bolted Ring <input type="checkbox"/> Other _____ <input type="checkbox"/> Bag/Sack <input type="checkbox"/> Tank <input type="checkbox"/> Other _____		Color _____ Condition _____ Markings _____ Vol. of Contents _____ Other _____																										
Disposition of Sample		Sample Description																										
<input type="checkbox"/> Container Sampled <input type="checkbox"/> Container opened but not sampled. Reason: _____ <input type="checkbox"/> Container not opened. Reason: _____		Layer 1 Phase <input type="checkbox"/> Sol. <input type="checkbox"/> Liq. Color _____ Viscosity <input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H % of Total _____ Volume _____ Other _____	Layer 2 Phase <input type="checkbox"/> Sol. <input type="checkbox"/> Liq. Color _____ Viscosity <input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H % of Total _____ Volume _____ Other _____	Layer 3 Phase <input type="checkbox"/> Sol. <input type="checkbox"/> Liq. Color _____ Viscosity <input type="checkbox"/> L <input type="checkbox"/> M <input type="checkbox"/> H % of Total _____ Volume _____ Other _____																								
Monitor Reading:		Type of Sample																										
Sample Method:		<input type="checkbox"/> Low Concentration <input type="checkbox"/> High Concentration		<input type="checkbox"/> Grab <input type="checkbox"/> Composite <input type="checkbox"/> Grab - Composite																								
Sample Date & Time:		<table border="1"> <tr> <td></td> <td align="center">Organic</td> <td align="center">Inorganic</td> </tr> <tr> <td>Traffic Report #</td> <td></td> <td></td> </tr> <tr> <td>Tag #</td> <td></td> <td></td> </tr> <tr> <td>AB #</td> <td></td> <td></td> </tr> <tr> <td>Date Shipped</td> <td></td> <td></td> </tr> <tr> <td>Time Shipped</td> <td></td> <td></td> </tr> <tr> <td>Lab</td> <td></td> <td></td> </tr> <tr> <td>Volume</td> <td></td> <td></td> </tr> </table>				Organic	Inorganic	Traffic Report #			Tag #			AB #			Date Shipped			Time Shipped			Lab			Volume		
	Organic	Inorganic																										
Traffic Report #																												
Tag #																												
AB #																												
Date Shipped																												
Time Shipped																												
Lab																												
Volume																												
Sampled By:																												
Signature(s):																												
Analysis:																												

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ATTACHMENT C-1

GROUNDWATER LEVEL MEASUREMENT SHEET

LOCATION

Project Name: _____
 Project No.: _____
 Personnel: _____
 Date: _____

Municipality: _____
 County: _____
 State: _____
 Street or
 Map Location
 (If Off-Site) _____

WEATHER CONDITIONS

Temperature Range: _____
 Precipitation: _____
 Barometric Pressure: _____

Equipment No.: _____
 Equipment Name: _____
 Latest Calibration Date: _____

Tidally-Influenced: Yes No

Well or Piezometer Number	Date/Time	Elevation of Reference Point (Feet)*	Water Level Indicator Reading (Feet)*	Adjusted Depth (Feet)*	Groundwater Elevation (Feet)*

* All elevations to nearest 0.01 foot.

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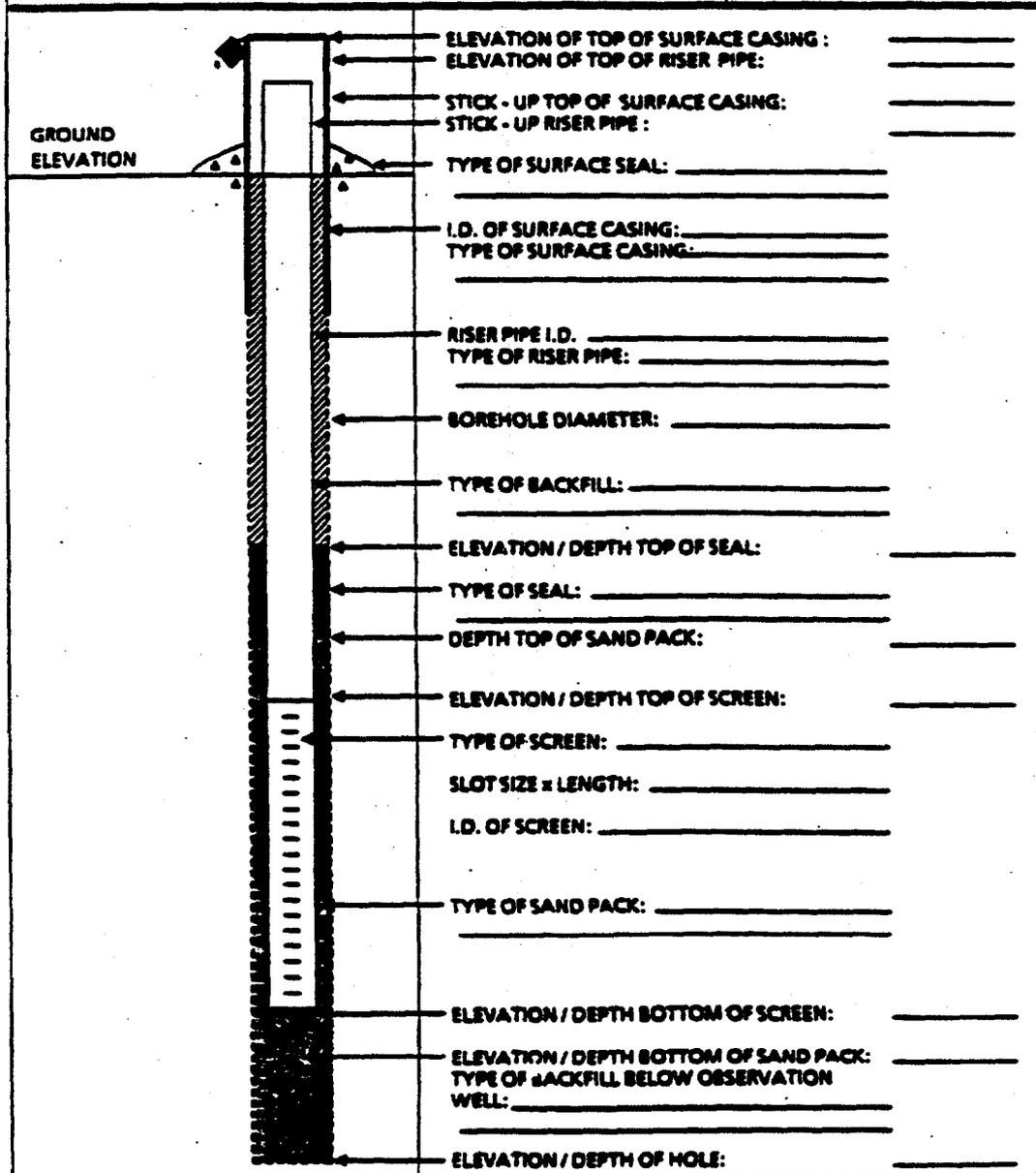
ATTACHMENT C-6



BORING NO _____

**OVERBURDEN
MONITORING WELL SHEET**

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
ELEVATION _____	DATE _____	DEVELOPMENT METHOD _____
FIELD GEOLOGIST _____		



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ATTACHMENT C-7



BORING NO.: _____

**CONFINING LAYER
MONITORING WELL SHEET**

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
ELEVATION _____	DATE _____	DEVELOPMENT METHOD _____
FIELD GEOLOGIST _____		

The diagram shows a vertical well casing with a riser pipe. A confining layer is shown as a shaded horizontal band. Below the casing, there is a sand pack, a screen, and a backfill area. The well is shown with various seals and casing types. The diagram is annotated with labels and arrows pointing to specific parts of the well, which correspond to the data fields on the right.

ELEVATION OF TOP OF PERM. CASING:	_____
ELEVATION OF TOP OF RISER PIPE:	_____
TYPE OF SURFACE SEAL:	_____
I.D. OF PERM. CASING:	_____
TYPE OF SURFACE CASING:	_____
RISER PIPE I.D.:	_____
TYPE OF RISER PIPE:	_____
BOREHOLE DIAMETER:	_____
PERM. CASING I.D.:	_____
TYPE OF CASING & BACKFILL:	_____
ELEVATION / DEPTH TOP CONFINING LAYER:	_____
ELEVATION / DEPTH BOTTOM OF CASING:	_____
ELEVATION / DEPTH BOT. CONFINING LAYER:	_____
ELEVATION / DEPTH TOP OF SEAL:	_____
TYPE OF SEAL:	_____
DEPTH TOP OF SAND PACK:	_____
ELEVATION/DEPTH TOP OF SCREEN:	_____
TYPE OF SCREEN:	_____
TYPE OF SAND PACK:	_____
BOREHOLE DIA. BELOW CASING:	_____
ELEVATION / DEPTH BOTTOM OF SCREEN:	_____
ELEVATION / DEPTH BOTTOM OF SAND PACK:	_____
TYPE OF BACKFILL BELOW OBSERVATION WELL:	_____
ELEVATION / DEPTH OF HOLE:	_____

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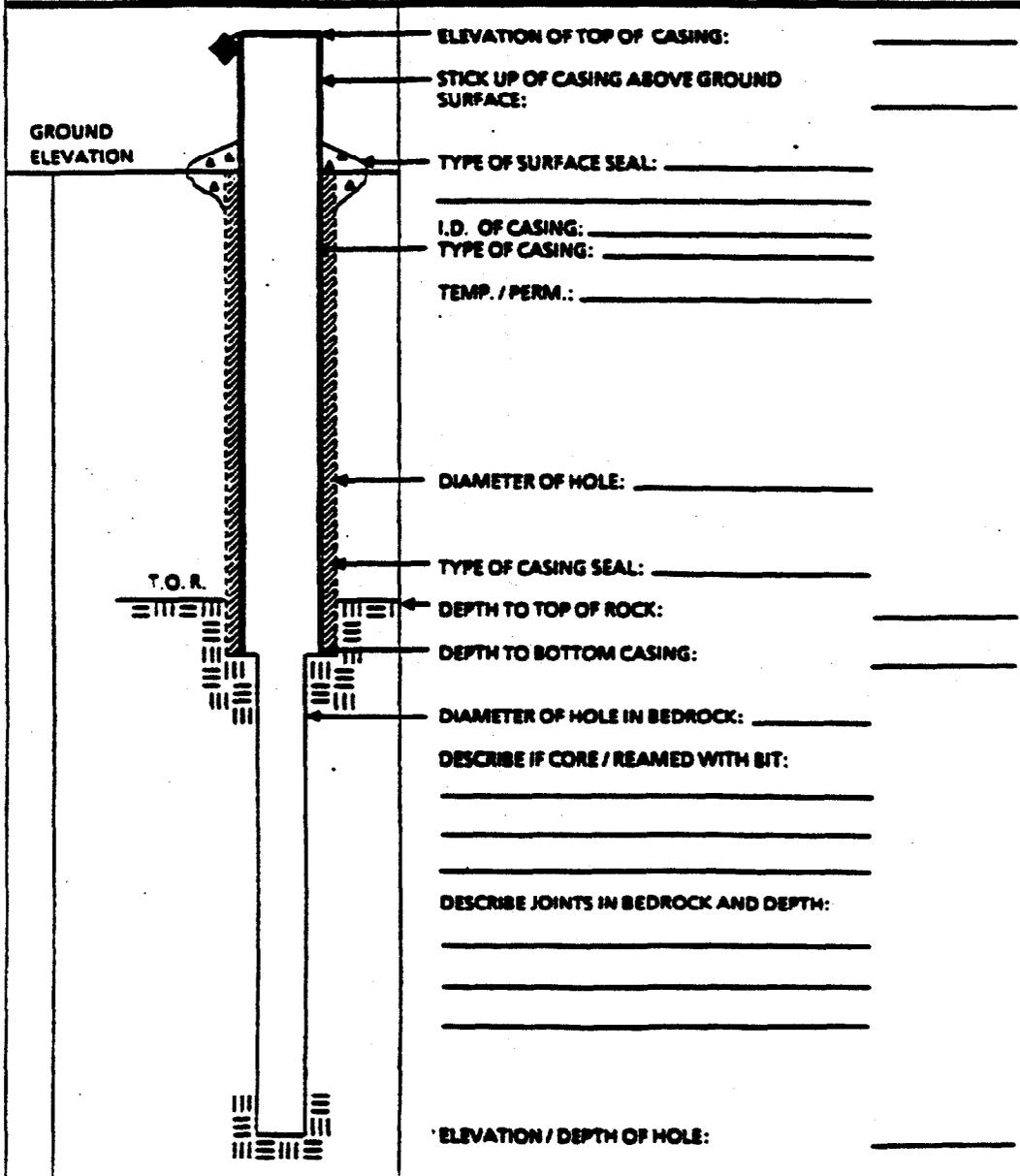
ATTACHMENT C-8



BORING NO.: _____

**BEDROCK
MONITORING WELL SHEET
OPEN HOLE WELL**

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
ELEVATION _____	DATE _____	DEVELOPMENT METHOD _____
FIELD GEOLOGIST _____		



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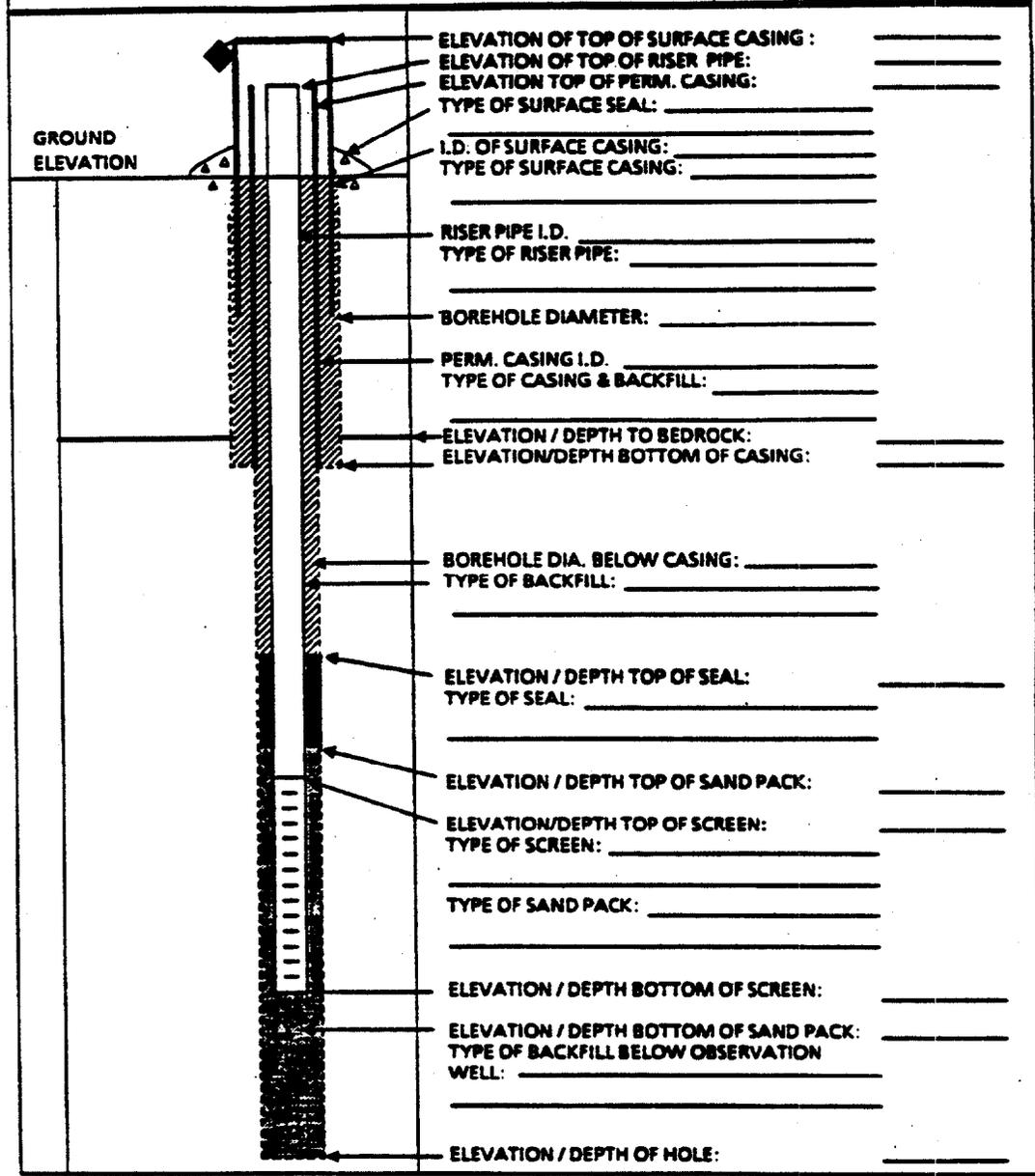
ATTACHMENT C-9



BORING NO.: _____

**BEDROCK
MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK**

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
ELEVATION _____	DATE _____	DEVELOPMENT METHOD _____
FIELD GEOLOGIST _____		



- ELEVATION OF TOP OF SURFACE CASING: _____
- ELEVATION OF TOP OF RISER PIPE: _____
- ELEVATION TOP OF PERM. CASING: _____
- TYPE OF SURFACE SEAL: _____
- I.D. OF SURFACE CASING: _____
- TYPE OF SURFACE CASING: _____
- RISER PIPE I.D. _____
- TYPE OF RISER PIPE: _____
- BOREHOLE DIAMETER: _____
- PERM. CASING I.D. _____
- TYPE OF CASING & BACKFILL: _____
- ELEVATION / DEPTH TO BEDROCK: _____
- ELEVATION/DEPTH BOTTOM OF CASING: _____
- BOREHOLE DIA. BELOW CASING: _____
- TYPE OF BACKFILL: _____
- ELEVATION / DEPTH TOP OF SEAL: _____
- TYPE OF SEAL: _____
- ELEVATION / DEPTH TOP OF SAND PACK: _____
- ELEVATION/DEPTH TOP OF SCREEN: _____
- TYPE OF SCREEN: _____
- TYPE OF SAND PACK: _____
- ELEVATION / DEPTH BOTTOM OF SCREEN: _____
- ELEVATION / DEPTH BOTTOM OF SAND PACK: _____
- TYPE OF BACKFILL BELOW OBSERVATION WELL: _____
- ELEVATION / DEPTH OF HOLE: _____

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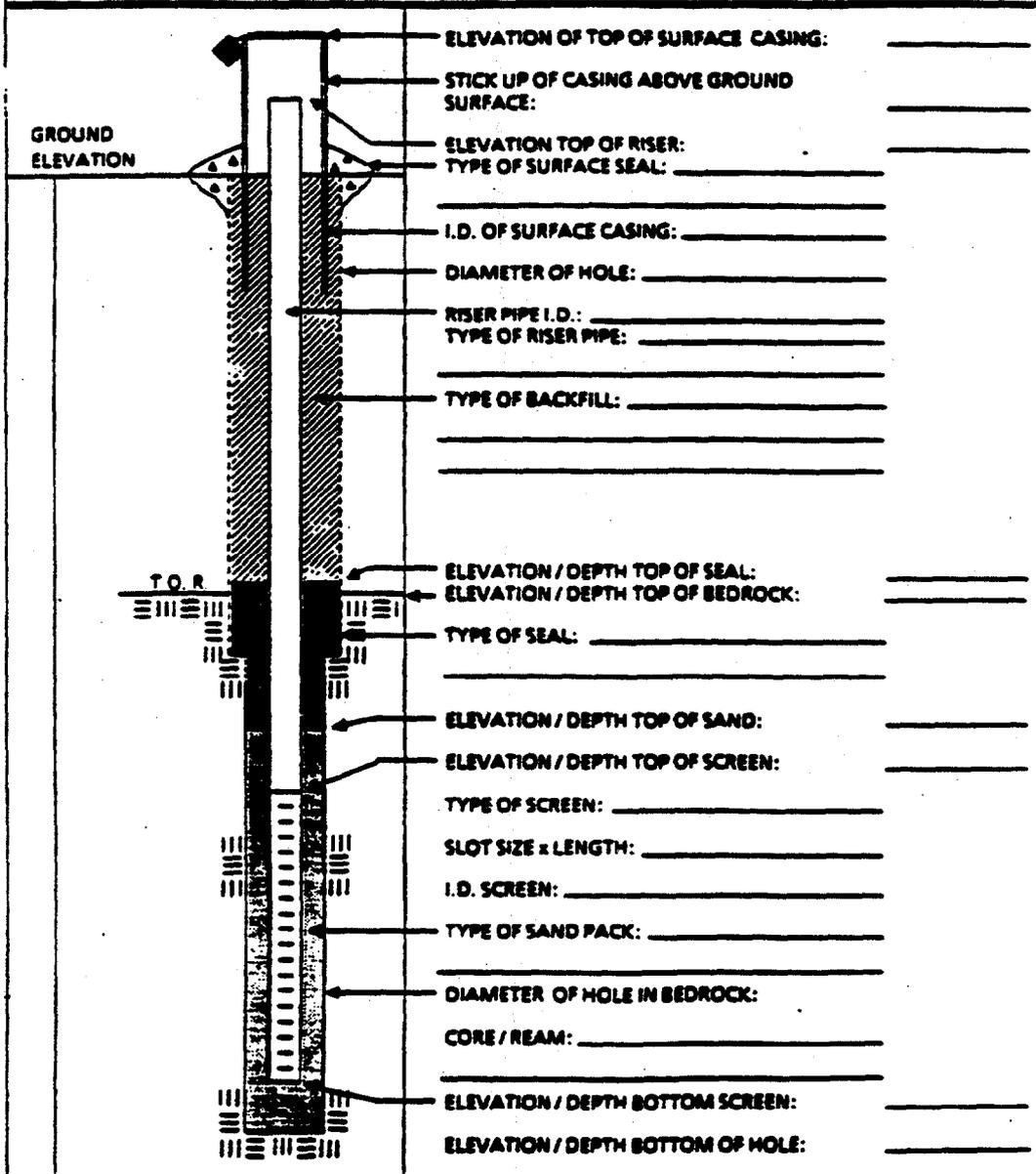
ATTACHMENT C-10



**BEDROCK
MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK**

BORING NO _____

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
ELEVATION _____	DATE _____	DEVELOPMENT METHOD _____
FIELD GEOLOGIST _____		



**ATTACHMENT D-1
EQUIPMENT CALIBRATION LOG**

Instrument (Name/Model Number/Serial Number): _____

Manufacturer: _____

Date Purchased: _____

Calibration Date	Initial Settings	Standard/Gas Used	Procedure	Adjustments Made	Final Settings	Signature	Comments

Subject
FIELD DOCUMENTATION

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ATTACHMENT E

DAILY ACTIVITIES RECORD - FIELD INVESTIGATION

DAILY ACTIVITIES RECORD - FIELD INVESTIGATION	HALLIBURTON NUS
------------------------------------------------------	------------------------

PROJECT NAME: _____ PROJECT NO.: _____
CLIENT: _____ LOCATION: _____
DATE: _____ ARRIVAL TIME: _____ DEPARTURE TIME: _____
CONTRACTOR: _____ DRILLER: _____
BORING NO.: _____ HNU REPRESENTATIVE: _____

ITEM ⁽¹⁾	ORIGINAL QUANTITY ⁽²⁾ ESTIMATE	QUANTITY ⁽²⁾ TODAY	PREVIOUS TOTAL ⁽²⁾ QUANTITY	CUMULATIVE QUANTITY ⁽²⁾ TO DATE
1. Mobilization/Demobilization	Job			
2. Overburden Drilling/Sampling, Minimum 6-inch	100 ft.			
3. Overburden Drilling, 10-inch	250 ft.			
4. Overburden Drilling, 14-inch	450 ft.			
5. Bedrock Drilling, 6-inch	530 ft.			
6. Bedrock Drilling, 10-inch	650 ft.			
7. Bedrock Drilling, 14-inch	150 ft.			
8. Temporary 6-inch Steel Casing	250 ft.			
9. Temporary 10-inch Steel Casing	200 ft.			
10. Temporary 14-inch Steel Casing	250 ft.			
11. Permanent 6-inch Steel Casing	1,250 ft.			
12. Permanent 10-inch Steel Casing	400 ft.			
13. PVC Well Construction/Installation	1,120 ft.			
14. Mine Void Sealing	8			
15. Boring Backfilling	NA			
16. Well Development	24 hrs.			
17. Test Borings	200 ft.			
18. Test Pit Excavation	50 hrs.			
19. Standby	20 hrs.			

COMMENTS: _____

⁽¹⁾ As listed in Specifications
⁽²⁾ include Quantity and Units
(Ex. 20 ft., 6 hrs.)

APPROVED BY: _____
HALLIBURTON NUS FIELD REPRESENTATIVE

DRILLER OR REPRESENTATIVE

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**ATTACHMENT F
PAGE 1 OF 2
FIELD TRIP SUMMARY REPORT**

SUNDAY

Date: _____ Personnel: _____
Weather: _____ Onsite: _____
Site Activities: _____

MONDAY

Date: _____ Personnel: _____
Weather: _____ Onsite: _____
Site Activities: _____

TUESDAY

Date: _____ Personnel: _____
Weather: _____ Onsite: _____
Site Activities: _____

WEDNESDAY

Date: _____ Personnel: _____
Weather: _____ Onsite: _____
Site Activities: _____

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**ATTACHMENT F
PAGE 2 OF 2
FIELD TRIP SUMMARY REPORT**

THURSDAY

Date: _____

Personnel: _____

Weather: _____

Onsite: _____

Site Activities: _____

FRIDAY

Date: _____

Personnel: _____

Weather: _____

Onsite: _____

Site Activities: _____

SATURDAY

Date: _____

Personnel: _____

Weather: _____

Onsite: _____

Site Activities: _____



HALLIBURTON NUS
Environmental Corporation

**ENVIRONMENTAL
TECHNOLOGIES GROUP**

**STANDARD
OPERATING
PROCEDURES**

Number SA-7.1

Page 1 of 9

Effective Date 01/02/91

Revision 0

Applicability
ETG

Prepared
Earth Sciences

Approved
D. Senovich

Subject **DECONTAMINATION OF FIELD EQUIPMENT
AND WASTE HANDLING**

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2.0 SCOPE	2
3.0 GLOSSARY	2
4.0 RESPONSIBILITIES	2
5.0 PROCEDURES	2
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1.0 PURPOSE

The purpose of this procedure is to provide reference information regarding the appropriate procedures to be followed when conducting decontamination activities of drilling equipment, monitoring well materials, chemical sampling equipment and field analytical equipment used during field investigations. This procedure also provides general reference information on the control of contaminated materials.

2.0 SCOPE

This procedure addresses drilling equipment and monitoring well materials decontamination, as well as chemical sampling and field analytical equipment decontamination. This procedure also describes methods of handling contaminated material during field investigations.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Field Operations Leader - Responsible for ensuring that project-specific plans and the implementation of field investigations are in compliance with these procedures.

5.0 PROCEDURES

To insure that analytical chemical results are reflective of the actual concentrations present at sampling locations, various drilling equipment and chemical sampling and analytical equipment involved in field investigations must be properly decontaminated. This will minimize the potential for cross-contamination between sampling locations, and the transfer of contamination off site.

5.1 DRILLING EQUIPMENT

Prior to the initiation of a drilling program, all drilling equipment involved in field sampling activities shall be decontaminated by steam cleaning at a predetermined area. The steam cleaning procedure shall be performed using a high-pressure spray of heated potable water producing a pressurized stream of steam. This steam shall be sprayed directly onto all surfaces of the various equipment which might contact environmental sample. The decontamination procedure shall be performed until all equipment is free of all visible potential contamination (dirt, grease, oil, noticeable odors, etc.) In addition, this decontamination procedure shall be performed at the completion of each sampling and/or drilling location, including soil borings, installation of monitoring wells, test pits, etc. Such equipment shall include drilling rigs, backhoes, downhole tools, augers, well casings, and screens.

The steam cleaning area shall be designed to contain decontamination wastes and waste waters, and can be a lined excavated pit or a bermed concrete or asphalt pad. For the latter, a floor drain must be provided which is connected to a holding facility. A shallow above-surface tank may be used or a pumping system with discharge to a waste tank may be installed.

In certain cases, due to budget constraints, such an elaborate decontamination pad is not possible. In such cases, a plastic lined gravel bed pad with a collection system may serve as an adequate

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decontamination area. The location of the steam cleaning area shall be on site in order to minimize potential impacts at certain sites.

Guidance to be used when decontaminating equipment shall include:

- As a general rule, any part of the drilling rig which extends over the borehole, shall be steam cleaned.
- All drilling rods, augers, and any other equipment which will be introduced to the hole shall be steam cleaned.
- The drilling rig, all rods and augers, and any other potentially contaminated equipment shall be decontaminated between each well location to prevent cross contamination of potential hazardous substances.

Prior to leaving at the end of each work day and/or at the completion of the drilling program, drilling rigs and transport vehicles used onsite for personnel or equipment transfer shall be steam cleaned. A drilling rig left at the drilling location does not need to be steam cleaned until it is finished drilling at that location.

5.2 SAMPLING EQUIPMENT

5.2.1 Bailers and Bailing Line

The potential for cross-contamination between sampling points via the use of common bailer, or its attached line, is high unless strict procedures for decontamination are followed. It is preferable, for the aforementioned reason, to dedicate an individual bailer and its line to each sample point, although this does not eliminate the need for decontamination of dedicated bailers. For non-dedicated sampling equipment, the following conditions and/or decontamination procedures should be followed.

Before the initial sampling and after each succeeding sampling point, the bailer must be decontaminated. The following steps should be followed if sampling for organic contaminants:

- Potable water rinse
- Alconox or Liquinox detergent wash
- Scrubbing of the line and bailer with a scrub brush may be required if the sample point is heavily contaminated with heavy or extremely viscous compounds
- Potable water rinse
- Rinse with 10 percent nitric acid solution*
- Deionized water rinse
- Acetone or methanol rinse
- Hexane rinse**

* Due to the leaching ability of nitric acid, on stainless steel, this step is to be omitted if a stainless steel sampling device is being used and metals analysis is required with detection limits less than approximately 50 ppb; or the sampling equipment is dedicated.

** If sampling for pesticides, PCBs, or fuels.

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- Distilled/Deionized water rinse
- Air dry

If sampling for organics only, the nitric acid, acetone, methanol, and hexane rinses may be omitted. Contract-specific requirements may permit alternative procedures.

Braided nylon or polypropylene lines may be used with a bailer, however, the same line must not come in contact with the sample medium, otherwise, the line must be discarded in an approved receptacle and replaced. Prior to use, the bailer should be wrapped in aluminum foil or polyethylene sheeting.

5.2.2 Sampling Pumps

Most sampling pumps are normally low volume (less than 2 gpm) pumps. These include peristaltic, diaphragm, air-lift, pitcher and bladder pumps, to name a few. If these pumps are used for sampling from more than one sampling point, they must be decontaminated.

The procedures to be used for decontamination of sampling pumps compare to those used for a bailer except the 10 percent nitric acid solution is omitted. Each of the liquid factions is to be pumped through the system. The amount of pumping is dependent upon the size of the pump and the length of the intake and discharge hoses. Certain types of pumps are unacceptable for sampling purposes.

An additional problem is introduced when the pump relies on absorption of water via an inlet or outlet hose. For organic sampling, this hose should be Teflon. Other types of hoses leach organics into the water being sampled (especially the phthalate esters) or adsorb organics from the sampled water. For all other sampling, the hose should be Viton, polyethylene, or polyvinyl chloride (in order of preference). Whenever possible, dedicated hoses should be used.

5.2.3 Filtering Equipment

Part of the sampling plan may incorporate the filtering of groundwater samples, and subsequent preservation. This should occur as soon after sample retrieval as possible; preferably in the field as soon as the sample is obtained. To this end, three basic filtration systems are most commonly used - the in-line disposable Teflon filter, the inert gas over-pressure filtration system, and the vacuum filtration system.

For the in-line filter, decontamination is not required since the filter cartridge is disposable, however, the cartridge must be disposed of in an approved receptacle and the intake and discharge lines must still be decontaminated.

For the over-pressure and the vacuum filtration systems, the portions of the apparatus which come in contact with the sample must be decontaminated as outlined in the paragraphs describing the decontamination of bailers. (Note: Varieties of both of these systems come equipped from the manufacturer with Teflon-lined surfaces for those that would come into contact with the sample. These filtration systems are preferred when decontamination procedures must be employed.)

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5.3 FIELD ANALYTICAL EQUIPMENT

5.3.1 Water Level Indicators

Water level indicators that come into contact with groundwater must be decontaminated using the following steps:

- Rinse with potable water
- Rinse with deionized water
- Acetone or methanol rinse
- Rinse with deionized water

Water level indicators that do not come in contact with the groundwater but may encounter incidental contact during installation or retrieval need only undergo the first and last steps stated above.

5.2.2 Probes

Probes, e.g., pH or specific ion electrodes, geophysical probes, or thermometers which would come in direct contact with the sample, will be decontaminated using the procedures specified above unless manufacturer's instructions indicate otherwise. Probes that contact a volume of groundwater not used for laboratory analyses can be rinsed with deionized water. For probes which make no direct contact, e.g., OVA equipment, the probe will be wiped with clean paper-towels or cloth wetted with alcohol.

5.4 WASTE HANDLING

For the purposes of these procedures, contaminated materials are defined as any byproducts of a field investigation that are suspected or known to be contaminated with hazardous substances. These byproducts include such materials as decontamination solutions, disposable equipment, drilling muds, well-development fluids, and spill-contaminated materials.

The procedures for obtaining permits for investigations of sites containing hazardous substances are not clearly defined at present. In the absence of a clear directive to the contrary by the EPA and the states, it must be assumed that hazardous wastes generated during investigations will require compliance with Federal agency requirements for generation, storage, transportation, or disposal. In addition, there may be state regulations that govern the disposal action. This procedure will exclusively describe the technical methods used to control contaminated materials.

The work plan for a site investigation must include a description of control procedures for contaminated materials. This planning strategy would assess the type of contamination, estimate the amounts that would be produced, describe containment equipment and procedures, and delineate storage or disposal methods. As a general policy, it is wise to select investigation methods that minimize the generation of contaminated spoils. Handling and disposing of potentially hazardous materials are expensive and dangerous. Until sample analysis is complete, it is assumed that all produced materials suspected of contamination from hazardous chemicals will always require containment.

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5.5 SOURCES OF CONTAMINATED MATERIALS AND CONTAINMENT METHODS

5.5.1 Decontamination Solutions

All decontamination solutions and rinses must be assumed to contain the hazardous chemicals associated with the site unless there are analytical or other data to the contrary. The solution volumes could vary from a few gallons to several hundred gallons in cases where large equipment required cleaning.

Containerized rinse solutions such as those recommended for the personnel decontamination station are best stored in 55-gallon drums (or equivalent containers) that can be sealed until ultimate disposal at an approved facility. Larger equipment such as backhoes and tractors should be decontaminated in an area provided with an impermeable liner and a liquid collection system. A decontamination area for large equipment could consist of a bermed concrete pad with a floor drain leading to a buried holding tank.

5.5.2 Disposal Equipment

Disposable equipment that could be contaminated during a site investigation typically includes rubber gloves, boots, broken sample containers, and laboratory tissues. These items are small and can easily be contained in 55-gallon drums with lids. These containers should be closed at the end of each work day and upon project completion to provide secure containment.

5.5.3 Drilling Muds and Well-Development Fluids

Drilling muds and well-development fluids are materials used in groundwater monitoring well installations. Their proper use could result in the surface accumulation of contaminated liquids and muds that require containment. Often monitoring wells are placed off the site to determine if hazardous chemicals have migrated below ground. These offsite wells require especially careful management since they threaten contamination of offsite property.

The volumes of drilling muds and well-development fluids used depend on well diameter and depth, groundwater characteristics, and geologic formations. There are no simple mathematical formulas available for accurately predicting these volumes. It is best to rely on the experience of reputable well drillers familiar with local conditions and the well installation techniques selected. These individuals should be able to estimate the sizes of containment structures required. Since guesswork is involved, one should always be prepared to halt drilling or other well-development operations if more containment capacity is needed.

Drilling fluid (mud) is mixed and stored in a container commonly referred to as a mud pit. This mud pit consists of a suction section from which drilling fluid is withdrawn and pumped through hoses and down the drill pipe to the bit and back up the hole to the settling section of the mud pit. In the settling section, the fluid velocity is reduced by a screen and several flow-restriction devices, thereby allowing the well cuttings to settle out of the fluid.

The mud pit may be either portable above-ground tanks commonly made of steel which is preferred or stationary in-ground pits (Attachment A). The above-ground tanks have a major advantage over the in-ground pits because the tanks isolate the natural soils from the contaminated fluids within the drilling system. The tanks are also portable and can usually be cleaned easily.

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As the well is drilled, the sediments that accumulate in the settling section must be removed. This is best done by shoveling them into drums or other similar containers. When the drilling is complete, the contents of the above-ground tank are likewise shoveled or pumped into drums, and the tank is cleaned and available for use.

If in-ground pits are used, they should not extend into the natural water table. They should also be lined with a bentonite-cement mixture followed by a layer of flexible impermeable material such as plastic sheeting. Of course, to maintain its impermeable seal, the material used would have to be nonreactive with the wastes. An advantage of the in-ground pits is that well cuttings do not necessarily have to be removed periodically during drilling because the pit can be made deep enough to contain them. Depending on site conditions, the in-ground pit may have to be totally excavated and refilled with uncontaminated natural soils when the drilling operation is complete.

When the above-ground tank or the in-ground pit is used, a reserve tank or pit should be located at the site as a backup system for leaks, spills, and overflows. In either case, surface drainage should be such that any excess fluid could be controlled within the immediate area of the drill site.

The containment procedure for well-development fluids is similar to that for drilling fluids. The volume and weight of contaminated fluid will be determined by the method of development. When a new well is bailed to produce clear water, substantially less volume and weight of fluid result than when backwashing or high-velocity jetting is used.

5.5.4 Spill-Contaminated Materials

A spill is always possible when a site investigation involves opening and moving containers of liquids. Contaminated sorbents and soils resulting from spills will have to be contained. Small quantities of spill-contaminated materials are usually best contained in drums, while larger quantities can be placed in lined pits or in other impermeable structures. In some cases on-site containment may not be feasible, and immediate transport to an approved disposal site will be required.

5.6 DISPOSAL OF CONTAMINATED MATERIALS

Actual disposal techniques for contaminated materials are the same as those for any hazardous substance—incineration, landfilling, treatment, and so on. The problem centers around the assignment of responsibility for disposal. The responsibility must be determined and agreed upon by all involved parties before the field work starts. If the site owner or manager was involved in activities that precipitated the investigation, it seems reasonable to encourage his acceptance of the disposal obligation. In instances where a responsible party cannot be identified, this responsibility may fall on the public agency or private organization investigating the site.

Another consideration in selecting disposal methods for contaminated materials is whether the disposal can be incorporated into subsequent site cleanup activities. For example, if construction of suitable onsite disposal structure is expected, contaminated materials generated during the investigation should be stored at the site for disposal with other site materials. In this case, the initial containment structures should be evaluated for use as long-term storage structures. Also, other site conditions such as drainage control, security, and soil type must be considered so that proper storage is provided. If onsite storage is expected, then the limited containment structures should be designed for that purpose.

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6.0 REFERENCES

HALLIBURTON NUS Environmental Corporation: Standard Operating Procedure No. 4.33, Control of Contaminated Material.

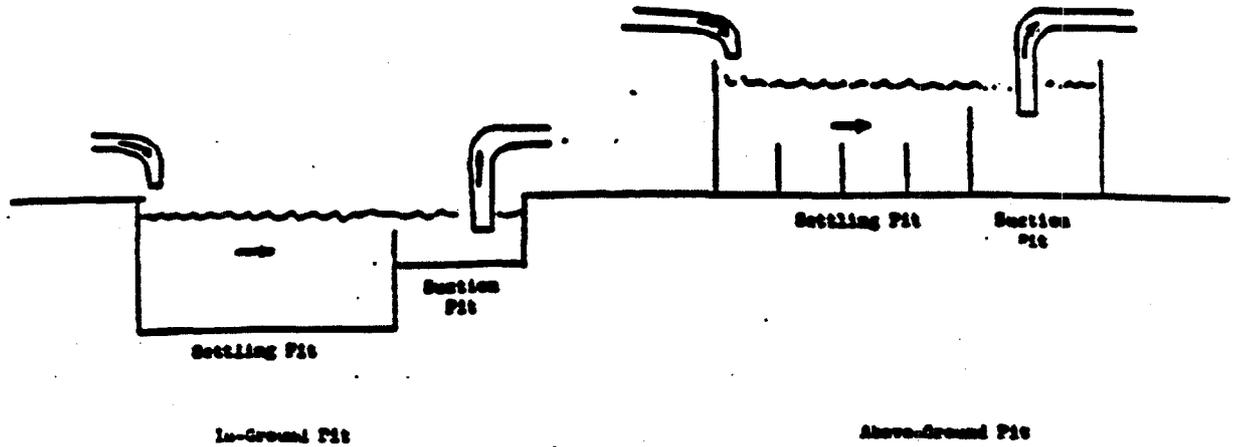
7.0 ATTACHMENTS

Attachment A - Two Types of Mud Pits Used in Drilling.

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FIGURE 5-1

TWO TYPES OF MUD PITS USED IN WELL DRILLING



Source: Ecology and Environment, Inc., Technical Methods for Investigating Sites Containing Hazardous Substances, Draft Technical Monographs, prepared for the U.S. Environmental Protection Agency, June 1981.

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1.0 PURPOSE

This procedure describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific Conductance
- Temperature
- Dissolved Oxygen (DO) Concentration
- Oxidation Reduction Potential
- Certain Dissolved Constituents Using Specific Ion Elements

2.0 SCOPE

This procedure is applicable for use in an on-site groundwater quality monitoring program to be conducted during a remedial investigation or site investigation program at a hazardous or nonhazardous site. The procedures and equipment described are applicable to nearly all aqueous samples, including potable well water, monitoring well water, surface water, leachate and drummed water, etc. and are not, in general, subject to solution interferences from color, turbidity and colloidal material, or suspended matter.

This procedure provides generic information for measuring the parameters listed above with instruments and techniques in common use. Since instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use.

3.0 GLOSSARY

3.1 pH MEASUREMENT

pH - The negative logarithm (base 10) of the hydrogen ion activity. The hydrogen ion activity is related to the hydrogen ion concentration, and, in relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is a measure of the hydrogen ion concentration.

pH Paper - Paper that turns different colors depending on the pH of the solution to which it is exposed. Comparison with color standards supplied by the manufacturer will then give an indication of the solution pH.

3.2 SPECIFIC CONDUCTANCE MEASUREMENT

Ohm - Standard unit of electrical resistance (R). A siemen (or umho) is the standard unit of electrical conductance, the inverse of the ohm.

Resistance - A measure of the solution's ability to oppose the passage of electrical current. For metals and solutions, resistance is defined by Ohm's law, $E = IR$, where E is the potential difference, I is the current, and R is the resistance.

Conductance - The conductance of a conductor 1 centimeter long and 1 square centimeter in cross-sectional area. Conductivity and specific conductance are used synonymously.

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3.3 TEMPERATURE MEASUREMENT

None.

3.4 DISSOLVED OXYGEN MEASUREMENT

Galvanic Cell - An electrochemical cell in which chemical energy is spontaneously converted to electrical energy. The electrical energy produced is supplied to an external circuit.

Electrolytic Cell - An electrochemical cell in which electrical energy is supplied from an external source. This cell functions in much the same way as a galvanic cell, only in the opposite direction due to the external source of applied voltage.

3.5 OXIDATION-REDUCTION POTENTIAL MEASUREMENT

Oxidation - The process in which an atom or group of atoms loses electrons to achieve an increasing positive charge.

Reduction - The gaining of electrons by an atom or group of atoms and subsequent increase in negative charge.

Oxidation-Reduction Potential (ORP) - A measure of the activity ratio of oxidizing and reducing species as determined by the electromotive force developed by a noble metal electrode, immersed in water, as referenced against a standard hydrogen electrode.

3.6 SPECIFIC ION ELECTRODES MEASUREMENT

Specific Ion Electrode - An electrode which develops a potential difference across a membrane in response to the concentration differences for selected ions on either side of that membrane.

4.0 RESPONSIBILITIES

Site Manager - in consultation with the Project Geochemist, is responsible for determining which on-site water quality measurements can contribute to the RI, when these measurements shall be made, and the data quality objectives (DQOs) for these measurements. The Project Operations Plan (POP) shall contain details of type, frequency and locations of the desired measurements.

Project Geochemist - primarily responsible for determining the type, frequency and locations for on-site water quality measurements as presented in the POP and for interpreting the results, including determination of which measurements are unrepresentative.

Field Operations Leader - responsible for implementing the POP, and also for deciding under what field conditions a particular on-site measurement will be unrepresentative or unobtainable.

Field Samplers/Analysts - responsible for the actual analyses that take place, including calibration, quality control and recording of results, as well as for the care and maintenance of the equipment in the field.

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5.0 GUIDELINES

5.1 MEASUREMENT OF pH

5.1.1 General

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment such as acid-base neutralization, water softening, and corrosion control, is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken.

Measurements of pH can also be used to check the quality and corrosivity of soil and solid waste samples. However, these samples must be immersed in water prior to analysis, and specific techniques are not described.

Two methods are given for pH measurement: the pH meter and pH indicator paper. The indicator paper is used when only a rough estimate of the pH is required, and the pH meter when a more accurate measurement is needed. The response of a pH meter can be affected to a slight degree by high levels of colloidal or suspended solids, but the effect is usually small and generally of little significance. Consequently, specific methods to overcome this interference are not described. The response of pH paper is unaffected by solution interferences from color, turbidity, colloidal or suspended materials unless extremely high levels capable of coating or masking the paper are encountered. In such cases, use of a pH meter is recommended.

5.1.2 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or basicity of the solution with the indicator compound on the paper. Depending on the indicator and the pH range of interest, a variety of different colors can be used. Typical indicators are weak acids or bases, or both. Process chemistry and molecular transformations leading to the color change are variable and complex.

Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on establishment of a potential difference across a glass or other type of membrane in response to hydrogen ion concentration across that membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to hydrogen ion concentration can be generated and measured.

5.1.3 Equipment

The following equipment is needed for taking pH measurements:

- Accumet 150 portable pH meter, or equivalent.
- Combination electrode with polymer body to fit the above meter (alternately a pH electrode and a reference electrode can be used if the pH meter is equipped with suitable electrode inputs).

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- pH indicator paper, such as Hydrion or Alkacid, to cover the pH range 2 through 12.
- Buffer solutions of pH 4, 7 and 10, or other buffers which bracket the expected pH range.

5.1.4 Measurement Techniques for Field Determination of pH

1. pH Meter

The following procedure is used for measuring pH with a pH meter (Standardization is according to manufacturers instructions):

- a. The instrument and batteries shall be checked and calibrated prior to initiation of the field effort.
- b. The accuracy of the buffer solutions used for field and laboratory calibration shall be checked. Buffer solutions need to be changed often due to degradation upon exposure to the atmosphere.
- c. Immerse the tip of the electrodes in water overnight. If this is not possible due to field conditions, immerse the electrode tip in water for at least an hour before use. The electrode tip may be immersed in a rubber or plastic sack containing buffer solution for field transport or storage. This is not applicable for all electrodes as some must be stored dry.
- d. Make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).
- e. Immerse the electrode(s) in a pH-7 buffer solution.
- f. Adjust the temperature compensator to the proper temperature (on models with automatic temperature adjustment, immerse the temperature probe into the buffer solution). Alternately, the buffer solution may be immersed in the sample and allowed to reach temperature equilibrium before equipment calibration. It is best to maintain buffer solution at or near expected sample temperature before calibration.
- g. Adjust the pH meter to read 7.0.
- h. Remove the electrode(s) from the buffer and rinse well with demineralized water. Immerse the electrode(s) in pH-4 or 10 buffer solution (depending on the expected pH of the sample) and adjust the slope control to read the appropriate pH. For best results, the standardization and slope adjustments shall be repeated at least once.
- i. Immerse the electrode(s) in the unknown solution, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a chemical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.

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- j. Read and record the pH of the solution, after adjusting the temperature compensator to the sample temperature. pH shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature.
- k. Rinse the electrode(s) with deionized water.
- l. Keep the electrode(s) immersed in deionized water when not in use.

The sample used for pH measurement shall never be saved for subsequent conductivity or chemical analysis. All pH electrodes leak small quantities of electrolytes (e.g., sodium or potassium chloride) into the solution. Precipitation of saturated electrolyte solution, especially at colder temperatures, or in cold water, may result in slow electrode response. Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted.

2. pH Paper

Use of pH paper is very simple and requires no sample preparation, standardization, etc. pH paper is available in several ranges, including wide-range (indicating approximately pH 1 to 12), mid-range (approximately pH 0 to 6, 6 to 9, 8 to 14) and narrow-range (many available, with ranges as narrow as 1.5 pH units). The appropriate range of pH paper shall be selected. If the pH is unknown the investigation shall start with wide-range paper.

5.2 MEASUREMENT OF SPECIFIC CONDUCTANCE

5.2.1 General

Conductance provides a measure of dissolved ionic species in water and can be used to identify the direction and extent of migration of contaminants in groundwater or surface water. It can also be used as a measure of subsurface biodegradation or to indicate alternate sources of groundwater contamination.

Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This value depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made. The mobility of each of the various dissolved ions, their valences, and their actual and relative concentrations affect conductivity.

It is important to obtain a specific conductance measurement soon after taking a sample, since temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect the specific conductance.

5.2.2 Principles of Equipment Operation

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions migrate toward the negative electrode, while the negatively charged ions migrate toward the positive electrode. Most inorganic acids, bases and salts (such as hydrochloric acid, sodium carbonate, or sodium chloride, respectively) are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not disassociate in aqueous solution, conduct a current very poorly, if at all.

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A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell may also be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

5.2.3 Equipment

The following equipment is needed for taking specific conductance measurements:

- YSI Model 33 portable conductivity, meter, or equivalent
- Probe for above meter

A variety of conductivity meters are available which may also be used to monitor salinity and temperatures. Probe types and cable lengths vary, so equipment may be obtained to meet the specific requirement of the sampling program.

5.2.4 Measurement Techniques for Specific Conductance

The steps involved in taking specific conductance measurements are listed below (standardization is according to manufacturers instructions):

- Check batteries and calibrate instrument before going into the field.
- Calibrate the instrument daily when used. Potassium chloride solutions with a specific conductance closest to the values expected in the field shall be used. Attachment A may be used for guidance.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.
- Immerse the electrode in the sample and measure the conductivity. Adjust the temperature setting to the sample temperature.
- Read and record the results in a field logbook or sample log sheet.

If the specific conductance measurements become erratic, or inspection shows that any platinum black has flaked off the electrode, replatinization of the electrode is necessary. See the manufacturer's instructions for details.

Note that specific conductance is occasionally reported at temperatures other than ambient.

5.3 MEASUREMENT OF TEMPERATURE

5.3.1 General

In combination with other parameters, temperature can be a useful indicator of the likelihood of biological action in a water sample. It can also be used to trace the flow direction of contaminated

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groundwater. Temperature measurements shall be taken in-situ, or as quickly as possible in the field. Collected water samples may rapidly equilibrate with the temperature of their surroundings.

5.3.2 Equipment

Temperature measurements may be taken with alcohol-toluene, mercury filled or dial-type thermometers. In addition, various meters such as specific conductance or dissolved oxygen meters, which have temperature measurement capabilities, may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature at great depths can be performed.

5.3.3 Measurement Techniques for Water Temperature

If a thermometer is used on a collected water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of contamination, the thermometer shall not be inserted into samples which will undergo subsequent chemical analysis.
- Record values in a field logbook or sample log sheet.

If a temperature meter or probe is to be used, the instrument shall be calibrated according to manufacturer's recommendations with an approved thermometer before each measurement or group of closely spaced measurements.

5.4 MEASUREMENT OF DISSOLVED OXYGEN CONCENTRATION

5.4.1 General

Dissolved oxygen (DO) levels in natural water and wastewater depend on the physical, chemical and biochemical activities in the water body. Conversely, the growth of many aquatic organisms as well as the rate of corrosivity, are dependent on the dissolved oxygen concentration. Thus, analysis for dissolved oxygen is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in-situ, since concentration may show a large change in a short time if the sample is not adequately preserved.

The method monitoring discussed herein is limited to the use of dissolved oxygen meters only. Chemical methods of analysis (i.e., Winkler methods) are available, but require more equipment and greater sample manipulation. Furthermore, DO meters, using a membrane electrode, are suitable for highly polluted waters, because the probe is completely submersible, and are free from interference caused by color, turbidity, colloidal material or suspended matter.

5.4.2 Principles of Equipment Operation

Dissolved oxygen probes are normally electrochemical cells that have two solid metal electrodes of different nobility immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of highest nobility (the cathode) is positioned at the membrane. When a suitable potential exists between the two metals, reduction of oxygen to hydroxide ion (OH) occurs at the cathode surface. An electrical current is developed that is directly proportional to the rate of arrival of oxygen molecules at the cathode.

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Since the current produced in the probe is directly proportional to the rate of arrival of oxygen at the cathode, it is important that a fresh supply of sample always be in contact with the membrane. Otherwise, the oxygen in the aqueous layer along the membrane is quickly depleted and false low readings are obtained. It is therefore necessary to stir the sample (or the probe) constantly to maintain fresh solution near the membrane interface. Stirring, however, shall not be so vigorous that additional oxygen is introduced through the air-water interface at the sample surface. To avoid this possibility, some probes are equipped with stirrers to agitate the solution near the probe, but to leave the surface of the solution undisturbed.

Dissolved oxygen probes are relatively free of interferences. Interferences that can occur are reactions with oxidizing gases (such as chlorine) or with gases such as hydrogen sulfide which are not easily depolarized from the indicating electrode. If the gaseous interference is suspected, it shall be noted in the field log book and checked if possible. Temperature variations can also cause interference because probes exhibit temperature sensitivity. Automatic temperature compensation is normally provided by the manufacturer.

5.4.3 Equipment

The following equipment is needed to measure dissolved oxygen concentration:

- YSI Model 56 dissolved oxygen monitor or equivalent.
- Dissolved oxygen/temperature probe for above monitor.
- Sufficient cable to allow the probe to contact the sample.

5.4.4 Measurement Techniques for Dissolved Oxygen Determination

Probes differ as to specifics of use. Follow the manufacturer's instructions to obtain an accurate reading. The following general steps shall be used to measure the dissolved oxygen concentration:

- The equipment shall be calibrated and have its batteries checked in the laboratory before going to the field.
- The probe shall be conditioned in a water sample for as long a period as practical before use in the field. Long periods of dry storage followed by short periods of use in the field may result in inaccurate readings.
- The instrument shall be calibrated in the field before each measurement or group of closely spaced measurements by placing the probe in a water sample of known dissolved oxygen concentration (i.e., determined by Winkler method) or in a freshly air-saturated water sample of known temperature. Dissolved oxygen values for air-saturated water can be determined by consulting a table listing oxygen solubilities as a function of temperature and salinity (see Attachment B).
- Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane, either by stirring the sample, or placing the probe in a flowing stream. Probes without stirrers placed in wells can be moved up and down.

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- Record the dissolved oxygen content and temperature of the sample in a field logbook or sample log sheet.
- Recalibrate the probe when the membrane is replaced, or as needed. Follow the manufacturer's instructions.

Note that in-situ placement of the probe is preferable, since sample handling is not involved. However, may not always be practical. Be sure to record whether the liquid was analyzed in-situ a sample was taken.

Special care shall be taken during sample collection to avoid turbulence which can lead to increased oxygen solubilization and positive test interferences.

5.5 MEASUREMENT OF OXIDATION-REDUCTION POTENTIAL

5.5.1 General

The oxidation-reduction potential (ORP) provides a measure of the tendency of organic or inorganic compounds to exist in an oxidized state. The technique therefore provides evidence of the likelihood of anaerobic degradation of biodegradable organics or the ratio of activities of oxidized to reduced species in the sample.

5.5.2 Principles of Equipment Operation

When an inert metal electrode, such as platinum, is immersed in a solution, a potential is developed at that electrode depending on the ions present in the solution. If a reference electrode is placed in the same solution, an ORP electrode pair is established. This electrode pair allows the potential difference between the two electrodes to be measured and will be dependent on the concentration of the ions in solution. By this measurement, the ability to oxidize or reduce species in solution may be determined. Supplemental measurements, such as dissolved oxygen, may be correlated with ORP to provide a knowledge of the quality of the solution, water, or wastewater.

5.5.3 Equipment

The following equipment is needed for measuring the oxidation-reduction potential of a solution:

- Accumet 150 portable pH meter or equivalent, with a millivolt scale.
- Platinum electrode to fit above pH meter.
- Reference electrode such as a calomel, silver-silver chloride, or equivalent.

5.5.4 Measurement Techniques for Oxidation-Reduction Potential

The following procedure is used for measuring oxidation-reduction potential:

- The equipment shall be calibrated and have its batteries checked before going to the field.
- Check that the platinum probe is clean and that the platinum bond or tip is unoxidized. If dirty, polish with emery paper or, if necessary, clean the electrode using aqua regia, nitric acid, or chromic acid, in accordance with manufacturer's instructions.

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- Thoroughly rinse the electrode with demineralized water.
- Verify the sensitivity of the electrodes by noting the change in millivolt reading when the pH of the test solution is altered. The ORP will increase when the pH of the test solution decreases and the ORP will decrease if the test solution pH is increased. Place the sample in a clean glass beaker and agitate the sample. Insert the electrodes and note the ORP drops sharply when the caustic is added, the electrodes are sensitive and operating properly. If the ORP increases sharply when the caustic is added, the polarity is reversed and must be corrected in accordance with the manufacturer's instructions. If the ORP does not respond as above when the caustic is added, the electrodes shall be cleaned and the above procedure repeated.
- After the assembly has been checked for sensitivity, wash the electrodes with three changes of water or by means of a flowing stream of water from a wash bottle. Place the sample in a clean glass beaker or sample cup and insert the electrodes. Set temperature compensator throughout the measurement period. Read the millivolt potential of the solution, allowing sufficient time for the system to stabilize and reach temperature equilibrium. Measure successive portions of the sample until readings on two successive portions differ by no more than 10 mV. A system that is very slow to stabilize properly will not yield a meaningful ORP. Record all results in a field logbook, including ORP (to nearest 10 mV), sample temperature and pH at the time of measurement.

5.6 SPECIFIC ION ELECTRODE MEASUREMENTS

5.6.1 General

Use of specific ion electrodes can be beneficial in the field for determining the presence and concentration of dissolved inorganic species which may be associated with contaminant plumes or leachate. Thus, electrodes can be used for rapid screening of water quality and determination of water migration pathways.

This procedure provides generic information for specific ion electrodes commonly used in groundwater quality monitoring programs and describes the essential elements of a field investigation program. Analytical methods using some specific ion electrodes have not been approved by the U.S. EPA. In addition, calibration procedures and solutions, interferences and conditions and requirements for use for various electrodes vary greatly. Consequently, review of manufacturer's literature is mandatory prior to use.

5.6.2 Principles of Equipment Operation

All specific ion electrode measurements involve the use of a reference electrode, a pH meter, and a specific ion electrode (SIE). When the SIE and the reference electrode are immersed in a solution of the ion to be measured, a potential difference is developed between the two electrodes. This potential can be measured by a pH meter and related to the concentration of the ion of interest through the use of standard solutions and calibration curves.

Several different types of SIEs are in use: glass, solid-state, liquid-liquid membrane, and gas-sensing. All of the electrodes function using an ion exchange process as the potential determining mechanism. Glass electrodes are used for pH measurement. The glass in the tip of the electrode actually acts as a semi-permeable membrane to allow solution. Solid-state electrodes replace the glass membrane with

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an ionically-conducting membrane (but act in essentially the same manner), while liquid-liquid membrane electrodes have an organic liquid ion exchanger contained in the pores of a hydrophobic membrane. Maintenance of the conducting interface, in combination with a reference electrode, allows completion of the electrical circuit and subsequent measurement of the potential difference. Gas-sensing electrodes have a membrane that permits the passage of gas only, thus allowing for the measurement of gas concentration. Regardless of the mechanism involved in the electrode, most SIEs are easy to use under field conditions. The sensitivity and applicable concentration range for various membranes and electrodes will vary.

5.6.3 Equipment

The following equipment is required for performing quantitative analyses using a specific ion electrode:

- A pH meter with a millivolt scale, or equivalent.
- The specific ion electrode for the parameter to be measured. A partial list of ions which can be measured includes cyanide, sulfide, ammonia, lead, fluoride and chloride.
- A suitable reference electrode to go with the above SIE.

Specific electrodes for other ions have also been developed, but are not widely used for field investigation efforts at this time. Note that of the specific electrodes referenced above, only fluoride and ammonia have analytical methods approved by the U.S. EPA.

5.6.4 Measurement Techniques for Inorganic Ions Using Specific Ion Electrodes

Different types of electrodes are used in slightly different ways and are applicable for different concentration ranges. Following the manufacturer's instructions, the general steps given below are usually followed:

- Immerse the electrode in water for a suitable period of time prior to sample analysis.
- Standardize the electrode according to the manufacturer's instructions, including necessary chemical additions for ionic strength adjustment, etc. Standard solutions normally differ by factors of ten in concentration. Constant stirring is needed for accurate readings.
- Immerse the electrode in the sample. Allow the reading to stabilize and record the results in a site logbook. Stir the sample at the same rate as the standards. Air bubbles near the membrane shall be avoided, since this may cause interference in millivolt readings.

(NOTE: Each SIE has substances which interfere with proper measurement. These may be eliminated using pretreatment methods as detailed by the manufacturer. It is important to know if interferences are present so that suspect readings may be noted as such.)

- If the pH meter does not read out directly, plot millivolts versus concentration for the standards and then determine sample concentration.

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6.0 REFERENCES

American Public Health Association, 1980. Standard Methods for the Examination of Water and Wastewater, 15th Edition, APHA, Washington, D.C.

U.S. EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020.

U.S. Geological Survey, 1984. National Handbook of Recommended Methods for Water Data Acquisition, Chapter 5: Chemical and Physical Quality of Water and Sediment. U.S. Department of the Interior, Reston, Virginia.

7.0 ATTACHMENTS

Attachment A - Specific Conductance of KCl Solutions at 25 degrees Centigrade

Attachment B - Variation of Dissolved Oxygen Concentration in Water as a Function of Temperature and Salinity.

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ATTACHMENT A

**SPECIFIC CONDUCTANCE OF M KCl
AT VARIOUS TEMPERATURES¹**

Temperature (°C)	Specific Conductance (µmhos/cm)
15	1,147
16	1,173
17	1,199
18	1,225
19	1,251
20	1,278
21	1,305
22	1,332
23	1,359
24	1,368
25	1,413
26	1,441
27	1,468
28	1,496
29	1,524
30	1,552

¹ Data derived from the International Critical Tables 1-3-8.

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ATTACHMENT B

**VARIATION OF DISSOLVED OXYGEN CONCENTRATION
IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY**

Temperature °C	Dissolved Oxygen (mg/L)					
	Chloride Concentration in Water					Difference/100 mg chloride
	0	5,000	10,000	15,000	20,000	
0	14.6	13.8	13.0	12.1	11.3	0.017
1	14.2	13.4	12.6	11.8	11.0	0.016
2	13.8	13.1	12.3	11.5	10.8	0.015
3	13.5	12.7	12.0	11.2	10.5	0.015
4	13.1	12.4	11.7	11.0	10.3	0.014
5	12.8	12.1	11.4	10.7	10.0	0.014
6	12.5	11.8	11.1	10.5	9.8	0.014
7	12.2	11.5	10.9	10.2	9.6	0.013
8	11.9	11.2	10.6	10.0	9.4	0.013
9	11.6	11.0	10.4	9.8	9.2	0.012
10	11.3	10.7	10.1	9.6	9.0	0.012
11	11.1	10.5	9.9	9.4	8.8	0.011
12	10.8	10.3	9.7	9.2	8.6	0.011
13	10.6	10.1	9.5	9.0	8.5	0.011
14	10.4	9.9	9.3	8.8	8.3	0.010
15	10.2	9.7	9.1	8.6	8.1	0.010
16	10.0	9.5	9.0	8.5	8.0	0.010
17	9.7	9.3	8.8	8.3	7.8	0.010
18	9.5	9.1	8.6	8.2	7.7	0.009
19	9.4	8.9	8.5	8.0	7.6	0.009
20	9.2	8.7	8.3	7.9	7.4	0.009
21	9.0	8.6	8.1	7.7	7.3	0.009
22	8.8	8.4	8.0	7.6	7.1	0.008
23	8.7	8.3	7.9	7.4	7.0	0.008
24	8.5	8.1	7.7	7.3	6.9	0.008

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**ATTACHMENT B
 VARIATION OF DISSOLVED OXYGEN CONCENTRATION
 IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY
 PAGE TWO**

Temperature °C	Dissolved Oxygen (mg/L)					
	Chloride Concentration in Water					Difference/100 mg chloride
	0	5,000	10,000	15,000	20,000	
25	8.4	8.0	7.6	7.2	6.7	0.008
26	8.2	7.8	7.4	7.0	6.6	0.008
27	8.1	7.7	7.3	6.9	6.5	0.008
28	7.9	7.5	7.1	6.8	6.4	0.008
29	7.8	7.4	7.0	6.6	6.3	0.008
30	7.6	7.3	6.9	6.5	6.1	0.008
31	7.5					
32	7.4					
33	7.3					
34	7.2					
35	7.1					
36	7.0					
37	6.9					
38	6.8					
39	6.7					
40	6.6					
41	6.5					
42	6.4					
43	6.3					
44	6.2					
45	6.1					
46	6.0					
47	5.9					
48	5.8					
49	5.7					
50	5.6					

Note: In a chloride solution, conductivity can be roughly related to chloride concentration (and therefore used to correct measured D.O. concentration) using Attachment A.

APPENDIX B

EXAMPLES OF FIELD DOCUMENTATION FORMS



HALLIBURTON NUS
Environmental Corporation

EQUIPMENT CALIBRATION LOG

Instrument (Name/Model Number/Serial Number): _____

Manufacturer: _____

Date Purchased: _____

Calibration Date	Initial Settings	Standard/Gas Used	Procedure	Adjustments Made	Final Settings	Signature	Comments

SAMPLE LOG SHEET

Page ____ of ____



- Monitoring Well Data
- Domestic Well Data
- Other _____

Case # _____
By _____

Project Site Name _____

Project Site Number _____

HALLIBURTON NUS Source No. _____

Source Location _____

Total Well Depth:	Purge Data				
Well Casing Size and Depth:	Volume	pH	S.C.	Temp. (°C)	Color & Turbidity
Static Water Level:					
One Casing Volume:					
Start Purge (hrs.):					
End Purge (hrs.):					
Total Purge Time (min.):					
Total Amount Purged (gal.):					
Monitor Reading:					
Purge Method:					
Sample Method:					
Depth Sampled:					
Sample Date and Time:	Sample Data				
Sampled By:	pH	S.C.	Temp. (°C)	Color & Turbidity	
Signature(s):	Observations/Notes:				
<input type="checkbox"/> Type of Sample <input type="checkbox"/> Low Concentration <input type="checkbox"/> High Concentration <input type="checkbox"/> Grab <input type="checkbox"/> Composite <input type="checkbox"/> Grab - Composite					
Analysis:	Preservative:	Organic		Inorganic	
		Traffic Report #			
		Tag #			
		AB #			
		Date Shipped			
		Time Shipped			
		Lab			
		Volume			

SAMPLE LOG SHEET

Page _____ of _____



- Surface Soil
- Subsurface Soil
- Sediment
- Lagoon/Pond
- Other _____

Case # _____

By _____

Project Site Name _____

Project Site Number _____

HALLIBURTON NUS Source No. _____

Source Location _____

Sample Method:	Composite Sample Data		
	Sample	Time	Color/Description
Depth Sampled:			
Sample Date & Time:			
Sampled By:			
Signature(s):			
Type of Sample <input type="checkbox"/> High Concentration <input type="checkbox"/> Low Concentration <input type="checkbox"/> Grab <input type="checkbox"/> Composite <input type="checkbox"/> Grab - Composite			
	Sample Data		
	Color	Description: (Sand, Clay, Dry, Moist, Wet, etc.)	
Analysis:	Observations/Notes:		
		Organic	Inorganic
Traffic Report #			
Tag #			
AB #			
Date Shipped			
Time Shipped			
Lab			
Volume			

