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Master Plans
for
Installation Restoration Program Environmental Investigations
at
Naval District Washington, Indian Head
Indian Head, Maryland

Engineering Field Activity Chesapeake
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888

Contract Task Order 0805

June 2004

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MASTER QUALITY ASSURANCE PROJECT PLAN

MASTER WORK PLAN

MASTER FIELD SAMPLING PLAN

HEALTH AND SAFETY PLAN GUIDANCE DOCUMENT

FACILITY STANDARD OPERATING PROCEDURES

EXECUTIVE SUMMARY

The Naval District Washington, Indian Head[1] (NDW,IH) in Indian Head, Maryland was placed on the National Priorities List (NPL) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1995. Ongoing and future environmental investigative work at the Facility will be in accordance with CERCLA requirements as described in this Master Plans document which consists of the following associated master planning documents:

- Master Quality Assurance Project Plan (QAPP)
- Master Work Plan
- Master Field Sampling Plan (FSP)
- Health and Safety Plan (HASP) Guidance Document (Master HASP)
- Facility Standard Operating Procedures (SOPs)

The master planning documents combined with project-specific work plans will describe the methods and procedures to perform environmental investigative work at the Facility.

This Master Work Plan provides information pertaining to the Facility and describes the general procedures for environmental investigations at the Facility. Sites will be investigated to determine the nature and extent of contamination, and then the data will be evaluated in terms of human health and, if applicable, ecological risk.

[1] On 1 October 2003, the installation management functions at Indian Head transferred from Indian Head Division/Naval Surface Warfare Center to Naval District Washington. References to this Installation will now be Naval District Washington, Indian Head.

Master Quality Assurance Project Plan

for

Installation Restoration Program Environmental Investigations

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020404/P

MASTER QUALITY ASSURANCE PROJECT PLAN
FOR
INSTALLATION RESTORATION PROGRAM
ENVIRONMENTAL INVESTIGATIONS
AT
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
Engineering Field Activity Chesapeake
1314 Harwood Street, S.E.
Washington Navy Yard, D.C. 20374-5018

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CONTRACT NUMBER N62467-94-D-0888
CONTRACT TASK ORDER 0805

JUNE 2004

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1.0 PROJECT DESCRIPTION

1.1 INTRODUCTION

This Master Quality Assurance Project Plan (QAPP) has been prepared by Tetra Tech NUS, Inc. (TtNUS) on behalf of the United States Navy Engineering Field Activity Chesapeake Naval Facilities Engineering Command and the Naval District Washington, Indian Head[1] (NDW,IH). The Master QAPP has been prepared under Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract N62467-94-D-0888, Contract Task Order 0805.

1.1.1 Overall Project Objectives

This Master QAPP is intended to outline general quality assurance (QA) guidelines that will be common to multiple site investigations to be conducted at the Facility. This Master QAPP outlines QA issues for what are expected to be the most common types of field efforts and analyses. Important companion documents to this Master QAPP include the Master Work Plan (WP), Master Field Sampling Plan (FSP), Health and Safety Plan (HASP) Guidance Document, and Facility standard operating procedures (SOPs). Specific project objectives will be identified in subsequent project-specific Work Plans. Additional QA issues will be addressed in addenda to this Master QAPP as necessary. Such addenda are to be provided as appendices to project-specific Work Plans.

1.1.2 Master QAPP Preparation Guidelines

This Master QAPP has been prepared in accordance with the general requirements and content outlined the EPA Requirements for Quality Assurance Project Plans, EPA QA/R-5 (USEPA, 2001a). Instead of using the QA/R-5 format, a separate Master WP, Master FSP, and Master QAPP have been prepared. The rationale for using this format is that TtNUS has found it to be more user friendly both in development and implementation. In addition, QA/R-5 allows deviations from the QA/R-5 format.

1.2 FACILITY DESCRIPTION

A Facility description, including the location and general description, Facility history, land use, water sources and usage, population, physiography and topography, geology, soils, hydrogeology, hydrology, ecology, and meteorology is provided in the Master WP.

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[1] On 1 October 2003, the installation management functions at Indian Head transferred from Indian Head Division/Naval Surface Warfare Center to Naval District Washington. References to this Installation will now be Naval District Washington, Indian Head.

1.3 PROJECT TARGET PARAMETERS AND INTENDED DATA USES

This section discusses the most frequently used field and laboratory analytical information to be generated during the course of future investigative activities at the Facility. This section presents generic information that will be further detailed as required in a project-specific addendum to this Master QAPP (project-specific WP appendix). Field parameters and intended data uses are discussed in Section 1.3.1. Laboratory parameters and intended data uses are discussed in Section 1.3.2.

1.3.1 Field Parameters

Field parameters include those associated with the completion of soil borings, installation and development of monitoring wells, groundwater sampling and analysis, and test pit excavation and sampling. Field measurements include only those measurements completed using field instrumentation.

Field measurements of total volatile organic compounds (VOCs) will be completed using a photoionization detector (PID) or flame ionization detector (FID) as specified in the project-specific addenda to this Master QAPP. The choice of PID or FID will be based on the anticipated contaminants of concern and ambient conditions. These measurements will be used as a screening tool to determine the following: (1) appropriate subsurface sample horizons to be submitted for laboratory analysis; (2) relative spatial distribution of VOC contamination; (3) locations that require additional investigative work; (4) breathing zone conditions of site workers; and (5) gross levels of VOC contamination in investigation-derived waste (IDW). In addition to the obvious health and safety advantages, PID or FID measurements aid in the decision-making process during data collection activities and are not intended to be a substitute for conventional analytical methodologies. Rather, they are used as a screening tool to enable conventional analytical methods to be used more effectively.

Field parameters including pH, specific conductivity, turbidity, dissolved oxygen (DO), and temperature will be collected for all aqueous phase samples. These measurements will be used to support monitoring well development and purging of stagnant water from well casings. Specific conductivity and pH can also be used as general indicators of water quality. It is anticipated that a Horiba® Model U-22 combination water-quality meter will be used as per the manufacturer's calibration instructions. All five parameters are measured simultaneously, and the instrument is capable of storing the data in memory, printing the stored data, or presenting it for viewing directly on the instrument panel. Calibration will be performed/checked daily.

1.3.2 Laboratory Parameters

It is anticipated that some or all of the analytical methods shown in Table 1-1 will be performed for samples collected at the Facility. Specific analytical programs for environmental samples will be provided in the project-specific addenda to this Master QAPP.

Tables 1-2 through 1-5 provide a summary of the anticipated laboratory parameters and their associated contract required quantitation limits (CRQLs) for Target Compound List (TCL) organics, contract required detection limits (CRDLs) for Target Analyte List (TAL) inorganics, or estimated practical quantitation limits (PQLs) for all parameters not included in United States Environmental Protection Agency (USEPA) Contract Laboratory Program (CLP) TCL or TAL statement of work (SOWs). Quantitation and detection limits are further discussed in Section 7.2 of this Master QAPP.

The analytical program for each individual project will be determined by examining the contaminants of concern and federal and/or State standards and criteria that must be satisfied versus the various analytical methods available for determination of contaminants of concern. Some analytical methods offer more quantitative results than others, and some offer lower limits of detection than others. To determine the appropriate analytical method necessary to achieve limits of detection capable of satisfying project-specific standards, criteria and/or preliminary remediation goals, a table containing the PQLs, method detection limits (MDL), and the applicable federal, State, project-specific criteria must be generated. Tables 1-6 and 1-7 are examples of the type of tables that are necessary. Each project-specific WP and Master QAPP addendum must include a similar table populated with applicable criteria.

1.4 DATA QUALITY OBJECTIVES

Data quality objectives (DQOs) will be discussed in project-specific WPs to be provided as the investigative efforts progress. A general discussion of DQOs appears in Section 5.0 of the Master Work Plan.

1.5 SAMPLE NETWORK DESIGN AND RATIONALE

Sample network design and rationale will be provided in project-specific WPs.

1.6 PROJECT SCHEDULE

Project schedules will be provided in project-specific WPs.

TABLE 1-1

ANALYTICAL METHODS SUMMARY
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	Preparation Method	Analytical Method
Aqueous Matrices		
Target Compound List (TCL) Volatile Organics	CLP OLM04.2[1]	CLP OLM04.2
TCL Volatile Organics (low conc.)	CLP OLC03.2[2]	CLP OLC03.2
TCL Semivolatile Organics	CLP OLM04.2	CLP OLM04.2
TCL Semivolatile Organics (low conc.)	CLP OLC03.2	CLP OLC03.2
TCL Organochlorine Pesticides/Polychlorinated Biphenyls (PCBs)	CLP OLM04.2	CLP OLM04.2
TCL Organochlorine Pesticides/PCBs (low conc.)	CLP OLC03.2	CLP OLC03.2
Nitroaromatics (Explosives)	SW-846 8330[3]	SW-846 8330
Target Analyte List (TAL) Metals (total and dissolved) + Cyanide	CLP ILM04.1[4]	CLP ILM04.1
TAL Metals (total and dissolved) + Cyanide	CLP ILM05.2[5]	CLP ILM05.2
Dioxin/furan	CLP OLM01.4	CLP OLM01.4
Perchlorate	EPA 314.0[7]	EPA 314.0[7]
Perchlorate	SW-846 8321A Modified[7]	SW-846 8321A Modified[7]
Solid Matrices		
TCL Volatile Organics	SW-846 5035	CLP OLM04.2
TCL Volatile Organics	CLP OLM04.2	CLP OLM04.2
TCL Semivolatile Organics	CLP OLM04.2	CLP OLM04.2
TCL Organochlorine Pesticides/PCBs	CLP OLM04.2	CLP OLM04.2
Perchlorate	SW-846 8321A Modified[7]	SW-846 8321A Modified[7]
Nitroaromatic (Explosives)	SW-846 8330	SW-846 8330
TAL Metals + Cyanide	CLP ILM05.2	CLP ILM05.2
TAL Metals + Cyanide	CLP ILM04.1	CLP ILM04.1
Dioxin/furan	CLP OLM01.4	CLP OLM01.4
Toxicity Characteristic Leaching Procedure (TCLP)	SW-846 1311	NA
Ignitability	NA	SW-846 1010
Corrosivity	NA	SW-846 1110
Reactivity	NA	SW-846 Ch 7

1 USEPA (United States Environmental Protection Agency), 1999. Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration, OLM04.2.
2 USEPA, 2001. Superfund Analytical Methods for Low Concentration Water for Organic Analysis, OLC03.2.

TABLE 1-1

ANALYTICAL METHODS SUMMARY
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

3 USEPA, 1986. Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods. SW-846, 3rd ed. with updates up to and including Update III.
4 USEPA, 2000. Statement of Work for Inorganics Analysis, Multi-Media, Multi-Concentration, ILM04.1.
5 USEPA, 2001. Statement of Work for Inorganic Analysis, Multi-Media, Multi-Concentration, ILM05.2.
6 USEPA, 1999. Determination of Perchlorate in Drinking Water Using Ion Chromatography, EPA 314.0 Revision 1. National Exposure Research Laboratory, Office of Research and Development, Cincinnati, Ohio. November.
7 DON (Department of the Navy), 2003. Navy Perchlorate Sampling Policy, Chief of Naval Operations, 5090, ser N456J/34574857. December 5.
NA - Not Applicable

TABLE 1-2

ANALYTICAL DETECTION LIMITS - TARGET COMPOUND LIST ORGANICS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	CRQL[1]	
	Aqueous Samples (µg/L)	Solid Samples (µg/kg)
Volatile Organic Compounds		
Dichlorodifluoromethane	10	10
Chloromethane	10	10
Vinyl Chloride	10	10
Bromomethane	10	10
Chloroethane	10	10
Trichlorofluoromethane	10	10
1,1-Dichloroethene	10	10
1,1,2-Trichloro-1,2,2-trifluoroethane	10	10
Acetone	10	10
Carbon Disulfide	10	10
Methyl Acetate	10	10
Methylene Chloride	10	10
trans-1,2-Dichloroethene	10	10
Methyl-tert-butyl-ether	10	10
1,1-Dichloroethane	10	10
cis-1,2-Dichloroethene	10	10
2-Butanone	10	10
Chloroform	10	10
1,1,1-Trichloroethane	10	10
Cyclohexane	10	10
Carbon Tetrachloride	10	10
Benzene	10	10
1,2-Dichloroethane	10	10
Trichloroethene	10	10
Methylcyclohexane	10	10
1,2-Dichloropropane	10	10
Bromodichloromethane	10	10
cis-1,3-Dichloropropene	10	10
4-Methyl-2-pentanone	10	10
Toluene	10	10
trans-1,3-Dichloropropene	10	10
1,1,2-Trichloroethane	10	10
Tetrachloroethene	10	10

TABLE 1-2

ANALYTICAL DETECTION LIMITS - TARGET COMPOUND LIST ORGANICS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	CRQL[1]	
	Aqueous Samples (µg/L)	Solid Samples (µg/kg)
2-Hexanone	10	10
Volatile Organic Compounds (Continued)		
Dibromochloromethane	10	10
1,2-Dibromoethane	10	10
Chlorobenzene	10	10
Ethylbenzene	10	10
Xylenes (total)	10	10
Styrene	10	10
Bromoform	10	10
Isopropylbenzene	10	10
1,1,2,2-Tetrachloroethane	10	10
1,3-Dichlorobenzene	10	10
1,2-Dichlorobenzene	10	10
1,4-Dichlorobenzene	10	10
1,2-Dibromo-3-Chloropropane	10	10
1,2,4-Trichlorobenzene	10	10
Diethyl Ether	10	10
Semivolatile Organic Compounds		
Benzaldehyde	10	330
Phenol	10	330
bis-(2-Chloroethyl) ether	10	330
2-Chlorophenol	10	330
2-Methylphenol	10	330
2,2-oxybis(1-Chloropropane)	10	330
Acetophenone	10	330
4-Methylphenol	10	330
N-Nitroso-di-n propylamine	10	330
Hexachloroethane	10	330
Nitrobenzene	10	330
Isophorone	10	330
2-Nitrophenol	10	330
2,4-Dimethylphenol	10	330
bis(2-Chloroethoxy) methane	10	330
2,4-Dichlorophenol	10	330

TABLE 1-2

ANALYTICAL DETECTION LIMITS - TARGET COMPOUND LIST ORGANICS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	CRQL[1]	
	Aqueous Samples (µg/L)	Solid Samples (µg/kg)
Naphthalene	10	330
4-Chloroaniline	10	330
Semivolatile Organic Compounds (Continued)		
Hexachlorobutadiene	10	330
Caprolactam	10	330
4-Chloro-3-methylphenol	10	330
2-Methylnaphthalene	10	330
Hexachlorocyclopentadiene	10	330
2,4,6-Trichlorophenol	10	330
2,4,5-Trichlorophenol	25	830
1,1'-Biphenyl	10	330
2-Chloronaphthalene	10	330
2-Nitroaniline	25	830
Dimethylphthalate	10	330
2,6-Dinitrotoluene	10	330
Acenaphthylene	10	330
3-Nitroaniline	25	830
Acenaphthene	10	330
2,4-Dinitrophenol	25	830
4-Nitrophenol	25	830
Dibenzofuran	10	330
2,4-Dinitrotoluene	10	330
Diethylphthalate	10	330
Fluorene	10	330
4-Chlorophenyl-phenyl ether	10	330
4-Nitroaniline	25	830
4,6-Dinitro-2-methylphenol	25	830
N-Nitroso diphenylamine	10	330
4-Bromophenyl-phenylether	10	330
Hexachlorobenzene	10	330
Atrazine	10	330
Pentachlorophenol	25	830
Phenanthrene	10	330
Anthracene	10	330

TABLE 1-2

ANALYTICAL DETECTION LIMITS - TARGET COMPOUND LIST ORGANICS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	CRQL[1]	
	Aqueous Samples (µg/L)	Solid Samples (µg/kg)
Carbazole	10	330
Di-n-butylphthalate	10	330
Fluoranthene	10	330
Semivolatile Organic Compounds (Continued)		
Pyrene	10	330
Butylbenzylphthalate	10	330
3,3'-Dichlorobenzidine	10	330
Benzo (a) anthracene	10	330
Chrysene	10	330
bis(2-Ethylhexyl) phthalate	10	330
Di-n-octylphthalate	10	330
Benzo (b) fluoroanthene	10	330
Benzo (k) fluoroanthene	10	330
Benzo (a) pyrene	10	330
Indeno (1,2,3-cd)-pyrene	10	330
Dibenzo (a,h)-anthracene	10	330
Benzo(g,h,i)perylene	10	330
Pesticides/Polychlorinated Biphenyls		
Aldrin	0.050	1.7
alpha-BHC	0.050	1.7
alpha-Chlordane	0.050	1.7
beta-BHC	0.050	1.7
4,4'-DDE	0.10	3.3
4,4'-DDD	0.10	3.3
4,4'-DDT	0.10	3.3
delta-BHC	0.050	1.7
Dieldrin	0.10	3.3
Endosulfan I	0.050	1.7
Endosulfan II	0.10	3.3
Endosulfan sulfate	0.10	3.3
Endrin	0.10	3.3
Endrin aldehyde	0.10	3.3
Endrin ketone	0.10	3.3
gamma-BHC (Lindane)	0.050	1.7

TABLE 1-2

ANALYTICAL DETECTION LIMITS - TARGET COMPOUND LIST ORGANICS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	CRQL[1]	
	Aqueous Samples (µg/L)	Solid Samples (µg/kg)
gamma-Chlordane	0.050	1.7
Heptachlor	0.050	1.7
Heptachlor epoxide	0.050	1.7
Methoxychlor	0.50	17
Pesticides/Polychlorinated Biphenyls (Continued)		
Toxaphene	5.0	170
Aroclor-1016	1.0	33
Aroclor-1221	2.0	67
Aroclor-1232	1.0	33
Aroclor-1242	1.0	33
Aroclor-1248	1.0	33
Aroclor-1254	1.0	33
Aroclor-1260	1.0	33

1 CRQL Contract Required Quantitation Limit, as specified in OLM04.2.

TABLE 1-3

ANALYTICAL DETECTION LIMITS - TARGET COMPOUND LIST
LOW CONCENTRATION ORGANICS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	CRQL[1] Aqueous Samples (µg/L)
Volatile Organic Compounds	
Dichlorodifluoromethane	0.5
Chloromethane	0.5
Vinyl Chloride	0.5
Bromomethane	0.5
Chloroethane	0.5
Trichlorofluoromethane	0.5
1,1-Dichloroethene	0.5
1,1,2-Trichloro-1,2,2-trifluoroethane	0.5
Acetone	5
Carbon Disulfide	0.5
Methyl Acetate	0.5
Methylene Chloride	0.5
Trans-1,2-Dichloroethene	0.5
Methyl-tert-butyl-ether	0.5
1,1-Dichloroethane	0.5
cis-1,2-Dichloroethene	0.5
2-Butanone	5
Bromochloromethane	0.5
Chloroform	0.5
1,1,1-Trichloroethane	0.5
Cyclohexane	0.5
Carbon Tetrachloride	0.5
Benzene	0.5
1,2-Dichloroethane	0.5
Trichloroethene	0.5
Methylcyclohexane	0.5
1,2-Dichloropropane	0.5
Bromodichloromethane	0.5
cis-1,3-Dichloropropene	0.5
4-Methyl-2-pentanone	5
Toluene	0.5
trans-1,3-Dichloropropene	0.5
1,1,2-Trichloroethane	0.5

TABLE 1-3

ANALYTICAL DETECTION LIMITS - TARGET COMPOUND LIST
LOW CONCENTRATION ORGANICS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	CRQL[1] Aqueous Samples (µg/L)
Volatile Organic Compounds (Continued)	
Tetrachloroethene	0.5
2-Hexanone	5
Dibromochloromethane	0.5
1,2-Dibromoethane	0.5
Chlorobenzene	0.5
Ethylbenzene	0.5
Xylenes (total)	0.5
Styrene	0.5
Bromoform	0.5
Isopropylbenzene	0.5
1,1,2,2-Tetrachloroethane	0.5
1,3-Dichlorobenzene	0.5
1,2-Dichlorobenzene	0.5
1,4-Dichlorobenzene	0.5
1,2-Dibromo-3-Chloropropane	0.5
1,2,4-Trichlorobenzene	0.5
1,2,3-Trichlorobenzene	0.5
Diethyl Ether	0.5
Semivolatile Organic Compounds	
Benzaldehyde	5
Phenol	5
bis-(2-Chloroethyl) ether	5
2-Chlorophenol	5
2-Methylphenol	5
2,2-oxybis(1-Chloropropane)	5
Acetophenone	5
4-Methylphenol	5
N-Nitroso-di-n propylamine	5
Hexachloroethane	5
Nitrobenzene	5
Isophorone	5
2-Nitrophenol	5
2,4-Dimethylphenol	5

TABLE 1-3

ANALYTICAL DETECTION LIMITS - TARGET COMPOUND LIST
LOW CONCENTRATION ORGANICS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	CRQL[1] Aqueous Samples (µg/L)
Semivolatile Organic Compounds (Continued)	
bis(2-Chloroethoxy) methane	5
2,4-Dichlorophenol	5
Naphthalene	5
4-Chloroaniline	5
Hexachlorobutadiene	5
Caprolactam	5
4-Chloro-3-methylphenol	5
2-Methylnaphthalene	5
Hexachlorocyclopentadiene	5
2,4,6-Trichlorophenol	5
2,4,5-Trichlorophenol	20
1,1'-Biphenyl	5
2-Chloronaphthalene	5
2-Nitroaniline	20
Dimethylphthalate	5
2,6-Dinitrotoluene	5
Acenaphthylene	5
3-Nitroaniline	20
Acenaphthene	5
2,4-Dinitrophenol	20
4-Nitrophenol	20
Dibenzofuran	5
2,4-Dinitrotoluene	5
Diethylphthalate	5
Fluorene	5
4-Chlorophenyl-phenyl ether	5
4-Nitroaniline	20
4,6-Dinitro-2-methylphenol	20
N-Nitroso diphenylamine	5
4-Bromophenyl-phenylether	5
Hexachlorobenzene	5
Atrazine	5
Pentachlorophenol	5

TABLE 1-3

ANALYTICAL DETECTION LIMITS - TARGET COMPOUND LIST
LOW CONCENTRATION ORGANICS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	CRQL[1] Aqueous Samples (µg/L)
Semivolatile Organic Compounds (Continued)	
Phenanthrene	5
Anthracene	5
Carbazole	5
Di-n-butylphthalate	5
Fluoranthene	5
Pyrene	5
Butylbenzylphthalate	5
3,3'-Dichlorobenzidine	5
Benzo (a) anthracene	5
Chrysene	5
bis(2-Ethylhexyl) phthalate	5
Di-n-octylphthalate	5
Benzo (b) fluoroanthene	5
Benzo (k) fluoroanthene	5
Benzo (a) pyrene	5
Indeno (1,2,3-cd)-pyrene	5
Dibenzo (a,h)-anthracene	5
Benzo (g,h,i) perylene	5
Pesticides/Polychlorinated Biphenyls	
Aldrin	0.01
alpha-BHC	0.01
alpha-Chlordane	0.01
beta-BHC	0.01
4,4'-DDD	0.02
4,4'-DDE	0.02
4,4'-DDT	0.02
delta-BHC	0.01
Dieldrin	0.02
Endosulfan I	0.01
Endosulfan II	0.02
Endosulfan sulfate	0.02
Endrin	0.02
Endrin aldehyde	0.02

TABLE 1-3

ANALYTICAL DETECTION LIMITS - TARGET COMPOUND LIST
LOW CONCENTRATION ORGANICS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	CRQL[1] Aqueous Samples (µg/L)
Pesticides/Polychlorinated Biphenyls (Continued)	
Endrin ketone	0.02
gamma-BHC (Lindane)	0.01
gamma-Chlordane	0.01
Heptachlor	0.01
Heptachlor epoxide	0.01
Methoxychlor	0.10
Toxaphene	1.0
Aroclor-1016	0.20
Aroclor-1221	0.40
Aroclor-1232	0.20
Aroclor-1242	0.20
Aroclor-1248	0.20
Aroclor-1254	0.20
Aroclor-1260	0.20

1 CRQL Contract Required Quantitation Limit, as specified in OLC03.2.

TABLE 1-4

ANALYTICAL DETECTION LIMITS - TARGET ANALYTE LIST INORGANICS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	CRQL(1)		
	Aqueous Samples(2) (µg/L) Analyzed by ICP-AES	Aqueous Samples(2) (µg/L) Analyzed by ICP-MS	Solid Samples(3) (mg/kg) Analyzed by ICP-AES
Target Analyte List Metals			
Aluminum	200	NA	40
Antimony	60	2	12
Arsenic	10	1	2
Barium	200	10	40
Beryllium	5	1	1
Cadmium	5	1	1
Calcium	5000	NA	1000
Chromium (total)	10	2	2
Cobalt	50	1	10
Copper	25	2	5
Cyanide	10	NA	10
Iron	100	NA	20
Lead	10	1	0.6
Magnesium	5000	NA	1000
Manganese	15	1	3
Mercury	0.2	NA	0.1
Nickel	40	1	8
Potassium	5000	NA	1000
Selenium	35	5	1
Silver	10	1	2
Sodium	5000	NA	1000
Thallium	25	1	2
Vanadium	50	1	10
Zinc	60	2	4

1 CRQL - Contract Required Quantitation Limit, as specified in ILM05.3; actual results will be reported to the laboratory-specific Instrument Detection Limits (IDLs) as per the Contract Laboratory Program Statements of Work.
2 Groundwater and surface water samples.
3 Soil and sediment samples.
NA – No detection limit

TABLE 1-5

ANALYTICAL DETECTION LIMITS - NITROAROMATICS (EXPLOSIVES) AND PERCHLORATE
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Parameter	PQL[1]	
	Aqueous Samples (µg/L)	Solid Samples (mg/kg)
Nitroaromatics (Explosives)		
1,3,5-Trinitrobenzene (1,3,5-TNB)	0.2	0.25
1,3-Dinitrobenzene (1,3-DNB)	0.2	0.25
2,4,6-Trinitrotoluene (2,4,6-TNT)	0.2	0.25
2,4-Dinitrotoluene (2,4-DNT)	0.2	0.25
2,6-Dinitrotoluene (2,6-DNT)	0.2	0.25
2-Amino-4,6-Dinitrotoluene (2-Am-4,6DNT)	0.2	0.25
2-Nitrotoluene (2-NT)	0.2	0.25
3-Nitrotoluene (3-NT)	0.2	0.25
4-Amino-2,6-Dinitrotoluene (4-Am-2,6-DNT)	0.2	0.25
4-Nitrotoluene (4-NT)	0.2	0.25
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	0.5	0.5
Nitrobenzene (NB)	0.2	0.25
Nitroglycerin (NG)	2.5	2.5
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	0.5	0.5
Methyl-2,4,6-trinitrophenylnitramine (Tetryl)	0.2	0.65
Perchlorate		
Perchlorate (EPA 314.0)	1	10 µg/kg
Perchlorate (SW-846 8321A modified HPLC/MS/MS) [2]	0.2	5 µg/kg

1 PQL Estimated Practical Quantitation Limit.
2 Reporting limits for HPLC/MS/MS (high performance liquid chromatography with mass spectral identification) as per Severn Trent Laboratories, Denver.

TABLE 1-6

EXAMPLE ANALYTICAL DETECTION LIMITS VERSUS CRITERIA - AQUEOUS SAMPLE MATRIX (ug/L)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	Laboratory Detection Limits[1]		USEPA Region III Tapwater RBC [2]	Federal MCL [3]	Federal AWQC [4]						Maryland Water Quality Standard [5]						Virginia Groundwater Standard [6]	USEPA Region III BTAG Screening Levels [7]	
					Freshwater		Saltwater		Protection of Human Health						Protection of Human Health				
	MDL/IDL	CRQL/ CRDL			Acute	Chronic	Acute	Chronic	Water and Organisms	Organisms Only	Acute	Chronic	Acute	Chronic	Public Water	Surface Water		Saltwater	Freshwater
TCL Volatile Organic Compounds - CLP SOW OLM04.2																			
1,1,1-TRICHLOROETHANE	0.12	10	3200	200														31200 [8]	9400 [8]
1,1,2,2-TETRACHLOROETHANE	0.24	10	0.053						0.17	11									
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE	NAT	10	59000																
1,1,2-TRICHLOROETHANE	0.88	10	0.19	5					0.6	42								31200 [8]	9400 [8]
1,1-DICHLOROETHANE	0.17	10	800															320000	160000
1,1-DICHLOROETHENE	0.76	10	0.044	7					0.057	3.2					310	17000		224000	11600
1,2,4-TRICHLOROBENZENE	1.4	10	190	70					260	940					260	950		129 [9]	50 [9]
1,2-DIBROMO-3-CHLOROPROPANE	NAT	10	0.047	0.2															
1,2-DIBROMOETHANE	NAT	10	0.00075	0.05															18000
1,2-DICHLOROBENZENE	1.3	10	550	600					2700	17000					2700	17000		129	763
1,2-DICHLOROETHANE	0.87	10	0.12	5					0.38	99					3.8	990		113000	20000
1,2-DICHLOROPROPANE	0.20	10	0.16	5					0.52	39								3040	5700
1,3-DICHLOROBENZENE	1.2	10	5.5						400	2600					400	2600			763
1,4-DICHLOROBENZENE	1.2	10	0.47	75					400	2600					400	2600		129	763
2-BUTANONE	3.0	10	1900																3220000
2-HEXANONE	1.3	10	1500																428000
4-METHYL-2-PENTANONE	0.30	10	140																460000
ACETONE	4.4	10	610																9000000
BENZENE	0.08	10	0.32	5					1.2	71					12	710		700	5300
BROMODICHLOROMETHANE	0.31	10	0.17	80 [10][11]					0.56	46					5.6	460		6400	11000
BROMOFORM	0.30	10	8.5	80 [10][11]					4.3	360					44	3600		1000	11000
BROMOMETHANE	0.88	10	8.5						48	4000									
CARBON DISULFIDE	0.08	10	1000															2	2
CARBON TETRACHLORIDE	0.12	10	0.16	5					0.25	4.4					2.5	45		50000	35200
CHLOROBENZENE	0.16	10	110	100					20 [12][13]	21000					680	21000		129	50
CHLORODIBROMOMETHANE	NAT	10	0.13	80 [10][11]					0.41	34					690	57000		6400	11000
CHLOROETHANE	0.32	10	3.6																
CHLOROFORM	0.22	10	0.15	80 [10][11]					5.7	470					57	4700			1240
CHLOROMETHANE	0.35	10	2.1																
CIS-1,2-DICHLOROETHENE	NAT	10	61	70														224000	11600
CIS-1,3-DICHLOROPROPENE	0.09	10	0.44 [14]						10 [14]	1700 [14]								790 [14]	244 [14]
CYCLOHEXANE	NAT	10																	
DICHLORODIFLUOROMETHANE	NAT	10	350															6400	11000
ETHYLBENZENE	0.15	10	1300	700					3100	29000					3100	29000		430	32000
FLUOROTRICHLOROMETHANE	NAT	10	1300															6400	11000
ISOPROPYLBENZENE	NAT	10	660																
METHYL ACETATE	NAT	10	6100																
METHYL TERT-BUTYL ETHER	NAT	10	6300																
METHYLCYCLOHEXANE	NAT	10	6300																
METHYLENE CHLORIDE	3.8	10	4.1	5					4.7	1600					47	16000		6400	11000
STYRENE	0.13	10	1600	100															
TETRACHLOROETHENE	0.15	10	1.1	5					0.8	8.85					320	3500		450	840
TOLUENE	0.12	10	750	1000					6800	200000					6800	200000		1050	17000
TRANS-1,2-DICHLOROETHENE	NAT	10	120	100					700	1400000								224000	11600
TRANS-1,3-DICHLOROPROPENE	0.09	10	0.44 [14]						10 [14]	1700 [14]								790 [14]	244 [14]
TRICHLOROETHENE	0.15	10	1.6	5					2.7	81					27	810		2000	21900
VINYL CHLORIDE	0.31	10	0.04 [15]	2					2	525					20	5300		224000	11600
XYLENES, TOTAL	0.23 / 0.37[16]	10	12000	10000														6000	6000
TCL Semivolatile Organic Compounds - CLP SOW OLM03.2																			
2,2'-OXYBIS(1-CHLOROPROPANE)	1.3	10	0.26						1400	170000									
2,4,5-TRICHLOROPHENOL	1.5	25	3700						1 [12][17]	9800								11	63
2,4,6-TRICHLOROPHENOL	1.4	10	6.1						2 [12][18]	6.5					21	65			970
2,4-DICHLOROPHENOL	1.4	10	110						0.3 [12][19]	790					93	790			365
2,4-DIMETHYLPHENOL	1.5	10	730						400 [12][20]	2300					540	2300			2120
2,4-DINITROPHENOL	14	25	73						70	14000								4850 [21]	150 [21]
2,4-DINITROTOLUENE	1.5	10	73						0.11	9.1					1.1	91		370	230
2,6-DINITROTOLUENE	1.8	10	37																
2-CHLORONAPHTHALENE	1.7	10	490						1700	4300								7.5	620
2-CHLOROPHENOL	1.3	10	30						0.1 [12][22]	400					120	400			970
2-METHYLNAPHTHALENE	1.7	10	120															300	
2-METHYLPHENOL	1.3	10	1800																
2-NITROANILINE	7.5	25																	
2-NITROPHENOL	1.2	10	290 [23]																
3,3'-DICHLOROBENZIDINE	9.3	10	0.15						0.04	0.077									
3-NITROANILINE	7.7	25																	
4,6-DINITRO-2-METHYLPHENOL	5.1	10																	
4-BROMOPHENYL PHENYL ETHER	1.8	10																	
4-CHLORO-3-METHYLPHENOL	1.9	10							3000 [12]										
4-CHLOROANILINE	7.6	10	150															29700	

TABLE 1-6

EXAMPLE ANALYTICAL DETECTION LIMITS VERSUS CRITERIA - AQUEOUS SAMPLE MATRIX (ug/L)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	Laboratory Detection Limits[1]		USEPA Region III Tapwater RBC [2]	Federal MCL [3]	Federal AWQC [4]						Maryland Water Quality Standard [5]						Virginia Groundwater Standard [6]	USEPA Region III BTAG Screening Levels [7]	
					Freshwater		Saltwater		Protection of Human Health						Protection of Human Health				
	MDL/IDL	CRQL/ CRDL			Acute	Chronic	Acute	Chronic	Water and Organisms	Organisms Only	Acute	Chronic	Acute	Chronic	Public Water	Surface Water		Saltwater	Freshwater
TCL Semivolatile Organic Compounds - CLP SOW OLM03.2 (Continued)																			
4-CHLOROPHENYL PHENYL ETHER	1.8	10																	
4-METHYLPHENOL	1.1	10	180																
4-NITROANILINE	7.5	25																	
4-NITROPHENOL	14	25	290															4850	150
ACENAPHTHENE	1.5	10	370						1200	2700					1200	2700		710	520
ACENAPHTHYLENE	1.7	10	370 [24]						20 [12]									300	
ANTHRACENE	1.6	10	1800						9600	110000					9600	110000		300	0.1
BENZO(A)ANTHRACENE	1.6	10	0.092						0.0044	0.049					0.044	0.49		8.2	6.3
BENZO(A)PYRENE	1.6	10	0.0092	0.2					0.0044	0.049					0.044	0.49		0.21	
BENZO(B)FLUORANTHENE	1.4	10																	
BENZO(G,H,I)PERYLENE	2	10	6.5 [25]															300	
BENZO(K)FLUORANTHENE	1.8	10	0.92						0.0044	0.049					0.044	0.49		300	
BIS(2-CHLOROETHOXY)METHANE	1.9	10																6400	11000
BIS(2-CHLOROETHYL)ETHER	1.3	10	0.0096						0.031	1.4									
BIS(2-ETHYLHEXYL) PHTHALATE	2.1	10	4.8	6					1.8	5.9					18	59		360	30
BUTYLBENZYL PHTHALATE	2	10	7300						3000	5200					3000	5200		3.4	3
CARBAZOLE	7.6	10	3.3																
CHRYSENE	1.6	10	9.2						0.0044	0.049					0.044	0.49		300	
DI-N-BUTYL PHTHALATE	1.7	10	3700						2700	12000					2700	12000		3.4	0.3
DI-N-OCTYL PHTHALATE	1.9	10	730															3.4	0.3
DIBENZO(A,H)ANTHRACENE	1.4	10	0.0092						0.0044	0.049					0.044	0.49		300	
DIBENZOFURAN	1.7	10	24																
DIETHYL PHTHALATE	1.9	10	29000						23000	120000					23000	120000		3.4	3
DIMETHYL PHTHALATE	1.9	10	370000						313000	2900000								3.4	3
FLUORANTHENE	1.5	10	1500						300	370					300	370		16	3980
FLUORENE	1.8	10	240						1300	14000					1300	14000		300	430
HEXACHLOROBENZENE	1.6	10	0.042	1					0.00075	0.00077								129	3.68
HEXACHLOROBUTADIENE	0.96	10	0.86						0.44	50								32	9.3
HEXACHLOROCYCLOPENTADIENE	3.8	10	260	50					1 [12] [26]	17000								7	5.2
HEXACHLOROETHANE	1.4	10	4.8						1.9	8.9								940	540
INDENO(1,2,3-CD)PYRENE	1.7	10	0.092						0.0044	0.049					0.044	0.49		300	
ISOPHORONE	1.7	10	70						36	2600					6900	490000		12900	117000
N-NITROSO-DI-N-PROPYLAMINE	1.8	10	0.0096						0.005	1.4									
N-NITROSODIPHENYLAMINE	7.7	10	14						5	16								3300000	5850
NAPHTHALENE	1.3	10	6.5															2300	100
NITROBENZENE	1.4	10	3.5						17 [27]	1900					17	1900		6680	27000
PENTACHLOROPHENOL	7.2	25	0.56	1	19	15	13	7.9	0.28 [27]	8.2			13	7.9	2.8	82		7.9	13
PHENANTHRENE	1.4	10	6.5 [25]															4.6	6.3
PHENOL	0.69	10	22000						300 [12] [28]	4600000					21000	4600000		5800	79
PYRENE	1.6	10	180						960	11000					960	11000		300	
TCL Pesticides/PCBs - CLP OLM03.2																			
4,4'-DDD	0.0012	0.10	0.28						0.00083	0.00084					0.0083	0.0084		0.68	0.6
4,4'-DDE	0.0011	0.10	0.2						0.00059	0.00059					0.0059	0.0059		14	1050
4,4'-DDT	0.029	0.10	0.2		1.1	0.001	0.13	0.001	0.00059	0.00059	1.1	0.001	0.13	0.001	0.0059	0.0059	0.001	0.001	0.001
ALDRIN	0.0013	0.05	0.0039		3		1.3		0.00013	0.00014	3	0.3	1.3	0.13	0.0013	0.0014	0.003	1.3	3
ALPHA-BHC	0.0013	0.05	0.011						0.0039	0.013								0.34 [29]	100 [29]
ALPHA-CHLORDANE	0.0012	0.05	0.19 [30]	2 [30]	2.4 [30]	0.0043 [30]	0.09 [30]	0.004 [30]	0.0021 [30]	0.0022 [30]	2.4 [30]	0.0043 [30]	0.09 [30]	0.004 [30]	0.0058 [30]	0.0059 [30]	0.01 [30]	0.004 [30]	0.0043 [30]
AROCLOR-1016	0.43	1.0	0.96 [31]	0.5 [31]		0.014 [32]		0.03 [32]	0.00017 [32]	0.00017 [32]		0.014 [32]		0.03 [32]	0.00044 [32]	0.00045 [32]		0.03 [32]	0.014 [32]
AROCLOR-1221	0.70	2.0	0.033 [32]	0.5 [32]		0.014 [32]		0.03 [32]	0.00017 [32]	0.00017 [32]		0.014 [32]		0.03 [32]	0.00044 [32]	0.00045 [32]		0.03 [32]	0.014 [32]
AROCLOR-1232	0.16	1.0	0.033 [32]	0.5 [32]		0.014 [32]		0.03 [32]	0.00017 [32]	0.00017 [32]		0.014 [32]		0.03 [32]	0.00044 [32]	0.00045 [32]		0.03 [32]	0.014 [32]
AROCLOR-1242	0.31	1.0	0.033 [32]	0.5 [32]		0.014 [32]		0.03 [32]	0.00017 [32]	0.00017 [32]		0.014 [32]		0.03 [32]	0.00044 [32]	0.00045 [32]		0.03 [32]	0.014 [32]
AROCLOR-1248	0.11	1.0	0.033 [32]	0.5 [32]		0.014 [32]		0.03 [32]	0.00017 [32]	0.00017 [32]		0.014 [32]		0.03 [32]	0.00044 [32]	0.00045 [32]		0.03 [32]	0.014 [32]
AROCLOR-1254	0.11	1.0	0.033 [32]	0.5 [32]		0.014 [32]		0.03 [32]	0.00017 [32]	0.00017 [32]		0.014 [32]		0.03 [32]	0.00044 [32]	0.00045 [32]		0.03 [32]	0.014 [32]
AROCLOR-1260	0.25	1.0	0.033 [28]	0.5 [32]		0.014 [32]		0.03 [32]	0.00017 [32]	0.00017 [32]		0.014 [32]		0.03 [32]	0.00044 [32]	0.00045 [32]		0.03 [32]	0.014 [32]
BETA-BHC	0.0019	0.05	0.037						0.014	0.046								0.34 [29]	100 [29]
DELTA-BHC	0.0062	0.05	0.011 [33]						0.0039 [33]	0.013 [33]									
DIELDRIN	0.0010	0.10	0.0042		0.24	0.056	0.71	0.0019	0.00014	0.00014	2.5	0.0019	0.71	0.0019	0.0014	0.0014	0.003	0.0019	0.0019
ENDOSULFAN I	0.0047	0.05	220 [34]		0.22 [34]	0.056 [34]	0.034 [34]	0.0087 [34]	110 [34]	240 [34]	0.22 [34]	0.056 [34]	0.034 [34]	0.0087 [34]	110 [34]	240 [34]		0.0087	0.056
ENDOSULFAN II	0.0011	0.10	220 [34]		0.22 [34]	0.056 [34]	0.034 [34]	0.0087 [34]	110 [34]	240 [34]	0.22 [34]	0.056 [34]	0.034 [34]	0.0087 [34]	110 [34]	240 [34]		0.0087	0.056
ENDOSULFAN SULFATE	0.0015	0.10	220 [34]		0.22 [34]	0.056 [34]	0.034 [34]	0.0087 [34]	110 [34]	240 [34]	0.22 [34]	0.056 [34]	0.034 [34]	0.0087 [34]	110 [34]	240 [34]			
ENDRIN	0.0012	0.10	11	2	0.086	0.036	0.037	0.0023	0.76	0.81	0.18	0.0023	0.037	0.0023	0.76	0.81	0.004	0.0023	0.0023
ENDRIN ALDEHYDE	0.0031	0.10	11 [35]	2 [35]	0.086 [35]	0.036 [35]	0.037 [35]	0.0023 [35]	0.76 [35]	0.81 [35]	0.18 [35]	0.0023 [35]	0.037 [35]	0.0023 [35]	0.76 [35]	0.81 [35]	0.004 [35]	0.0023	0.0023
ENDRIN KETONE	0.0038	0.10	11 [35]	2 [35]	0.086 [35]	0.036 [35]	0.037 [35]	0.0023 [35]	0.76 [35]	0.81 [35]	0.18 [35]	0.0023 [35]	0.037 [35]	0.0023 [35]	0.76 [35]	0.81 [35]	0.004 [35]	0.0023	0.0023
GAMMA-BHC (LINDANE)	0.001	0.05	0.052	0.2	0.95		0.16		0.019	0.063	2	0.08	0.16	0.01	7	25	0.01	0.16	0.08
GAMMA-CHLORDANE	0.0015	0.05	0.19 [30]	2 [30]	2.4 [30]	0.0043 [30]	0.09 [30]	0.004 [30]	0.0021 [30]	0.0022 [30]	2.4 [30]	0.0043 [30]	0.09 [30]	0.004 [30]	0.0058 [30]	0.0059 [30]	0.01 [30]	0.004 [30]	0.0043 [30]
HEPTACHLOR	0.0038	0.05	0.015	0.4	0.52	0.0038	0.053	0.0036	0.00021	0.00021	0.52	0.0038	0.053	0.0036	0.0021	0.0021	0.001	0.0036	0.0038
HEPTACHLOR EPOXIDE	0.001	0.05	0.0074	0.2	0.52	0.0038	0.053	0.0036	0.0001	0.00011							0.001	0.0036	0.0038
METHOXYCHLOR	0.0066	0.50	180	40		0.03		0.03	100			0.03		0.03	40		0.03	0.03	0.03
TOXAPHENE	0.47	5.0	0.061	3	0.73	0.0002	0.21	0.0002	0.00073	0.00075	0.73	0.0002	0.21	0.0002	0.0073	0.0075		0.0002	0.0002

TABLE 1-6

EXAMPLE ANALYTICAL DETECTION LIMITS VERSUS CRITERIA - AQUEOUS SAMPLE MATRIX (ug/L)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	Laboratory Detection Limits[1]		USEPA Region III Tapwater RBC [2]	Federal MCL [3]	Federal AWQC [4]						Maryland Water Quality Standard [5]						Virginia Groundwater Standard [6]	USEPA Region III BTAG Screening Levels [7]	
					Freshwater		Saltwater		Protection of Human Health						Protection of Human Health				
	MDL/IDL	CRQL/ CRDL			Acute	Chronic	Acute	Chronic	Water and Organisms	Organisms Only	Acute	Chronic	Acute	Chronic	Public Water	Surface Water		Saltwater	Freshwater
TAL Metals (plus Cyanide) - CLP ILM04.1																			
ALUMINUM	27	200	37000	50 - 200 [36]	750	87													25
ANTIMONY	2.1	60	15	6					14	4300					14	4300		500	30
ARSENIC	1.1	10	0.045	50	340	150	69	36	0.018	0.14	360 [37]	190	69 [37]	36 [37]	50		50	10 [38]	48 [38]
BARIUM	0.72	200	2600	2000					1000						2000		1000	10000	10000
BERYLLIUM	0.06	5	73	4														1500	5.3
CADMIUM	0.38	5	18 [39]	5	4.3 [40]	2.2 [40]	42	9.3			3.9 [40]	1.1 [40]	43	9			0.4	9.3	0.53
CALCIUM	146	5000																	
CHROMIUM (TOTAL)	0.95	10	110 [41]	100 [42]	16 [43]	11 [43]	1100 [43]	50 [43]			16 [43]	11 [43]	1100 [43]	50 [43]			50	50 [43]	2 [43]
COBALT	0.61	50	2200																35000
COPPER	2.3	25	1500	1300 [44]	13 [40]	9 [40]	4.8	3.1	1000 [12] [45]		18 [40]	12 [40]	5.9	3.8	1300		1000	2.9	6.5
CYANIDE	8.6	10	730	200	22	5.2	1	1	700	220000	22	5.2	1	1	700	215000	5	1	5.2
IRON	6.2	100	11000	300 [36]		1000			300						300 [46]		300 [47]		320 [48]
LEAD	0.78	3	15 [49]	15 [44]	65 [40]	2.5 [40]	210	8.1			120 [40]	14 [40]	240	9.3 [40]	15		50	5.1	3.2
MAGNESIUM	27	5000																	
MANGANESE	0.35	15	730 [50]	50 [36]					50	100					50 [46]		50 [47]	10	14500
MERCURY	0.2	0.20	11 [51]	2	1.4	0.77	1.8	0.94	0.05	0.051	2.4 [40]	0.012	2.1 [40]	0.025 [40]	0.052	0.053	0.05	0.025	0.012
NICKEL	1.2	40	730		470 [40]	52 [40]	74 [40]	8.2	610	4600	180 [40]	20 [40]	75	8	610	4600		8.3	160
POTASSIUM	62	5000																	
SELENIUM	3	5	180	50		5	290	71	170	11000	20	5	300	71	170	11000	10	35	5
SILVER	1.6	10	180	100 [36]	3.4 [40]		2				4.1 [40]		2					0.0001	0.0001
SODIUM	719	5000															270000		
THALLIUM	2	10	2.6	2					1.7	6.3								2130	40
VANADIUM	0.49	50	260															10000	10000
ZINC	3.8	20	11000	5000 [36]	120 [40]	120 [40]	90	81	5000 [12] [52]	69000	120 [40]	110 [40]	95	86	5000 [46]		50	19	30

APCL	Applied Physics and Chemistry Laboratory	CRQL	Contract Required Quantitation Level	PCBs	Polychlorinated biphenyls	TAL	Target Analyte List
AWQC	Ambient Water Quality Criteria	IDL	Instrument Detection Limit	RBC	Risk-Based Concentration	TCL	Target Compound List
BTAG	Biological Technical Assistance Group	MCL	Maximum Contaminant Level	RfD_o	Oral Reference Dose	VAC	Virginia Administrative Code
CLP	Contract Laboratory Program	MDL	Method Detection Limit	SDWA	Safe Drinking Water Act		
CRDL	Contract Required Detection Limit	NAT	Not available at this time	SOW	Statement of Work		

The MDL/IDL and specific criterion/standard are shaded if the MDL/IDL exceeds the criteria/standard.
Blank cells indicate criterion is not available.

1 MDLs are provided by APCL. For volatile organic compounds, the values for CLP SOW OLM03.2 are presented. MDLs for all chemicals (organics and inorganics) are in the process of being updated by APCL. The project-specific final documents will include revisions to these values.
2 USEPA Region III, 2000.
3 USEPA, 2000b.
4 USEPA, 1999a.
5 State surface water standards.
6 State groundwater standards.
7 USEPA Region III, 1995.
8 Trichloroethane.
9 Trichlorobenzene.
10 MCL for disinfection by-products (Federal Register, 1998).
11 Value is the total for trihalomethanes --- chloroform, bromodichloromethane, dibromochloromethane, and bromoform.
12 Value presented is based on organoleptic effects (i.e., which would make water and edible aquatic life unpalatable but not toxic to humans).
13 AWQC for the protection of human health, water, and organisms is 680 ug/L.
14 1,3-Dichloropropene.
15 Value presented is for lifetime exposure to vinyl chloride.
16 Value presented is for o- and m-/p-xylenes.
17 AWQC for the protection of human health, water, and organisms is 2,600 ug/L.
18 AWQC for the protection of human health, water, and organisms is 2.1 ug/L.
19 AWQC for the protection of human health, water, and organisms is 93 ug/L.
20 AWQC for the protection of human health, water, and organisms is 540 ug/L.
21 Dinitrophenol.
22 AWQC for the protection of human health, water, and organisms is 120 ug/L.
23 4-Nitrophenol.
24 Acenaphthene.
25 Naphthalene.
26 AWQC for the protection of human health, water, and organisms is 240 ug/L.
27 Value for organoleptic effects is 30 ug/L.
28 AWQC for the protection of human health, water, and organisms is 21,000 ug/L.
29 Hexachlorocyclohexane.
30 The standard/criteria/screening value for chlordane is presented.
31 Criterion is applicable if Aroclor-1016 only is present. If other Aroclors are present, an RBC for tap water of 0.033 ug/L applies to the mixture.
32 Total for all PCB congeners (Aroclors) is presented.
33 alpha-BHC.
34 Endosulfan.
35 Endrin.
36 Secondary MCL based on aesthetic drinking water qualities, such as color, odor, taste, etc. (i.e., which would make water and edible aquatic life unpalatable, but not toxic to humans).

TABLE 1-6

EXAMPLE ANALYTICAL DETECTION LIMITS VERSUS CRITERIA - AQUEOUS SAMPLE MATRIX (ug/L)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND
PAGE 4 OF 4

Chemical	Laboratory Detection Limits[1]		USEPA Region III Tapwater RBC [2]	Federal MCL [3]	Federal AWQC [4]						Maryland Water Quality Standard [5]						Virginia Groundwater Standard [6]	USEPA Region III BTAG Screening Levels [7]	
					Freshwater		Saltwater		Protection of Human Health						Protection of Human Health				
	MDL/IDL	CRQL/ CRDL			Acute	Chronic	Acute	Chronic	Water and Organisms	Organisms Only	Acute	Chronic	Acute	Chronic	Public Water	Surface Water		Saltwater	Freshwater

37 Trivalent arsenic.
38 Arsenic V.
39 The RBC for tapwater calculated using the RfD_o for water is presented. The RBC for tapwater calculated using the RfD_o for food is 37 ug/L.
40 Criteria are hardness dependent.
41 The RBC for tapwater for hexavalent chromium is presented. The RBC for tapwater for trivalent chromium is 55,000 ug/L.
42 Standard/criterion/screening value presented for total chromium.
43 Hexavalent chromium.
44 The MCL for this parameter is actually a treatment technique. The SDWA action level (at the tap) has been presented.
45 AWQC for the protection of human health, water, and organisms is 1,300 ug/L.
46 To maintain acceptable taste, odor, and aesthetic quality of drinking water.
47 Groundwater standard values for the Coastal Plain Physiographic Province are presented. Values vary according to Virginia provinces (Coastal Plain, Piedmont and Blue Ridge, Valley and Ridge, and Cumberland Plateau).
48 Value applies to invertebrates. A value of 900 ug/L applies to fish.
49 No RBC is available. The Action Level promulgated under the SDWA is typically used for screening purposes.
50 The RBC for tapwater calculated using the RfD_o for nonfood is presented. The RBC for tapwater calculated using the RfD_o for food is 5,100 ug/L.
51 Mercuric chloride.
52 AWQC for the protection of human health, water and organisms is 9,100 ug/L.

Table provided as an example only of analtyical detection limits versus criteria.
Analytical detection limits, criteria, standards, references, etc. are subject to change.

TABLE 1-7

EXAMPLE ANALYTICAL DETECTION LIMITS VERSUS CRITERIA
SOLID SAMPLE MATRIX (MG/KG)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	Laboratory Detection Limits [1]		USEPA Region III Soil RBC [2]		USEPA Generic SSL Inhalation [3]	USEPA Region III SSL Migration to Groundwater [2]		USEPA Region III BTAG Screening Levels [4]	
	MDL/IDL	CRQL/ CRDL	Industrial	Residential		DAF = 1	DAF = 20	Soil	Sediment
TCL Volatile Organic Compounds - CLP OLM04.2									
1,1,1-TRICHLOROETHANE	0.00034	0.01	570000	22000	1200	3	60	0.30 [5]	0.031 [5]
1,1,2,2-TETRACHLOROETHANE	**0.00041**	0.01	29	3.2	0.6	**0.000034**	0.00068		
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE	NAT	0.01	61000000	2300000		120	2300		
1,1,2-TRICHLOROETHANE	**0.00045**	0.01	100	11	1	**0.000039**	0.00078	0.30	0.031
1,1-DICHLOROETHANE	0.00022	0.01	200000	7800	1300	0.23	4.5	0.30	
1,1-DICHLOROETHENE	**0.00024**	0.01	9.5	1.1	0.07	**0.000018**	0.00036		
1,2,4-TRICHLOROBENZENE	0.04000	0.01	20000	780	3200	0.38	7.5	0.10	0.40
1,2-DIBROMO-3-CHLOROPROPANE	NAT	0.01	4.1	0.46		0.000044	0.00087		
1,2-DIBROMOETHANE	NAT	0.01	0.067	0.0075		0.00000043	0.0000085	5.0	
1,2-DICHLOROBENZENE	**0.045**	0.01	180000	7000	560	0.46	9.3	0.10	**0.035**
1,2-DICHLOROETHANE	**0.00084**	0.01	63	7	0.4	**0.000052**	0.0010	870	
1,2-DICHLOROPROPANE	**0.00033**	0.01	84	9.4	15	**0.00010**	0.0021	0.30	
1,3-DICHLOROBENZENE	**0.041**	0.01	1800	70		**0.0044**	0.087		
1,4-DICHLOROBENZENE	**0.037**	0.01	240	27		**0.00036**	**0.0071**	0.10	0.11
2-BUTANONE	0.0029	0.01	1200000	47000		0.40	7.9		
2-HEXANONE	0.0012	0.01	82000	3100					
4-METHYL-2-PENTANONE	NAT	0.01	160000	6300		0.065	1.3	100	
ACETONE	0.0029	0.01	200000	7800	100000	0.12	2.5		
BENZENE	**0.00014**	0.01	100	12	0.8	**0.00009**	0.0018	0.10	
BROMODICHLOROMETHANE	**0.00023**	0.01	92	10	3000	**0.000054**	0.0011	450	
BROMOFORM	0.00072	0.01	720	81	53	0.0033	0.067	1147	
BROMOMETHANE	0.0012	0.01	2900	110	10	0.0021	0.041		
CARBON DISULFIDE	0.00012	0.01	200000	7800	720	0.95	19		
CARBON TETRACHLORIDE	**0.00037**	0.01	44	4.9	0.3	**0.00011**	0.0021	0.30	
CHLOROBENZENE	0.00016	0.01	41000	1600	130	0.040	0.80	0.10	
CHLORODIBROMOMETHANE	**0.00053**	0.01	68	7.6	1300	**0.000041**	0.00083		
CHLOROETHANE	**0.0013**	0.01	2000	220		**0.00096**	0.019		
CHLOROFORM	**0.0002**	0.01	940	100	0.3	**0.000045**	0.00089	0.30	
CHLOROMETHANE	0.0004	0.01	440	49		0.00052	0.010		
CIS-1,2-DICHLOROETHENE	NAT	0.01	20000	780	1200	0.017	0.35	0.30	
CIS-1,3-DICHLOROPROPENE	**0.00018**	0.01	57 [6]	6.4 [6]	0.1	**0.00016 [6]**	0.0031 [6]	0.30 [6]	
CYCLOHEXANE	NAT	0.01							
DICHLORODIFLUOROMETHANE	NAT	0.01	410000	16000		0.55	11		
ETHYLBENZENE	0.00026	0.01	200000	7800	400	0.75	15	0.10	0.010
FLUOROTRICHLOROMETHANE	NAT	0.01	610000	23000		1.1	23		
ISOPROPYLBENZENE	NAT	0.01	200000	7800		3.2	64		
METHYL ACETATE	NAT	0.01	2000000	78000		1.2	25		
METHYL TERT-BUTYL ETHER	NAT	0.01				1.4	28		
METHYLCYCLOHEXANE	NAT	0.01							
METHYLENE CHLORIDE	**0.002**	0.01	760	85	13	**0.00095**	0.019	0.30	
STYRENE	0.00031	0.01	410000	16000	1500	2.9	57	0.10	
TETRACHLOROETHENE	0.000072	0.01	110	12	11	0.0024	0.048	0.30	0.057
TOLUENE	0.0002	0.01	410000	16000	650	0.44	8.8	0.10	
TCL Volatile Organic Compounds - CLP OLM04.2 (Continued)									
TRANS-1,2-DICHLOROETHENE	0.00026	0.01	41000	1600	3100	0.041	0.82	0.30	
TRANS-1,3-DICHLOROPROPENE	**0.00022**	0.01	57 [6]	6.4 [6]	0.1	**0.00016 [6]**	0.0031 [6]	0.30 [6]	

TABLE 1-7

EXAMPLE ANALYTICAL DETECTION LIMITS VERSUS CRITERIA
SOLID SAMPLE MATRIX (MG/KG)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	Laboratory Detection Limits [1]		USEPA Region III Soil RBC [2]		USEPA Generic SSL Inhalation [3]	USEPA Region III SSL Migration to Groundwater [2]		USEPA Region III BTAG Screening Levels [4]	
	MDL/IDL	CRQL/ CRDL	Industrial	Residential		DAF = 1	DAF = 20	Soil	Sediment
TRICHLOROETHENE	0.00024	0.01	520	58	5	0.00077	0.015	0.30	
VINYL CHLORIDE	**0.00026**	0.01	3.8 [7]	0.43 [7]	0.03	**0.000017** [7]	0.00033 [7]	0.30	
XYLENES, TOTAL	0.00035 / 0.00045 [8]	0.01	4100000	160000	410	8.5	170	0.10	0.040
TCL Semivolatile Organic Compounds - CLP OLM03.2									
2,2'-OXYBIS(1-CHLOROPROPANE)	**0.051**	0.33	82	9.1		**0.000084**	**0.0017**		
2,4,5-TRICHLOROPHENOL	0.081	0.83	200000	7800				0.10	
2,4,6-TRICHLOROPHENOL	0.063	0.33	520	58	200	/KG		0.10	
2,4-DICHLOROPHENOL	0.059	0.33	6100	230		0.060	1.2	0.10	
2,4-DIMETHYLPHENOL	**0.07**	0.33	41000	1600		0.34	6.7	0.10	**0.029**
2,4-DINITROPHENOL	**0.283**	0.83	4100	160				**0.10** [9]	
2,4-DINITROTOLUENE	**0.05**	0.33	4100	160		**0.029**	0.57		
2,6-DINITROTOLUENE	**0.072**	0.33	2000	78		**0.012**	0.25		
2-CHLORONAPHTHALENE	0.07	0.33	160000	6300		1.6	32		
2-CHLOROPHENOL	0.04	0.33	10000	390	53000	/KG			
2-METHYLNAPHTHALENE	**0.073**	0.33	41000	1600		1.1	22		**0.070**
2-METHYLPHENOL	0.063	0.33	100000	3900				0.10	0.063
2-NITROANILINE	0.249	0.83							
2-NITROPHENOL	0.058	0.33	16000 [10]	630 [10]		0.087 [10]	1.7 [10]		
3,3'-DICHLOROBENZIDINE	**0.297**	0.33	13	1.4		**0.00025**	**0.0049**		
3-NITROANILINE	0.489	0.83							
4,6-DINITRO-2-METHYLPHENOL	0.12	0.33							
4-BROMOPHENYL PHENYL ETHER	0.046	0.33							
4-CHLORO-3-METHYLPHENOL	0.074	0.33							
4-CHLOROANILINE	**0.673**	0.33	8200	310		**0.048**	0.97		
4-CHLOROPHENYL PHENYL ETHER	0.063	0.33							
4-METHYLPHENOL	0.077	0.33	10000	390				0.10	0.67
4-NITROANILINE	0.523	0.83							
4-NITROPHENOL	**0.213**	0.83	16000	630		**0.087**	1.7	**0.10**	
ACENAPHTHENE	**0.074**	0.33	120000	4700		5.2	100	0.10	**0.016**
ACENAPHTHYLENE	**0.072**	0.33	120000 [11]	4700 [11]		5.2 [11]	100 [11]	0.10	**0.044**
ANTHRACENE	0.072	0.33	610000	23000		23	470	0.10	0.085
BENZO(A)ANTHRACENE	**0.099**	0.33	7.8	0.87		**0.073**	1.5	0.10	0.26
BENZO(A)PYRENE	**0.068**	0.33	0.78	0.087		**0.019**	0.37	0.10	0.43
BENZO(B)FLUORANTHENE	0.072	0.33	7.8	0.87					
BENZO(G,H,I)PERYLENE	**0.077**	0.33	41000 [12]	1600 [12]		**0.0077** [12]	0.15 [12]	0.10	0.67
BENZO(K)FLUORANTHENE	0.076	0.33	78	8.7		2.3	45	0.10	
BIS(2-CHLOROETHOXY)METHANE	0.086	0.33							
BIS(2-CHLOROETHYL)ETHER	**0.053**	0.33	5.2	0.58	0.2	**0.0000022**	**0.000044**		
BIS(2-ETHYLHEXYL) PHTHALATE	0.109	0.33	410	46	31000	140	2900		1.3
CARBAZOLE	**0.73**	0.33	290	32		**0.023**	**0.47**		
CHRYSENE	0.09	0.33	780	87		7.3	150	0.10	0.38
DI-N-BUTYL PHTHALATE	0.112	0.33	200000	7800	2300	250	5000		1.4
DI-N-OCTYL PHTHALATE	0.088	0.33	41000	1600	10000	120000	2400000		6.2
DIBENZO(A,H)ANTHRACENE	**0.098**	0.33	0.78	**0.087**		**0.070**	1.4	0.10	**0.063**
DIBENZOFURAN	0.058	0.33	8200	310		0.38	7.7		0.54
DIETHYL PHTHALATE	0.067	0.33	1600000	63000	2000	23	450		0.20

TABLE 1-7

EXAMPLE ANALYTICAL DETECTION LIMITS VERSUS CRITERIA
SOLID SAMPLE MATRIX (MG/KG)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	Laboratory Detection Limits [1]		USEPA Region III Soil RBC [2]		USEPA Generic SSL Inhalation [3]	USEPA Region III SSL Migration to Groundwater [2]		USEPA Region III BTAG Screening Levels [4]	
	MDL/IDL	CRQL/ CRDL	Industrial	Residential		DAF = 1	DAF = 20	Soil	Sediment
TCL Semivolatile Organic Compounds - CLP OLM03.2 (Continued)									
DIMETHYL PHTHALATE	0.053	0.33	20000000	780000					0.071
FLUORANTHENE	0.075	0.33	82000	3100		310	6300	0.10	0.60
FLUORENE	**0.057**	0.33	82000	3100		6.8	140	0.10	**0.019**
HEXACHLOROBENZENE	**0.52**	0.33	3.6	**0.4**	1	**0.0026**	**0.052**		**0.022**
HEXACHLOROBUTADIENE	**0.04**	0.33	73	8.2	8	0.092	1.8		**0.011**
HEXACHLOROCYCLOPENTADIENE	0.454	0.33	14000	550	10	100	2000		
HEXACHLOROETHANE	**0.037**	0.33	410	46	55	**0.018**	0.36		
INDENO(1,2,3-CD)PYRENE	**0.106**	0.33	7.8	0.87		0.64	13	**0.10**	0.60
ISOPHORONE	0.106	0.33	6000	670	4600	0.021	0.41		
N-NITROSO-DI-N-PROPYLAMINE	**0.098**	0.33	0.82	**0.091**		**0.0000024**	**0.000047**		
N-NITROSODIPHENYLAMINE	**0.423**	0.33	1200	130		**0.038**	0.76		**0.028**
NAPHTHALENE	**0.052**	0.33	41000	1600		**0.0077**	0.15	0.10	0.16
NITROBENZENE	**0.062**	0.33	1000	39	92	**0.0012**	**0.023**		
PENTACHLOROPHENOL	**0.259**	0.83	48	5.3				**0.10**	0.36
PHENANTHRENE	**0.056**	0.33	41000 [12]	1600 [12]		**0.0077 [12]**	0.15 [12]	0.10	0.24
PHENOL	0.064	0.33	1200000	47000		6.7	130	0.10	0.42
PYRENE	0.089	0.33	61000	2300		34	680	0.10	0.67
TCL Pesticides/PCBs - CLP OLM03.2									
4,4'-DDD	0.0018	0.0033	24	2.7		0.56	11	0.10	0.016
4,4'-DDE	0.000042	0.0033	17	1.9		1.8	35	0.10	0.0022
4,4'-DDT	**0.0018**	0.0033	17	1.9		0.058	1.2	0.10	**0.0016**
ALDRIN	0.000084	0.0017	0.34	0.038	3	0.00038	0.0077	0.10	
ALPHA-BHC	**0.000047**	0.0017	0.91	0.1	0.8	**0.000045**	0.00089	100 [13]	
ALPHA-CHLORDANE	0.000025	0.0017	16 [14]	1.8 [14]	20 [14]	0.046 [14]	0.92 [14]	0.10 [14]	
AROCLOR-1016	0.016	0.033	82 [15] [16]	5.5 [15] [17]		0.21 [18]	4.2 [19]	0.10 [15]	0.023 [15]
AROCLOR-1221	0.0076	0.067	2.9 [15]	0.32 [15]		0.21 [15]	0.41 [15]	0.10 [15]	0.023 [15]
AROCLOR-1232	0.0062	0.033	2.9 [15]	0.32 [15]		0.21 [15]	0.41 [15]	0.10 [15]	0.023 [15]
AROCLOR-1242	0.001	0.033	2.9 [15]	0.32 [15]		0.21 [15]	0.41 [15]	0.10 [15]	0.023 [15]
AROCLOR-1248	0.0039	0.033	2.9 [15]	0.32 [15]		0.21 [15]	0.41 [15]	0.10 [15]	0.023 [15]
AROCLOR-1254	0.0027	0.033	2.9 [15]	0.32 [15]		0.054 [20]	1.1 [21]	0.10 [15]	0.023 [15]
AROCLOR-1260	0.0086	0.033	2.9 [15]	0.32 [15]		0.021 [15]	0.41 [15]	0.10 [15]	0.023 [15]
BETA-BHC	0.00007	0.0017	3.2	0.35		0.00016	0.0031	100 [13]	
DELTA-BHC	**0.0002**	0.0017	0.91 [22]	0.1 [22]	0.8 [22]	**0.000045 [22]**	0.00089 [22]		
DIELDRIN	0.000042	0.0033	0.36	0.04	1	0.00011	0.0022	0.10	
ENDOSULFAN I	0.00016	0.0017	12000 [23]	470 [23]		0.98 [23]	20 [23]		
ENDOSULFAN II	0.000053	0.0033	12000 [23]	470 [23]		0.98 [23]	20 [23]		
ENDOSULFAN SULFATE	0.000056	0.0033	12000 [23]	470 [23]		0.98 [23]	20 [23]		
ENDRIN	0.000056	0.0033	610	23		0.27	5.4	0.10	
ENDRIN ALDEHYDE	0.000059	0.0033	610 [24]	23 [24]		0.27 [24]	5.4 [24]		
ENDRIN KETONE	0.00015	0.0033	610 [24]	23 [24]		0.27 [24]	5.4 [24]		
GAMMA-BHC (LINDANE)	0.00004	0.0017	4.4	0.49		0.00022	0.0043	0.10	
GAMMA-CHLORDANE	0.0001	0.0017	16 [14]	1.8 [14]	20 [14]	0.046 [14]	0.92 [14]	0.10 [14]	
HEPTACHLOR	0.00013	0.0017	1.3	0.14	4	0.042	0.84		
HEPTACHLOR EPOXIDE	0.000049	0.0017	0.63	0.07	5	0.0012	0.025	0.10	

TABLE 1-7

EXAMPLE ANALYTICAL DETECTION LIMITS VERSUS CRITERIA
SOLID SAMPLE MATRIX (MG/KG)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	Laboratory Detection Limits [1]		USEPA Region III Soil RBC [2]		USEPA Generic SSL Inhalation [3]	USEPA Region III SSL Migration to Groundwater [2]		USEPA Region III BTAG Screening Levels [4]	
	MDL/IDL	CRQL/ CRDL	Industrial	Residential		DAF = 1	DAF = 20	Soil	Sediment
TCL Pesticides/PCBs - CLP OLM03.2 (Continued)									
METHOXYCHLOR	0.00025	0.017	10000	390		15	310	0.10	
TOXAPHENE	0.014	0.17	5.2	0.58	89	0.031	0.63		
TAL Metals (plus Cyanide) - CLP ILM04.1									
ALUMINUM	0.42	40	2000000	78000				1.0	
ANTIMONY	0.11	4	820	31		0.66	13	0.48	150
ARSENIC	**0.099**	2	3.8	0.43	750	**0.0013**	**0.026**	328	8.2
BARIUM	0.057	40	140000	5500	690000	110	2100	440	
BERYLLIUM	0.003	1	4100	160	1300	58	1200	0.02	
CADMIUM	0.015	1	2000 [25]	78 [26]	1800	2.7 [27]	55 [28]	2.5	1.2
CALCIUM	4.8	1000							
CHROMIUM (TOTAL)	**0.036**	2	6100 [29]	230 [30]	270	2.1 [31]	42 [32]	**0.0075**	81 [33]
COBALT	0.022	10	120000	4700				100	
COPPER	0.039	5	82000	3100		530	11000	15	34
CYANIDE	**0.94**	1	41000	1600		7.4	150	**0.0050**	
IRON	1.4	20	610000	23000				12	
LEAD	**0.12**	1	750 [34]	400 [35]				**0.010**	46.7
MAGNESIUM	1.2	1000						4400	
MANGANESE	0.02	3	41000 [36]	1600 [37]		48 [38]	950 [39]	330	
MERCURY	0.03	0.03	0.31 [40]	23 [40]	10	/KG		0.058	0.15
NICKEL	0.02	8	41000	1600	13000	/KG		2.0	20.9
POTASSIUM	2.1	1000							
SELENIUM	0.17	1	10000	390		0.95	19	1.8	
SILVER	**0.08**	2	10000	390		1.6	31	**0.000010**	1.0
SODIUM	70	1000							
THALLIUM	**0.074**	2	140	5.5		0.18	3.6	**0.0010**	
VANADIUM	0.035	10	14000	550		260	5100	0.50	
ZINC	0.16	4	610000	23000		680	14000	10.0	150

APCL	Applied Physics and Chemistry Laboratory	IDL	Instrument Detection Limit	RfD_o	Oral Reference Dose
BTAG	Biological Technical Assistance Group	MDL	Method Detection Limit	SSL	Soil Screening Level
CLP	Contract Laboratory Program	NAT	Not available at this time	TAL	Target Analyte List
CRDL	Contract Required Detection Limit	OSWER	Office of Solid Waste and Emergency Response	TCL	Target Compound List
CRQL	Contract Required Quantitation Level	PCBs	Polychlorinated biphenyls		
DAF	Dilution Attenuation Factor	RBC	Risk-Based Concentration		

The MDL/IDL and specific criterion/standard are shaded if the MDL/IDL exceeds the criterion/standard.
Blank cells indicate criterion is not available.

1 MDLs are provided by APCL. For volatile organic compounds, the values for CLP OLM03.2 are presented. MDLs for all chemicals (organics and inorganics) are in the process of being updated by APCL. The project-specific documents will include revisions to these values.
2 USEPA, Region III, 2000.
3 USEPA, 1996a.
4 USEPA Region III, 1995.
5 Trichloroethane.
6 1,3-Dichloropropene.
7 Value represented if for lifetime exposure to vinyl chloride.

TABLE 1-7

EXAMPLE ANALYTICAL DETECTION LIMITS VERSUS CRITERIA
SOLID SAMPLE MATRIX (MG/KG)
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Chemical	Laboratory Detection Limits [1]		USEPA Region III Soil RBC [2]		USEPA Generic SSL Inhalation [3]	USEPA Region III SSL Migration to Groundwater [2]		USEPA Region III BTAG Screening Levels [4]	
	MDL/IDL	CRQL/ CRDL	Industrial	Residential		DAF = 1	DAF = 20	Soil	Sediment

8 Values presented are for o- and m-/p-xylenes.
9 Dinitrophenol.
10 4-Nitrophenol.
11 Acenaphthene.
12 Naphthalene.
13 Hexachlorocyclohexane.
14 The standard/criterion/screening value for chlordane is presented.
15 Total for all PCB congeners (Aroclors) is presented.
16 Criterion is applicable if Aroclor-1016 only is present. If other Aroclors are present, an RBC for industrial land use of 2.9 mg/kg applies to the mixture.
17 Criterion is applicable if Aroclor-1016 only is present. If other Aroclors are present, an RBC for residential land use of 0.32 mg/kg applies to the mixture.
18 Criterion is applicable if Aroclor-1016 only is present. If other Aroclors are present, an SSL of 0.021 mg/kg applies to the mixture.
19 Criterion is applicable if Aroclor-1016 only is present. If other Aroclors are present, an SSL of 0.41 mg/kg applies to the mixture.
20 Criterion is applicable if Aroclor-1254 only is present. If other Aroclors are present, an SSL of 0.021 mg/kg applies to the mixture.
21 Criterion is applicable if Aroclor-1254 only is present. If other Aroclors are present, an SSL of 0.41 mg/kg applies to the mixture.
22 alpha-BHC.
23 Endosulfan.
24 Endrin.
25 The RBC for industrial land use calculated using the RfDo for food is presented. The RBC for industrial land use calculated using the RfDo for water is 1000 mg/kg.
26 The RBC for residential land use calculated using the RfDo for food is presented. The RBC for residential land use calculated using the RfDo for water is 39 mg/kg.
27 Value presented is the cadmium SSL (DAF = 1) for food. The SSL value for water (DAF = 1) is 1.4 mg/kg.
28 Value presented is the cadmium SSL (DAF = 20) for food. The SSL value for water (DAF = 20) is 27 mg/kg.
29 The RBC for industrial land use for hexavalent chromium is presented. The RBC for industrial land use for trivalent chromium is 3,100,000 mg/kg.
30 The RBC for residential land use for hexavalent chromium is presented. The RBC for residential land use for trivalent chromium is 120,000 mg/kg.
31 Value presented is the SSL (DAF = 1) for hexavalent chromium. The SSL value for trivalent chromium (DAF = 1) is 99,000,000 mg/kg.
32 Value presented is the SSL (DAF = 20) for hexavalent chromium. The SSL value for trivalent chromium (DAF = 20) is 2,000,000,000 mg/kg.
33 Hexavalent chromium.
34 Recommended soil screening level for industrial land use. Value was developed using the USEPA Technical Review Workgroup adult exposure to lead model (USEPA, 1996b).
35 OSWER soil screening level for residential land use (USEPA, 1994c). Value was developed using the USEPA Integrated Exposure Uptake Biokinetic Model (USEPA, 1994a).
36 The RBC for industrial land use calculated using the RfD_o for nonfood is presented. The RBC for industrial land use calculated using the RfD_o for food is 290,000 mg/kg.
37 The RBC for residential land use calculated using the RfD_o for nonfood is presented. The RBC for residential land use calculated using the RfD_o for food is 11,000 mg/kg.
38 Value presented is the manganese SSL (DAF = 1) for nonfood. The SSL value for food (DAF = 1) is 330 mg/kg.
39 Value presented is the manganese SSL (DAF = 20) for nonfood. The SSL value for food (DAF = 20) is 6,700 mg/kg.
40 Mercuric chloride.

Table provided as an example only of analytical detection limits versus criteria.
Analytical detection limits, criteria, standards, references, etc. are subject to change.

2.0 PROJECT ORGANIZATION

The project organization for field activities will be project-specific. Therefore, the project organization will be provided in project-specific WPs (typically in Section 1.3). Personnel expected to be involved with the activities at a programmatic level for the foreseeable future include the Navy Remedial Project Manager, the Facility Point of Contact, and the contractor's Program Manager, Project Manager, and Quality Assurance Manager (QAM). Navy personnel are as follows:

Mr. Jeffrey W. Morris (C21EC)
Engineering Field Activity Chesapeake
Naval Facilities Engineering Command
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(202) 685-3279
(202) 433-6193 (FAX)

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(301) 744-4180 (FAX)
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The TtNUS Program Manager and QAM for projects performed by TtNUS are as follows:

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(412) 921-4040 (FAX)
carperk@ttnus.com

Additional key project personnel shall be identified in project-specific WPs.

3.0 QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT DATA

The overall QA objective is to develop and implement procedures for field sampling, chain-of-custody, laboratory analysis, and reporting that will provide results achieving the objectives of the planned work as well as establishing a data set that is legally defensible in a court of law. Specific procedures for sampling, chain-of-custody, laboratory instrument calibration, laboratory analysis, reporting of data, internal quality control (QC), audits, preventive maintenance of field equipment, and corrective action are described in other sections of this Master QAPP.

The PARCC parameters (precision, accuracy, representativeness, comparability, and completeness) are qualitative and/or quantitative statements regarding the quality characteristics of the data used to support project objectives and ultimately, environmental decisions. These parameters are discussed in the remainder of this section. Specific routine procedures used to assess the quantitative parameters (precision, accuracy, and completeness) are provided in Section 12.0.

3.1 PRECISION

3.1.1 Definition

Precision is a measure of the amount of variability and bias inherent in a data set. Precision describes the reproducibility of measurements of the same parameter for samples under similar conditions. The equation for determining precision is provided in Section 12.2.

3.1.2 Field Precision Objectives

Field duplicate precision monitors the consistency with which environmental samples were obtained and analyzed. Field duplicate results for solid matrix samples are considered to be precise if the relative percent difference (RPD) is less than or equal to 50 percent. Field duplicate results for aqueous matrix samples are considered to be precise if the RPD is less than or equal to 30 percent. Field precision is assessed through the collection and measurement of field duplicates at a rate of one duplicate per 10 environmental samples or one duplicate per sampling day per matrix, whichever is greater.

3.1.3 Laboratory Precision Objectives

Laboratory precision QC samples are analyzed at a frequency of 5 percent (i.e., one QC sample per 20 environmental samples). Laboratory precision is measured via comparison of calculated RPD values and precision control limits specified in the analytical method or by the laboratory's QA/QC program.

Three distinct types of analyses will typically be completed for environmental samples collected during investigation activities at the Facility, as follows:

- TCL organic analyses via OLM04.2 or OLC03.2
- TAL inorganic/cyanide analysis via ILM04.1 or ILM05.2
- Explosives analysis via SW-846 Method 8330

Precision for TCL organic analysis will be measured via the RPDs for matrix spike (MS)/matrix spike duplicate (MSD) samples. Precision for TAL inorganic analysis will be measured via RPDs for laboratory duplicates. Tables 3-1 and 3-2 present RPD precision control limits for the major categories of analysis. Precision requirements for explosives and perchlorate analysis will be measured via the RPDs for MS/MSD samples, which should be statistically derived at the laboratory. These limits will be provided in each analytical data package. In the event that project-specific requirements dictate the use of additional (or alternate) analytical methods, specific precision objectives will be provided in addenda to this Master QAPP (i.e., project-specific WP).

3.2 ACCURACY

3.2.1 Definition

Accuracy is the degree of agreement between an observed value and an accepted reference value. The equation for determining accuracy is provided in Section 12.1.

3.2.2 Field Accuracy Objectives

Accuracy in the field is assessed through the use of field, equipment, and trip blanks and is ensured through the adherence to all sample handling, preservation, and holding times requirements. Accuracy and precision requirements for field measurements (e.g., pH) are ensured through calibration as discussed in Section 6.0.

3.2.3 Laboratory Accuracy Objectives

Accuracy in the laboratory is measured through the comparison of a spiked sample result to a known or calculated value expressed as a percent recovery (%R). Percent recoveries are derived from the analysis of known amounts of compounds spiked into deionized water [i.e., laboratory control sample (LCS) analysis], or into actual samples (i.e., surrogate or MS analysis). These analyses measure the accuracy of laboratory operations as affected by matrix. LCS and/or MS analyses are performed with a frequency of one per 20 associated samples of like matrix. Surrogate spike analysis is performed for all

organic analyses. Laboratory accuracy is assessed via comparison of calculated %R values with accuracy control limits specified in the analytical method or by the laboratory's QA/QC program.

Accuracy for TCL organic and explosives analyses will be measured via the %Rs for surrogate spikes and MS/MSDs. Accuracy for TAL inorganic analysis will be measured via %Rs for MSs and LCSs. Tables 3-3 and 3-4 present control limits for LCSs and surrogate spike recoveries, respectively, for low concentration TCL organics. Tables 3-5 and 3-6 present control limits for MS and surrogate spike samples, respectively, for multi-media, multi-concentration TCL organics. Tables 3-7 and 3-8 present control limits for MSs and LCSs, respectively, for TAL inorganics. QC limits for matrix and surrogate spike recoveries in explosives and perchlorate analyses are statistically derived by the laboratory and will be provided in each analytical data package. In the event that additional (or alternate) analytical methods are required on a project-specific basis, specific accuracy objectives will be provided in addenda to this Master QAPP (i.e., project-specific WP).

3.3 COMPLETENESS

3.3.1 Definition

Completeness is a measure of the amount of usable, valid, analytical data obtained compared to the amount expected to be obtained. Completeness is typically expressed as a percentage.

The ideal objective for completeness is 100 percent (i.e., every sample planned to be collected is collected; every sample submitted for analysis yields valid data). However, samples can be rendered unusable during shipping or preparation (e.g., bottles broken or extracts accidentally destroyed), errors can be introduced during analysis (e.g., loss of instrument sensitivity, introduction of ambient laboratory contamination), or strong matrix effects can become apparent (e.g., extremely low MS recovery). These instances result in data that do not meet QC criteria. Based on these considerations, 95 percent is considered an acceptable target for the data completeness objective. If critical data points are lost, resampling and/or reanalysis may be required.

One hundred percent of the CLP data for the field activities shall be validated in accordance with the USEPA National Functional Guidelines for Organic and Inorganic Data Review as modified for use in USEPA Region III, (USEPA, 1993 and USEPA, 1994) unless dictated otherwise by project-specific DQOs. If additional non-CLP (e.g., explosives and perchlorate) analyses are required, 100 percent of non-CLP data will be validated (pursuant to DQOs) in accordance with analytical method-specific requirements and the USEPA National Functional Guidelines for Organic and Inorganic Data Review as modified for use in USEPA Region III to the extent practicable. Data rejected as a result of the validation process will be treated as incomplete data.

3.3.2 Field Completeness Objectives

Field completeness is a measure of the amount of valid field measurements obtained from all the field measurements taken in the project. The equation for completeness is presented in Section 12.3. Field data completeness is expected to be 95 percent.

3.3.3 Laboratory Completeness Objectives

Laboratory completeness is a measure of the amount of valid laboratory measurements obtained from all the laboratory measurements made in support of a given project. The equation for completeness is presented in Section 12.3. Laboratory completeness is expected to be at least 95 percent.

3.4 REPRESENTATIVENESS

3.4.1 Definition

Representativeness is an expression of the degree to which the data accurately and precisely depict the actual characteristics of a population or environmental condition existing at an individual sampling point. Use of standardized sampling, handling, analytical, and reporting procedures ensures that the final data accurately represent actual site conditions.

3.4.2 Measures to Ensure Representativeness of Field Data

Representativeness is dependent on the proper design of the sampling program and will be satisfied by ensuring that the project-specific WPs are followed and that proper sampling techniques are used.

3.4.3 Measures to Ensure Representativeness of Laboratory Data

Representativeness in the laboratory is ensured by using the proper analytical procedures, meeting sample holding times, and analysis of field duplicate samples.

3.5 COMPARABILITY

3.5.1 Definition

Comparability is defined as the confidence with which one data set can be compared to another (e.g., between sampling points; between sampling events). Comparability is achieved by using standardized sampling and analysis methods and data reporting formats (including use of consistent units of measure

and reporting of solid matrix sample results on a dry-weight basis). Additionally, consideration is given to seasonal conditions and other environmental variations that could exist to influence data results.

3.5.2 Measures to Ensure Comparability of Field Data

Comparability is dependent on the proper design of the sampling program and will be satisfied by ensuring that the project-specific WPs are followed and that proper sampling techniques are used. It is also dependent on recording field measurements using the correct units. Field measurements may include pH, specific conductance, temperature, turbidity, and DO. The units used for these field measurements are as follows:

- pH is measured to the nearest 0.1 standard pH unit.
- Specific conductance is measured in μmhos (the inverse of the ohm).
- Temperature is measured in degrees Celsius.
- Turbidity is measured in nephelometric turbidity units (NTUs).
- DO is measured in mg/L.

3.5.3 Measures to Ensure Comparability of Laboratory Data

Analytical data will be comparable when similar sampling and analytical methods are used and documented. Results will be reported in units that ensure comparability with previous data and with current State and federal standards and guidelines. Organic chemicals will be reported in µg/L for aqueous samples and µg/kg for solid samples, except for explosives, for which solid results will be reported in mg/kg. Metals and cyanide will be reported as µg/L for aqueous samples and mg/kg for solid samples. Detection/reporting limits are discussed in Sections 7.2 and 1.3.2 of this Master QAPP.

3.6 LEVEL OF QUALITY CONTROL EFFORT

Trip blank, equipment blank, field blank, field duplicate, standard reference materials, and MS samples will be analyzed to assess the quality of the data resulting from the field sampling and analytical programs. In addition, duplicate field measurements will be completed for temperature, DO, pH, specific conductance, and turbidity, as applicable.

External QC samples (i.e., field QC samples) consist of field duplicates, field blanks, trip blanks, and equipment (rinsate) blanks. Each of these types of field QC samples undergo the same preservation, analysis, and reporting procedures as the related environmental samples. Each type of field QC sample is discussed below. Internal field QC checks are discussed in Section 8.2 of this Master QAPP. A

summary of the types and frequencies of QC checks (both internal and external) is presented in Table 3-9.

Field duplicates are either two samples collected independently at a sampling location (e.g., surface water) or a single sample homogenized and split into two portions. Where VOCs are to be analyzed, the VOC sample aliquots are containerized first to avoid loss of constituents, then the remaining sample matrix is homogenized. Field duplicates are collected and analyzed for chemical constituents to measure the precision of the sampling and analysis methods employed. The general level of the QC effort will be one field duplicate for every 10 or fewer investigative samples or one duplicate per matrix per sampling day, whichever is greater.

Trip blanks and field blanks (ambient condition blanks), consisting of distilled water, will be submitted to the laboratories to provide the means to assess the quality of the data resulting from the field sampling program. Field blank samples are analyzed to check for background contamination at the Facility (e.g., vapors or exhaust fumes) that may cause sample contamination. Field blanks will be collected based on conditions at the time of sampling at the discretion of the Field Operations Leader (FOL), with a minimum of one field blank being collected per individual contiguous area of potential concern. Trip blanks pertain to VOCs only. Trip blanks are used to assess the potential for contamination with VOCs resulting from contaminant migration into sample bottles/jars during sample shipment and storage. Trip blanks are prepared by the laboratory prior to the sampling event, shipped to the site with the sample containers, and kept with the investigative samples throughout the sampling event. They are then packaged for shipment with other VOC samples and sent for analysis. There should be one trip blank included in each sample shipping container that contains VOCs. At no time after trip blank preparation are the trip blank sample containers opened before they reach the laboratory.

Equipment (rinsate) blanks are obtained under representative field conditions by collecting the rinse water generated by running analyte-free water through sample collection equipment after decontamination and prior to use. One rinsate blank will be collected per each type of sampling equipment used (i.e., bailer, split-barreled sampler, hand tools, etc.) per day that sampling is conducted at a minimum frequency of 10 percent. A sampling event is matrix specific; therefore, an equipment blank must be collected for each matrix sampled. If pre-cleaned, dedicated, or disposable sampling equipment is used, one rinsate blank must be collected as a "batch blank." Rinsate blanks are analyzed for the same chemical constituents as the associated environmental samples.

MS/MSD samples are investigative samples. Soil MS/MSD samples require no extra volume for VOCs or extractable organics. However, aqueous MS/MSD samples must be collected at triple the volume for

VOCs and double the volume for extractable organics. One MS/MSD sample will be collected/designated for every 20 or fewer investigative samples per sample matrix (i.e., groundwater, soil).

The level of QC effort provided by the contracted laboratories will be equivalent to the level of QC effort specified under the CLP SOW being utilized for analysis. The level of QC effort for testing of TCL organics [volatiles, semivolatiles, pesticides/polychlorinated biphenyls (PCBs)] will conform to CLP SOW OLM04.2 or OLC03.2. The level of QC effort for testing of inorganics (metals and cyanide) will conform to the CLP SOW ILM04.1 or ILM05.2. The level of QC effort for testing of explosive compounds and perchlorate will conform to those listed in the analytical method (i.e., SW-846 Method 8330, 8321A, or EPA 314).

TABLE 3-1

PRECISION CONTROL LIMITS - MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES
ORGANIC ANALYSIS(1)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	RPD(2)	
	Aqueous Samples	Solid Samples
Volatile Organics		
1,1-Dichloroethene	14	22
Trichloroethene	14	24
Benzene	11	21
Toluene	13	21
Chlorobenzene	13	21
Semivolatile Organics		
Phenol	42	35
2-Chlorophenol	40	50
N-Nitroso-di-n-propylamine	38	38
4-Chloro-3-methylphenol	42	33
Acenaphthene	31	19
4-Nitrophenol	50	50
2,4-Dinitrotoluene	38	47
Pentachlorophenol	50	47
Pyrene	31	36
Pesticides/PCBs		
gamma-BHC (Lindane)	15	50
Heptachlor	20	31
Aldrin	22	43
Dieldrin	18	38
Endrin	21	45
4,4'-DDT	27	50

1 USEPA, 1999. Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration, OLM04.2. and USEPA, 2001b. Superfund Analytical Methods for Low Concentration Water for Organics Analysis, OLC03.2.

2 RPD - Relative Percent Difference as described in Section 12.0.

TABLE 3-2

PRECISION CONTROL LIMITS - LABORATORY DUPLICATE SAMPLES
INORGANIC ANALYSIS(1)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	RPD(2)	
	Aqueous Samples(3)	Solid Samples(4)
Aluminum	20	35
Antimony	20	35
Arsenic	20	35
Barium	20	35
Beryllium	20	35
Cadmium	20	35
Calcium	20	35
Chromium (total)	20	35
Cobalt	20	35
Copper	20	35
Iron	20	35
Lead	20	35
Magnesium	20	35
Manganese	20	35
Mercury	20	35
Nickel	20	35
Potassium	20	35
Selenium	20	35
Silver	20	35
Sodium	20	35
Thallium	20	35
Vanadium	20	35
Zinc	20	35
Cyanide	20	35

1 RPD - Relative Percent Difference as described in Section 12.0.
2 USEPA, 2001. Statement of Work for Inorganic Analysis, Multi-Media, Multi-Concentration, ILM05.2 or USEPA 2000. Statement of Work for Inorganics Analysis, Multi-Media, Multi-Concentration, ILM04.
3 For aqueous sample results less than 5 times the CRDL, a control limit of ±CRDL is used.
4 For solid sample results less than 5 times the CRDL, a control limit of ±2 times the CRDL is used.

TABLE 3-3

ACCURACY CONTROL LIMITS - LABORATORY CONTROL SAMPLES
LOW CONCENTRATION ORGANIC ANALYSIS(1)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	%R(2) - Aqueous Samples
Volatile Organics	
Vinyl chloride	60-140
1,2-Dichloroethane	60-140
Carbon tetrachloride	60-140
1,2-Dichloropropane	60-140
Trichloroethene	60-140
1,1,2-Trichloroethane	60-140
Benzene	60-140
cis-1,3-Dichloropropene	60-140
Bromoform	60-140
Tetrachloroethene	60-140
1,2-Dibromoethane	60-140
1,4-Dichlorobenzene	60-140
Semivolatile Organics	
Phenol	44-120
2-Chlorophenol	58-110
4-Chloroaniline	35-98
2,4,6-Trichlorophenol	65-110
bis(2-Chloroethyl)ether	64-110
N-Nitroso-di-n-propylamine	34-102
Hexachloroethane	32-77
Isophorone	49-110
1,2,4-Trichlorobenzene	44-96
Naphthalene	56-160
2,4-Dinitrotoluene	61-140
Diethylphthalate	76-104
N-Nitrosodiphenylamine	35-120
Hexachlorobenzene	30-95
Benzo(a)pyrene	55-92
Pesticides/Polychlorinated Biphenyls	
gamma-BHC (Lindane)	56-123
Heptachlor epoxide	74-150
Dieldrin	33-150
4,4'-DDE	50-150

TABLE 3-3

ACCURACY CONTROL LIMITS - LABORATORY CONTROL SAMPLES
LOW CONCENTRATION ORGANIC ANALYSIS[1]
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	%R[2] - Aqueous Samples
Pesticides/ Polychlorinated Biphenyls (Continued)	
Endrin	56-121
Endosulfan sulfate	50-100
gamma-Chlordane	33-130

1 USEPA, 2001. Superfund Analytical Methods for Low Concentration Water for Organic Analysis, OLC03.2.
2 %R - Percent Recovery as described in Section 12.0.

TABLE 3-4

ACCURACY CONTROL LIMITS - SURROGATE SPIKES
LOW CONCENTRATION ORGANIC ANALYSIS(1)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	%R(2) - Aqueous Samples
Volatile Organics	
Bromofluorobenzene	80-120
Semivolatile Organics	
Nitrobenzene-d5	40-112
2-Fluorobiphenyl	42-110
Terphenyl-d14	24-140
Phenol-d5	17-113
2-Fluorophenol	16-108
2,4,6-Tribromophenol	18-126
Pesticides/ Polychlorinated Biphenyls	
Tetrachloro-m-xylene	60-150
Decachlorobiphenyl	60-150

1 USEPA, 2001. Superfund Analytical Methods for Low Concentration Water for Organic Analysis. OLC03.2.
2 %R - Percent Recovery as described in Section 12.0.

TABLE 3-5

ACCURACY CONTROL LIMITS - MATRIX SPIKE/MATRIX SPIKE DUPLICATE SAMPLES
ORGANIC ANALYSIS[1]
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	%R[2]	
	Aqueous Samples	Solid Samples
Volatile Organics		
1,1-Dichloroethene	61-145	59-172
Trichloroethene	71-120	62-137
Benzene	76-127	66-142
Toluene	76-125	59-139
Chlorobenzene	75-130	60-133
Semivolatile Organics		
Phenol	12-110	26-90
2-Chlorophenol	27-123	25-102
1,4-Dichlorobenzene	36-97	28-104
N-Nitroso-di-n-propylamine	41-116	41-126
1,2,4-Trichlorobenzene	39-98	38-107
4-Chloro-3-methylphenol	23-97	26-103
Acenaphthene	46-118	31-137
4-Nitrophenol	10-80	11-114
2,4-Dinitrotoluene	24-96	28-89
Pentachlorophenol	9-103	17-109
Pyrene	26-127	35-142
Pesticides/ Polychlorinated Biphenyls		
gamma-BHC (Lindane)	56-123	46-127
Heptachlor	40-131	35-130
Aldrin	40-120	34-132
Dieldrin	52-126	31-134
Endrin	56-121	42-139
4,4'-DDT	38-127	23-134

1 USEPA, 1999. Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration, OLM04.2 and USEPA, 2001b. Superfund Analytical Methods for Low Concentration Water for Organic Analysis, OLC03.2.

2 %R - Percent Recovery as described in Section 12.0.

TABLE 3-6

ACCURACY CONTROL LIMITS - SURROGATE SPIKES
ORGANIC ANALYSIS[1]
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	%R[2]	
	Aqueous Samples	Solid Samples
Volatile Organics		
Toluene-d8	88-110	84-138
Bromofluorobenzene	86-115	59-113
1,2-Dichloroethane-d4	76-114	70-121
Semivolatile Organics		
Nitrobenzene-d5	35-114	23-120
2-Fluorobiphenyl	43-116	30-115
Terphenyl-d14	33-141	18-137
Phenol-d5	10-110	24-113
2-Fluorophenol	21-110	25-121
2,4,6-Tribromophenol	10-123	19-122
2-Chlorophenol-d4	33-110[3]	20-130[3]
1,2-Dichlorobenzene-d4	16-110[3]	20-130[3]
Pesticides/ Polychlorinated Biphenyls		
Tetrachloro-m-xylene	30-150	30-150
Decachlorobiphenyl	30-150	30-150

1 USEPA, 1999. Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration, OLM04.2.
2 %R - Percent Recovery as described in Section 12.0.
3 Advisory limits only.

TABLE 3-7

ACCURACY CONTROL LIMITS - MATRIX SPIKE SAMPLES
INORGANIC ANALYSIS(1)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	%R(2)	
	Aqueous Samples	Solid Samples
Aluminum	75-125	NS
Antimony	75-125	75-125
Arsenic	75-125	75-125
Barium	75-125	75-125
Beryllium	75-125	75-125
Cadmium	75-125	75-125
Calcium	NS	NS
Chromium (total)	75-125	75-125
Cobalt	75-125	75-125
Copper	75-125	75-125
Iron	75-125	75-125
Lead	75-125	75-125
Magnesium	NS	NS
Manganese	75-125	75-125
Mercury	75-125	75-125
Nickel	75-125	75-125
Potassium	NS	NS
Selenium	75-125	75-125
Silver	75-125	75-125
Sodium	NS	NS
Thallium	75-125	75-125
Vanadium	75-125	75-125
Zinc	75-125	75-125
Cyanide	75-125	75-125

1 USEPA, 2001. Statement of Work for Inorganic Analysis, Multi-Media, Multi-Concentration, ILM05.2 or USEPA, 2000. Statement of Work for Inorganics Analysis, Multi-Media, Multi-Concentration, ILM04.1.
2 %R - Percent Recovery as described in Section 12.0.

NS No spike required.

TABLE 3-8

ACCURACY CONTROL LIMITS - LABORATORY CONTROL SAMPLES
INORGANIC ANALYSIS(1)
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Chemical	%R(2)	
	Aqueous Samples	Solid Samples
Aluminum	80-120	TBD
Antimony	80-120(3)	TBD
Arsenic	80-120	TBD
Barium	80-120	TBD
Beryllium	80-120	TBD
Cadmium	80-120	TBD
Calcium	80-120	TBD
Chromium (total)	80-120	TBD
Cobalt	80-120	TBD
Copper	80-120	TBD
Iron	80-120	TBD
Lead	80-120	TBD
Magnesium	80-120	TBD
Manganese	80-120	TBD
Mercury	NA	TBD
Nickel	80-120	TBD
Potassium	80-120	TBD
Selenium	80-120	TBD
Silver	80-120(3)	TBD
Sodium	80-120	TBD
Thallium	80-120	TBD
Vanadium	80-120	TBD
Zinc	80-120	TBD
Cyanide	NA	TBD

1 USEPA, 2001. Statement of Work for Inorganic Analysis, Multi-Media, Multi-Concentration, ILM05.2 or USEPA, 2000. Statement of Work for Inorganics Analysis, Multi-Media, Multi-Concentration, ILM04.1.
2 %R - Percent Recovery as described in Section 12.0.
3 Advisory limits only.

TBD - To Be Determined at time of analysis based on USEPA laboratory control sample lot number.
NA - Not Applicable.

TABLE 3-9

NON-CALIBRATION QC SAMPLE USAGE FREQUENCIES, ACCEPTANCE LIMITS, AND CORRECTIVE ACTIONS NAVAL DISTRICT WASHINGTON, INDIAN HEAD INDIAN HEAD, MARYLAND

QC Sample Type	Collection Frequency	Acceptance Limits	Corrective Action
Field Duplicate	1 per 10 investigative samples collected.	Aqueous = 30% RPD Soil/Sediment = 50% RPD	Qualify data according to data validation requirements.
Equipment Rinsate Blank	1 per 10 investigative samples collected, with a minimum of one per day of sampling, per non-disposable sampling device/instrument. For pre-cleaned, dedicated, and/or disposable equipment (i.e., disposable plastic trowels, etc.), one rinsate blank will be collected and analyzed at a frequency of one per lot or "batch blank" for a specific equipment type.	< CRQL (soil and water)	Identify source of contamination, if possible. Qualify data according to validation criteria. Qualify use of data if contamination appears to have adversely affected its usability.
Source Water Blank	1 per each source of water used for sampling equipment decontamination.	< CRQL (soil and water)	Identify source of contamination, if possible. Qualify data according to validation criteria. Qualify use of data if contamination appears to have adversely affected its usability.
Ambient Condition Blanks	At discretion of FOL.	< CRQL (soil and water)	Identify source of contamination, if possible. Qualify data according to validation criteria. Qualify use of data if contamination appears to have adversely affected its usability.
Trip Blanks	1 per cooler containing samples for volatile organics analysis.	< CRQL (soil and water)	Identify source of volatiles contamination, if possible. Qualify data according to validation criteria. Qualify use of data if contamination appears to have adversely affected its usability.
Internal Standard	At least one internal standard per sample for GC/MS analyses.	Retention times stable to ±30 seconds; area counts stable to within factor of 2.	Laboratory to re-extract and reanalyze. Contractor action taken per validation protocols, and Section 13.3.
Laboratory Control Sample	1 per 20 environmental samples per matrix.	See Tables 3-3 and 3-8.	Laboratory to re-extract and reanalyze. Contractor action taken per validation protocols, and Section 13.3.

TABLE 3-9

NON-CALIBRATION QC SAMPLE USAGE FREQUENCIES, ACCEPTANCE LIMITS, AND CORRECTIVE ACTIONS NAVAL DISTRICT WASHINGTON, INDIAN HEAD INDIAN HEAD, MARYLAND

QC Sample Type	Collection Frequency	Acceptance Limits	Corrective Action
Laboratory Duplicate	1 per 20 environmental samples analyzed for inorganic target analytes.	See Table 3-2.	Laboratory to reanalyze. Contractor action taken per validation protocols, and Section 13.3.
Laboratory Method Blank	1 per 20 environmental samples or per preparation batch, whichever is more frequent.	< CRQL (soil and water)	Laboratory must reanalyze if detection is 5 times greater than the RL. Contractor action taken per validation protocols, and Section 13.3.
Matrix Spike (1)	1 per 20 environmental samples.	See Tables 3-1, 3-5, and 3-7	Laboratory to confirm matrix interference by reanalysis and evaluation of all other quality control data. Contractor action taken per validation protocols, and Section 13.3.
Matrix Spike Duplicate(1)	1 per 20 environmental samples analyzed for organic target analytes.	See Tables 3-1, 3-5, and 3-7	Laboratory to confirm matrix interference by reanalysis and evaluation of all other quality control data. Contractor action taken per validation protocols, and Section 13.3.
Post-digestion Spike	Only if out-of-control matrix spike exists (metals only).	100 ± 20%	Contractor action taken per validation protocols, and Section 13.3.
Surrogate	At least one per sample for organic chromatographic analyses (GC, GC/MS, and HPLC).	See Tables 3-4 and 3-6	Laboratory must re-extract and reanalyze. Contractor action taken per validation protocols, and Section 13.3.
Temperature Blank	One blank per sample cooler.	4 ± 2 °C	Laboratory to call contractor for direction. Contactor action taken per validation protocols, and Section 13.3.

1 Matrix spikes and matrix spike duplicates are not analyzed in the field, but additional sample material must be collected in the field to ensure that the laboratory has enough material for spiking and duplicate analysis.

RPD Relative Percent Difference
CRQL Contract Required Quantitation Limit
FOL Field Operations Leader
GC/MS Gas Chromatography/Mass Spectrometer
HPLC High Performance Liquid Chromatography
°C Degrees Celsius
RL Reporting limit

4.0 SAMPLING PROCEDURES

Sampling procedures for project-specific field activities are presented in the master documents, Facility SOPs, and project-specific WP. Sampling information contained in the master documents and Facility SOPs is as follows:

- Field sampling by matrix
- Field QC sample collection/preparation procedures
- Sample containers, preservatives, and volume requirements
- Decontamination procedures
- Sample packaging and shipping procedures
- Mobilization/demobilization
- Monitoring well installation
- Monitoring well development
- Groundwater sampling
- Water-level measurements
- Soil sampling procedures
- Surveying
- Aquifer testing
- Waste handling
- QC sample procedures
- Field measurements/screening
- Preventive maintenance procedures/schedule
- Sample disposal

5.0 CUSTODY PROCEDURES

Custody is one of several factors necessary to produce data achieving the objectives of the planned work as well as establishing a data set that is legally defensible in a court of law. Custody procedures help to satisfy the two major requirements for evidentiary admissibility: relevance and authenticity. Sample custody is addressed in three parts: field sample collection, laboratory analysis, and final evidence files. Final evidence files, including all originals of laboratory reports and purge files, are maintained under document control in a secure area. A sample or evidence file is under custody if one or more of the following are true:

- the item is in the actual physical possession of an authorized person.
- the item is in view of the person after being in his or her possession.
- the item was placed in a secure area to prevent tampering.
- the item is in a designated and identified secure area with access restricted to authorized personnel only.

The chain-of-custody (COC) report is a multi-part, standardized form used to summarize and document pertinent sample information such as sample identification and type, matrix, date and time of collection, preservation, and requested analyses. Furthermore, through the sequential signatures of various sample custodians (e.g., sampler, airbill number, laboratory sample custodian), the COC report documents sample custody and tracking. Custody procedures apply to all environmental and associated field QC samples obtained as part of the data collection system.

5.1 FIELD CUSTODY PROCEDURES

The FOL (or designee) is responsible for the care and custody of the samples collected until they are relinquished to the analyzing laboratory or entrusted to a commercial overnight courier. COC reports are completed for each sample shipment. The reports are filled out in a legible manner, using waterproof ink, and are signed (and dated) by the sampler. Pertinent notes, such as whether the sample was field filtered or whether the sample is suspected to be high in contaminant concentration, are also indicated on the COC report. Information similar to that contained in the COC report is also written on the sample label using waterproof ink, which is securely attached to the sample bottle. COC report forms and sample labels are generally supplied by the laboratory. In accordance with Naval Facilities Engineering Service Center (NFESC) guidelines protocols, samples for chemical constituent analysis must be sent (for next-day receipt) to the laboratory within 24-hours of collection.

Full details regarding sample COC (including use of custody seals and sample shipment protocols) are contained in Facility SOP SA-6.1. Facility SOP SA-6.3 discusses maintenance of site logbooks, site notebooks, and other field records. Additionally, each of the various types of sampling are discussed in the Facility SOPs, including relevant sample documentation (i.e., completion of sample logsheets, etc.). All sample records are to be docketed into the contractor's project central file.

5.2 LABORATORY CUSTODY PROCEDURES

When samples are received by the laboratory, the laboratory's sample custodian examines each cooler's custody seals to verify that they are intact and that the integrity of the environmental samples has been maintained. The custodian then opens the cooler and measures its internal temperature. The temperature reading is noted on the accompanying COC report. The sample custodian then signs the COC report and examines the contents of the cooler. Sample container breakages or discrepancies between the COC report and sample label documentation are recorded. The pH of chemically preserved samples is checked using Hydrion paper and recorded. All problems or discrepancies noted during this process are to be promptly reported to the contractor's Project Manager.

5.3 FINAL EVIDENCE FILES

The contractor's central file will be the repository for all documents that constitute evidence relevant to sampling and analysis activities as described in this Master QAPP. The contractor is the custodian of the evidence file and maintains the contents of these files for the project, including all relevant records, reports, logs, field notebooks, photographs, subcontractor reports and data reviews in a secure, limited access location and under custody of the Facility manager. The control file will include at a minimum the following:

- Field logbooks
- Field data and data deliverables
- Photographs
- Drawings
- Soil boring logs
- Laboratory data deliverables
- Data validation reports
- Data assessment reports
- Progress reports, QA reports, interim project reports, etc.
- All custody documentation (tags, forms, airbills, etc.)

Upon completion of the contract, all pertinent files will be relinquished to the custody of the Navy.

6.0 CALIBRATION PROCEDURES AND FREQUENCY

All instrumentation used to perform chemical measurements must be properly calibrated prior to use to obtain valid and usable results. The requirement to properly calibrate instruments prior to use applies equally to field instruments as it does to fixed laboratory instruments.

6.1 FIELD INSTRUMENT CALIBRATION

Field instrument calibration is discussed in the Facility SOPs.

6.2 LABORATORY INSTRUMENT CALIBRATION

Calibration procedures for a specific laboratory instrument will consist of initial calibration (generally three to five points), initial calibration verification (inorganic methods only), and continuing calibration verification. In all cases, the initial calibration will be verified using an independently prepared calibration verification solution. The frequency of calibration will be performed according to the requirements of the specific methods.

All standards used to calibrate analytical instruments must be obtained from National Institute of Science and Technology (NIST) or through a reliable commercial supplier with a proven record for quality standards. All commercially supplied standards must be traceable to NIST reference standards, where possible, and appropriate documentation will be obtained from the supplier. In cases where documentation is not available, the laboratory will analyze the standard and compare the results to an USEPA-supplied known or previous NIST-traceable standard.

All calibration data, including dates and times of analyses, standards used, and other pertinent information must be documented in laboratory logbooks or on analysis run logs.

The calibration procedures and frequencies used by the laboratory will comply with the applicable CLP SOW or analytical method. Brief descriptions of calibration procedures for major instrument types are provided in the remainder of this section.

6.2.1 <u>Volatile Organic Compound Analyses</u>

For VOCs, the gas chromatography (GC)/mass spectrometer system will be tuned and calibrated in accordance with the appropriate CLP SOW (low concentration water - OLC03.2; multi-media/multi-concentration - OLM04.2). A bromofluorobenzene (BFB) instrument performance check (tuning check) must be run prior to the initial and each continuing calibration and must meet all method-specified criteria

before analyses may continue. Initial calibration is required before any samples are analyzed and must include a blank and a minimum of five different concentrations as specified in the method. A BFB tuning check and a continuing calibration check, including the mid-range standard and a blank, must be performed at the beginning of each 12-hour shift during which analyses are performed.

6.2.2 Semivolatile Organic Compound Analyses

For semivolatile organic compounds (SVOCs), the GC/MS system will be tuned and calibrated in accordance with the appropriate CLP SOW (low concentration water - OLC03.2; multi-media/multi-concentration - OLM04.2). A decafluorotriphenyl phosphine (DFTPP) instrument performance check (tuning check) must be run prior to the initial and each continuing calibration and must meet all method-specified criteria before analyses may continue. Initial calibration is required before any samples are analyzed and must include a blank plus five different concentrations as specified in the method. A DFTPP tuning check and a continuing calibration check, including the mid-range standard and a blank, must be performed at the beginning of each 12-hour shift during which analyses are performed.

6.2.3 Organochlorine Pesticide/PCB Analyses

For organochlorine pesticide/PCB analyses, the GC system will be calibrated in accordance with appropriate CLP SOW (low concentration water - OLC03.2; multi-media/multi-concentration - OLM04.2). Initial calibration is required before any samples are analyzed. An 18-point initial calibration sequence is analyzed using dual column injection. The calibration sequence consists of an instrument blank to show system cleanliness, a resolution check to prove analyte separation, a performance evaluation mixture (PEM) to show endrin and 4,4'-DDT degradation, a single point of each Aroclor, and a three-point calibration of the individual pesticides to prove linearity. A second instrument blank and PEM sample are then analyzed.

If all initial calibration criteria are met, samples may be analyzed for a period of 12 hours after the injection of the second instrument blank. At the end of the 12-hour period, a third instrument blank followed by continuing calibration standard mixtures must be analyzed. If continuing calibration criteria are met, sample analysis may continue for an additional 12 hours. At this point, an instrument blank followed by a PEM is analyzed. The 12-hour clock continues, alternating between the continuing calibration standard mixtures and the PEM, until failure to meet method-specified criteria requires a new initial calibration.

6.2.4 Nitroaromatics Analyses

High performance liquid chromatographs (HPLCs) used for nitroaromatics (explosives) analysis will be calibrated as specified in the applicable analytical methods. A five-point initial calibration is required before any samples are analyzed. A mid-point continuing calibration is required, at a minimum, at the beginning of the day, at the mid-point of the run, and after the last sample of the day (assuming a sample group of 10 samples or less).

6.2.5 Inorganic Analyses

6.2.5.1 Inductively Coupled Plasma and Inductively Coupled Plasma/Mass Spectrometer Analyses

Inductively coupled plasma (ICP) and ICP/mass spectrometer systems will be calibrated for the analysis of TAL metals in accordance with the CLP SOWs ILM04.1 and ILM05.2. Initial calibration is required each day before any samples are analyzed and consists of a calibration blank and at least one standard. The standard must be within the demonstrated linear range of the instrument. The linear range is verified quarterly. Following initial calibration, an initial calibration verification sample (obtained from a different source than the solutions used for calibration), an initial calibration blank, and an interference check sample are analyzed. A continuing calibration verification sample and a continuing calibration blank are run every 2 hours or every 10 samples, whichever occurs first, based on CLP protocol. A continuing calibration verification sample, a continuing calibration blank, and an interference check sample are also run after analysis of the last sample. The initial calibration verification standard, continuing calibration verification standard, and interference check sample each contain analytes of interest at different concentrations. In addition, for CLP analysis, a standard prepared at a concentration of two times the quantitation limit is analyzed at the beginning and end of each sample analysis run and at a frequency not greater than 20 analytical samples per run. Linearity spanning the range of analysis is verified using this combination of standards. All calibration standards contain acids at the same concentrations as the sample digestates.

6.2.5.2 Atomic Absorption Analyses

Graphite furnace and cold vapor atomic absorption (GFAA and CVAA) instrumentation will be calibrated in accordance with CLP SOW ILM04.1 and ILM05.2 or the applicable analytical method. Initial calibration is required each day before any samples are analyzed and consists of a calibration blank and at least three calibration standards (at least four standards for mercury) covering the range of concentrations of interest. The correlation coefficient of the regression of concentration versus response should be 0.995 or greater. Immediately following initial calibration, an initial calibration verification sample (obtained from

a different source than the solutions used for calibration) and an initial calibration blank are analyzed. A continuing calibration verification sample and a continuing calibration blank are run every 2 hours or every 10 samples, whichever occurs first. A continuing calibration verification sample and a continuing calibration blank are also run after analysis of the last sample.

6.2.6 Cyanide Analyses

Calibration for cyanide analyses will be performed as specified in CLP SOW ILM04.1 and ILM05.2. Initial calibration is required each day before any samples are analyzed and consists of a calibration blank and at least three calibration standards covering the range of concentrations of interest. The correlation coefficient of the regression of concentration versus response should be 0.995 or greater. Immediately following initial calibration, an initial calibration verification sample (obtained from a different source than the solutions used for calibration) and an initial calibration blank are analyzed. The initial calibration verification must be distilled in the same manner as the associated field samples. A continuing calibration verification sample and a continuing calibration blank are run every 2 hours or every 10 samples, whichever occurs first. A continuing calibration verification sample and a continuing calibration blank are also run after analysis of the last sample.

If any of the continuing calibration samples fail to yield a response within 15 percent of the true value, initial calibration will be repeated, and all field samples analyzed since the last in-control calibration standard will be reanalyzed.

6.2.7 Perchlorate Analyses

Calibration and standardization requirements for the analysis of perchlorate will be performed as specified in the applicable analytical methods.

7.0 ANALYTICAL AND MEASUREMENT PROCEDURES

Typically samples will be subjected to field parameter measurement and will be analyzed for TCL volatiles, semivolatiles, and pesticides/PCBs, TAL inorganics and cyanide, and explosive compounds. Selected laboratories will be NFESC approved. In the event that additional, non-CLP methods are required on a project-specific basis, the non-CLP methods will be provided in the project-specific QAPP.

Table 1-1 provided a summary of the most commonly used laboratory analytical methods for solid and aqueous samples. A list of the target compounds/analytes and limits of detection for the most common and most frequently used laboratory analytical methods was also provided in Tables 1-2 through 1-5 of this Master QAPP. The analytical programs for environmental samples will be provided in the project-specific QAPP addenda.

7.1 FIELD MEASUREMENT PROCEDURES

Field measurements to be completed during the field investigations will be discussed in project-specific WPs and may include those completed in support of health and safety considerations, well development and purging, general chemical and physical characterization of groundwater, and selection of soil samples for laboratory analysis. Chemical/physical parameters to be measured using field instrumentation may include volatile organics as methane equivalents (breathing zone air and soil vapors), temperature, specific conductance, hydronium ion concentration (pH), DO, and turbidity (groundwater samples). Measurement of field parameters is discussed in the Facility SOPs. Calibration of field instruments is discussed in the Facility SOPs.

7.2 LABORATORY ANALYTICAL AND MEASUREMENT PROCEDURES

Data generated through use of the CLP SOWs will be reported to the CRQL for organics analysis and to the CRDL for inorganics analysis. Analytes that are positively identified and quantitated at concentrations less than the CRQL/CRDL will be reported as specified in the appropriate CLP SOW. All environmental data generated through use of non-CLP protocols will be reported to the analyte's PQL. An analyte's PQL is an expression of the method detection limit (MDL) with consideration given to required adjustments to ensure that the precision and accuracy requirements of the method are attainable.

All solid sample results will be reported on a dry-weight basis. Quantitation and detection limits will also be adjusted, as necessary, based on dilution and sample volume.

8.0 INTERNAL QUALITY CONTROL CHECKS

Field-related QC checks were discussed in Section 3.0 of this Master QAPP and in the Master WP. This section provides additional information regarding internal QC checks for the field and the laboratory.

8.1 FIELD QUALITY CONTROL CHECKS

QC procedures for pH, specific conductance, temperature, DO, and turbidity will include calibrating the instruments as described in the Facility SOPs. Assessment of field sampling precision and bias will be made by collection of field duplicates and equipment blanks for laboratory analysis. Collection of the field QC samples (or external QC checks) will be in accordance with the procedures provided in the Master WP at the frequency discussed in Section 3.6 and Table 3-9 of this Master QAPP.

8.2 LABORATORY QUALITY CONTROL CHECKS

The laboratory will have a QC program that ensures the reliability and validity of the analyses performed at the laboratory. Internal QC procedures for CLP analyses (volatile and semivolatile organics, organochlorine pesticides/PCBs, metals, and cyanide) will comply with the SOWs for low concentration water organics (OLC03.2), multi-media/multi-concentration organics (OLM04.2), and inorganics (ILM04.1 and ILM05.2). Internal QC procedures for non-CLP analyses will comply with applicable analytical method requirements. Additionally only NFESC-approved laboratories will be utilized to perform work at NDW,IH.

Several internal laboratory QC checks are briefly discussed in the remainder of this section.

Laboratory method blanks are prepared and analyzed in accordance with the analytical method employed to determine whether contaminants originating from laboratory sources have been introduced and have affected environmental sample analyses. A method blank generally consists of an aliquot of analyte-free water (or purified sodium sulfate for soil/sediment samples) that is subjected to the same preparation and analysis procedures as the environmental samples undergoing analysis. With the exception of recognized volatile and semivolatile common laboratory contaminants (i.e., methylene chloride, acetone, 2-butanone, and phthalate esters) detected through use of the multi-media/multi-concentration organic SOW, method blanks must not contain levels of target analytes greater than the reported detection limits (i.e., greater than 2.5 times the CRQL for methylene chloride and greater than 5 times the CRQL for acetone, 2-butanone, and phthalate esters). If method blank contamination is found to exist above allowable limits, corrective actions contained in the CLP SOWs or laboratory SOPs

must be followed. Under no circumstances are laboratory method blank contaminant values subtracted from environmental sample analysis results.

Laboratory method blanks are performed at the frequency specified in the analytical method. However, in general, organic analyses method blanks are analyzed at a frequency of one per extraction or analysis batch up to a maximum of 20 samples. In general, inorganic analysis method blanks are analyzed at a frequency of one method blank per batch of samples processed at the same time, up to a maximum of 20 samples.

Instrument blank analysis is performed during organochlorine pesticide/PCB analysis to demonstrate that pesticides/PCBs are not detected at greater than 0.5 times the CRQL (or not greater than the CRQL for low concentration analysis) and that the surrogate retention times are within the retention time windows. If analytes are detected at greater than half the CRQL (greater than the CRQL for low concentration analyses), or the surrogate retention times are outside the retention time windows, all data collection must be stopped and corrective action must be taken. An acceptable instrument blank must be run before additional data is collected. One instrument blank every 12 hours is the minimum contract requirement.

MS analysis for organic fraction analyses is performed in duplicate as a measure of laboratory precision. For inorganic analyses, one MS analysis and one **laboratory duplicate** analysis will be performed for every 20 environmental samples per matrix per site. With the exception of VOC MSD analyses, laboratory duplicates are prepared by thoroughly mixing and splitting a sample aliquot into two portions and analyzing each portion following the same analytical procedures used for the environmental sample analyses. For VOC MSD analyses, a second sample aliquot is used for analysis to avoid VOC constituent loss through the homogenization process. The field crew provides extra volumes of sample matrices designated for laboratory QC analyses, as required. Control limits for MS and laboratory duplicate analyses are specified in the SOWs for CLP analyses and are established by the laboratory for non-CLP analyses.

Surrogates or System Monitoring Compounds are organic compounds (typically brominated, fluorinated, or isotopically labeled) that are similar in nature to the compounds of concern and that are not likely to be present in environmental media. Surrogates are spiked into each sample, standard, and method blank prior to analysis and are used only in organic chromatographic analysis procedures as a check of method effectiveness. Surrogate recoveries are evaluated against control limits specified in the CLP SOW, where applicable, or laboratory-derived control limits.

LCSs serve to monitor the overall performance of each step during the analysis, including the sample preparation. LCS analysis will be performed in accordance with the analytical method for low concentration TCL volatiles, TAL inorganics, and most non-CLP analyses. Aqueous LCS results must fall within the control limits specified in the CLP SOW, where applicable, or established by the laboratory. Solid LCS results must fall within the control limits established by the supplier of the LCS standard, where applicable, or established by the laboratory. Aqueous and solid LCSs shall be analyzed utilizing the same sample preparations, analytical methods, and QA/QC procedures as employed for the samples.

Internal standard performance criteria ensure that GC/MS analysis sensitivity and response are stable during every analytical run. Internal standard area counts for samples and blanks must not vary by more than a factor of two (- 50 to + 100 percent) from the associated 12-hour calibration standard (± 40 percent for low concentration volatile analyses). The retention time of the internal standards in samples and blanks must not vary by more than ±30 seconds from the retention time of the associated 12-hour calibration standard (±20 seconds for low-concentration volatile and semivolatile analyses).

Additional internal laboratory QC checks include mass tuning for GC/MS analysis, endrin/DDT degradation checks for pesticide/PCB analysis, and second-column confirmation for GC analysis.

9.0 DATA REDUCTION, VALIDATION, AND REPORTING

This section describes the procedures to be used for data reduction, validation, and reporting for samples collected during the NDW,IH investigations. All data generated during the course of the proposed activities will be maintained in hardcopy and/or portable document format (PDF) form by the contractor in the CLEAN central project files.

In addition to the central files, photocopies of all hardcopy/PDF data (as well as electronic data) will be maintained in the contractor's Chemistry/Toxicology/Risk Assessment Department database records files. Upon completion of the contract, all files will be relinquished to the Navy as per CLEAN Contract requirements.

9.1 DATA REDUCTION

Data reduction will be completed for both field measurement- and laboratory-generated analytical data. Field data reduction will be relatively limited versus the degree of laboratory data reduction required for the project. Reduction of both field data and laboratory data are discussed in the remainder of this section.

9.1.1 Field Data Reduction

Field data will be generated as a result of real-time measurement of organic vapor concentrations via a PID or FID (for health and safety monitoring and to support selection of samples for shipment to the laboratory) and through onsite water quality testing for general indicator parameters including pH, specific conductivity, turbidity, DO, and temperature.

Field measurements of organic vapor concentrations (parts per million on a volume to volume basis relative to methane or benzene) and data collected as a result of the use of field test kits will be recorded in the site logbook and incorporated into the project-specific reports. General water-quality indicator parameter data will also be recorded in the site logbook and on sample logsheets immediately after the measurements are taken. If an error is made in the logbook, the error will be legibly crossed out (single-line strikeout), initialed and dated by the field member, and corrected in a space adjacent to the original (erroneous) entry. General groundwater quality data and field screening data will be recorded and reported in the following units:

- Hydronium ion concentration (standard pH units)
- Temperature (degrees Celsius)

- Specific conductivity (milliSiemen per centimeter)
- Turbidity (NTU)
- Dissolved oxygen (mg/L)

Standard pH units as specified above is the negative logarithm (base 10) of the hydronium ion concentration in moles per liter.

9.1.2 Laboratory Data Reduction

Data reduction for laboratory analytical data generated via USEPA CLP analytical methods, QA requirements, and reporting procedures will be completed in accordance with the most current SOWs for organic and inorganic analysis, as identified in previous sections of this Master QAPP. Laboratory data reduction of analytical results generated via non-CLP methods will be completed as specified in the analytical methods.

Laboratory analytical data will be reported using standard concentration units to ensure comparability with regulatory standards/guidelines and previous analytical results. Organic chemicals will be reported in µg/L for aqueous samples and µg/kg for solid samples, except explosives for which solid samples will be reported in mg/kg. Metals and cyanide will be reported in µg/L for aqueous samples and mg/kg for solid samples.

Typically, field QC sample results will be included in the database for NDW,IH investigations. Specifically, the analytical results for trip blanks, rinsate blanks, and ambient condition blanks will be provided. The results for field QC blanks will be considered during the course of data validation (in concert with laboratory method blanks) to eliminate false positive results according to the 5- and 10-times rules specified in the USEPA National Functional Guidelines for Organic and Inorganic Data Review as modified for use in USEPA Region III, (USEPA, 1993 and USEPA, 1994). The results for laboratory QC samples such as method blanks will not be presented in the NDW,IH master database. In addition, only the original (unspiked) sample results for MS/MSD samples will be provided in the database.

9.2 DATA VALIDATION

Validation of field measurements and laboratory analytical data are discussed in this section. Validation of field data will be limited to real-time "reality" checks, whereas laboratory analytical data will be validated in accordance with current USEPA guidance.

9.2.1 Field Measurement Data Validation

Field measurements will not be subjected to a formal data validation process. However, field technicians will ensure that the equipment used for field measurement is performing accurately via compliance with the Facility SOPs. As described in Section 9.1.1, all field data entered into the electronic database will be independently reviewed for transcription errors.

9.2.2 Laboratory Data Validation

Typically, 100 percent of the laboratory data will be validated. Validation of analytical data will be completed by the contractor. Final review and approval of validation deliverables will be completed by the contractor's Data Validation Coordinator.

All CLP laboratory analytical data will be subjected to validation in accordance with the USEPA National Functional Guidelines for Organic and Inorganic Data Review as modified for use in USEPA Region III, (USEPA, 1993 and USEPA, 1994). Data validation will be completed to ensure that the data are of evidentiary quality. Particular emphasis will be placed on holding time compliance, equipment calibration, spike recoveries, and blank results, although all required elements of the validation process will be considered.

The analytical results for non-CLP parameters will be validated based on the analytical methods. Validation of these data will conform to the, USEPA National Functional Guidelines for Organic and Inorganic Data Review as modified for use in USEPA Region III (USEPA, 1993 and USEPA, 1994), to the greatest extent practicable.

9.3 DATA REPORTING

9.3.1 Field Measurement Data Reporting

Field data will be reported in the units discussed in Section 9.1.1. The project-specific reports will typically include all field measurements (specifically pH, specific conductance, temperature, DO, and turbidity).

All records regarding field measurements (i.e., field logbooks, sampling logbooks, and sample logsheets) will be placed in the CLEAN central files upon completion of the field effort. Field measurement data will typically be reported in an appendix to the project-specific report and may also be reported in summary fashion if they are indicative of the presence of contamination (e.g., high specific conductance readings).

The contractor's Information Management Resources Department will typically hold responsibility for field data reporting subject to oversight by the Department Manager.

9.3.2 Laboratory Data Reporting

Data reported by the laboratory will be in accordance with CLP reporting format, including all non-CLP data (to the extent practicable). All pertinent QC data including raw data and summary forms for blanks, standards analysis, calibration information, etc. will be provided for the non-CLP analyses. Case narratives will be provided for each sample delivery group (SDG).

Typically, all environmental and field QC sample results (trip blanks, duplicates, rinsate blanks, ambient condition blanks) will be included in each project-specific report as an appendix. The database will include pertinent sampling information such as sample number, sampling date, general location, depth, and survey coordinates (if applicable). Sample-specific detection limits will be reported for nondetected analytes. Units will be clearly summarized in the database and will conform to those identified in Section 9.1.2. The analytical data may also be reported in summary fashion within the body of the project-specific report text in tabular and graphic fashion.

Data will be handled electronically pursuant to the electronic deliverable requirements that must be specified in the contractor's agreement with analytical laboratories. This agreement should require the analytical laboratories to provide data as a PDF of the hardcopy and in electronic form (database or text files). The original electronic diskettes and the original hardcopy/PDF analytical data are maintained in the CLEAN central project files as received.

Validation will be completed using the hardcopy/PDF data. Upon completion of validation of a SDG and review by the Data Validation Coordinator, the validation qualifiers will be entered in the electronic database and will be subjected to independent review for accuracy. During this review process, the electronic database printout will also be contrasted with the hardcopy/PDF data (i.e., Form Is) to ensure that the hardcopy/PDF data and electronic data are consistent.

The contractor's Information Management Resource Department will typically hold responsibility for laboratory data reporting subject to oversight by the Department Manager. Key data handling personnel within the Department include the Department Manager and the Database Supervisor (Information Management Resource Department), and the Data Validation Coordinator (Chemistry Department). It is not currently planned to provide copies of all the data validation deliverables to USEPA Region III. However, a summary of the validation results (actions taken and completeness, precision, and accuracy) will be provided in the project-specific reports, and example data validation reports and analytical data packages will be provided upon request.

10.0 PERFORMANCE AND SYSTEM AUDITS

Performance and system audits will be performed periodically to ensure that work is being implemented in accordance with the approved project plans and in an overall satisfactory manner. Examples of pertinent audits are as follows:

- The FOL will supervise and check daily that the field measurements are made accurately, equipment is thoroughly decontaminated, samples are collected and handled properly, and fieldwork is documented accurately and neatly.

- Performance and system audits for the laboratory will be performed regularly, in accordance with the requirements of the CLP, by a Navy Contractor and by the laboratory's QA staff in accordance with the laboratory QA plan.

- External field or laboratory audits maybe performed at the discretion of USEPA Region III and/or Maryland Department of the Environment (MDE).

- Data validators will review (on a timely basis) the chemical analytical data packages submitted by the laboratory. The data validators will check that the data were obtained through use of the approved methodology, the appropriate level of QC effort and reporting were conducted, and the results are in conformance with QC criteria. On the basis of these factors, the data validator will generate a report describing data limitations, which will be reviewed internally by the Data Validation Coordinator prior to submittal to the contractor's Project Manager.

- A formal audit of the field sampling procedures may be conducted by the contractor's CLEAN QAM or designee in addition to the auditing that is an inherent part of the daily project activities. The purpose of this audit is to ensure that sample collection, handling, and shipping protocols, as well as equipment decontamination and field documentation procedures, are being performed in accordance with the approved project plans and SOPs.

- The contractor's Project Manager will maintain contact with the FOL and Data Validation Coordinator to ensure that management of the acquired data proceeds in an organized and expeditious manner.

- The QA officer or appropriate designee of the laboratory performs routine internal audits of the laboratory. The Navy, through the NFESC, also conducts internal laboratory audits. The contractor holds no responsibility for such audits. Performance and system audits of laboratories are

coordinated through the NFESC by an independent QA contractor. It is the responsibility of the NFESC and its contractor to ensure that the subcontracted laboratories comply with good laboratory practices and the general requirements of all analytical services provided by the laboratories. The contractor will use only NFESC-approved laboratories for analysis of samples collected from NDW,IH.

11.0 PREVENTIVE MAINTENANCE PROCEDURES

Measuring equipment used in environmental monitoring or analysis shall be maintained in accordance with the manufacturer's operation and maintenance manuals. Equipment and instruments shall be calibrated in accordance with the procedures and at the frequencies, discussed in Section 6.0 (Calibration Procedures and Frequency) and in Facility SOPs (field measurement equipment). Preventive maintenance for field and laboratory equipment is discussed in the remainder of this section.

11.1 FIELD EQUIPMENT PREVENTIVE MAINTENANCE

Preventive maintenance of field equipment is described in the Facility SOPs. The contractor's Equipment Manager and the instrument operator will be responsible for ensuring that equipment is operating properly prior to use and that routine maintenance is performed and documented. Any problems encountered while operating the instrument will be recorded in the field logbook including a description of the symptoms and corrective actions taken. If problem equipment is detected or should require service, the equipment should be logged, tagged, and segregated from equipment in proper working order. Use of the instrument will not resume until the problem is resolved.

11.2 LABORATORY INSTRUMENT PREVENTIVE MAINTENANCE

Proper maintenance of laboratory instruments and equipment is essential to ensuring their readiness when needed. Dependent on manufacturer's recommendations, maintenance intervals are established for each instrument. All instruments must be labeled with a model number and serial number, and a maintenance logbook must be maintained for each instrument. Personnel must be alert to the maintenance status of the equipment they are using at all times.

11.2.1 Major Instruments

Table 11-1 provides a summary of preventive maintenance procedures typically performed by environmental laboratories for key analytical instruments.

Maintenance of key instruments may also be covered under service contracts with external firms. Such contracts provide for periodic routine maintenance to help guard against unexpected instrument downtime. These contracts also typically provide for quick response for unscheduled service calls when malfunctions are observed by the operator.

The use of manufacturer-recommended grades or better of supporting supplies and reagents is also a form of preventive maintenance. For example, gases used in the various GC and metals instruments are

of sufficient grade to minimize fouling of the instrument. The routine use of septa, chromatographic columns, ferrules, furnace tubes, and other supporting supplies from reputable manufacturers will assist in averting unnecessary periods of instrument downtime.

11.2.2 Refrigerators/Ovens

The temperatures of refrigerators used for sample storage will be monitored once daily. The acceptable range for refrigerator temperatures is 4°C ± 2°C. The temperatures will be recorded in the refrigerator temperature log. Maintenance of the log will be the responsibility of the sample custodian or designee. The log will contain the following information:

- Date
- Temperature
- Initials of person performing the check

Assignment of responsibilities for temperature monitoring to specific personnel does not preclude the participation of other laboratory personnel. If unusual temperature fluctuations are noted, it is the responsibility of the observer to immediately notify the person in charge of the discrepancy before the condition of the samples is compromised.

Unstable or fluctuating temperatures may be indicative of malfunctions in the cooling system. On the other hand, the instability may be due to frequent opening of the door. Regardless of the cause, such an observation must be investigated, and modifications to access procedures or repairs to equipment must be made to prevent jeopardizing the integrity of the samples.

TABLE 11-1

TYPICAL PREVENTIVE MAINTENANCE FOR ANALYTICAL INSTRUMENTS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Instrument	Preventive Maintenance	Maintenance Frequency
GC/MS	Volatiles: Bake oven, replace septum, check carrier gas.	As required.
	Semivolatiles: Replace septum, clean injection port, replace liner, bake oven, check carrier gas, clean source.	As required.
	Replace solvent washes and clean syringe.	Daily.
GC	Replace solvent washes and clean syringe.	Daily.
	Clip column, clean injection port, replace liner, and bake oven.	As required.
ICP	Change sample introduction tubing, clean nebulizer, clean spray chamber, clean torch, manual profile, and automatic profile optics.	As required.
CVAA	Change sample introduction tubing, change drying cell, re-zero detector.	As required.
IC	Replace pump seals.	Annually.
	Lubricate analytical pump motor.	Semi-annually.
	Check chromatography module and all gas lines for leaks.	Every run.
	Clean conductivity detector cell electrodes, check cell calibration.	Monthly.
	Replace bed supports, clean columns, clean membrane suppressor, replace autosampler pipette tip.	As needed.
HPLC	Change filter frits.	Monthly.
	Change column prefilters.	As needed.
	Change pump seals.	As needed
ICP/MS	Service intercooler.	Annually.
	Rinse and clean nebulizer cap and spray chamber.	Monthly or as needed.
	Clean torch, vacuum filters.	Bi-monthly.
	Profile instrument, examine autosampler tubing and replace as needed.	Daily.
	Empty rinse container, fill rinse water reservoir.	As needed.

GC – Gas Chromatograph
MS – Mass Spectroscopy
HPLC – High Performance Liquid Chromatography
ICP – Inductively Coupled Plasma
CVAA – Cold Vapor Atomic Absorption
IC – Ion Chromatograph

12.0 SPECIFIC ROUTINE PROCEDURES USED TO ASSESS DATA PRECISION, ACCURACY, AND COMPLETENESS

Compliance with quantitative QC objectives for laboratory accuracy and precision as outlined in Tables 3-1 through 3-8 will be evaluated during data validation (Section 9.0). Compliance with completeness objectives for field and laboratory data may be computed. Sections 12.1 and 12.2 present equations to be used for computing accuracy and precision values, respectively. Section 12.3 describes the means and presents the equation for determining completeness. Section 12.4 addresses the overall data assessment process.

In general, data validation requires that data be evaluated batch by batch based on the results of quality indicators for the respective batches. Section 12.4 presents additional data quality considerations that may be evaluated after data validation. These considerations are designed to incorporate data quality factors that extend beyond evaluation of the simple quantitative estimators for precision, accuracy, and completeness.

12.1 ACCURACY ASSESSMENT

The accuracy of chemical analyses is assessed through the use of surrogate spikes, MSs, post-digestion spikes (PDSs), LCSs, calibration check standards, internal standards, and blanks. Blanks are used to infer the potential for positive biases because of contamination. To assure the accuracy of the analytical procedures, at least one of every 20 environmental samples will be spiked with known amounts of target analytes (i.e., MSs) prior to preparation for analysis. The spiked samples will be analyzed, and the concentrations of each target analyte observed in the spiked sample will be compared to the reported value of the analyte in the unspiked sample to determine the %R of the analyte. Control charts are plotted by the laboratory for each target analyte and are kept on matrix- and analyte-specific bases. The %R for a spiked sample is calculated using the following formula:

$$\%R = \frac{\text{Amount in Spiked Sample} - \text{Amount in Sample}}{\text{Known Amount Added}} \text{ X } 100\,\%$$

As discussed in Section 3.2.3, LCSs and surrogate spikes are also analyzed to assess accuracy. The %R calculation for LCSs and surrogate spikes is as follows:

$$\%R = \frac{\text{Experimental Concentration}}{\text{Certified or Known Concentration}} \text{ X } 100\,\%$$

12.2 PRECISION ASSESSMENT

As presented in Section 3.1.3, laboratory duplicate samples (for inorganic analyses) and MSD samples (for organic analyses) will be prepared and analyzed at a minimum frequency of one per every 20 environmental samples per matrix. As described in Section 3.1.2, field duplicate samples also will be collected at a minimum frequency of one per 10 environmental samples per matrix. The RPD between a sample or MS (Sample 1) and its duplicate or MSD (Sample 2) is calculated for chemical analyses using the following formula:

$$\text{RPD} = \frac{|\text{Amount in Sample 1} - \text{Amount in Sample 2}|}{0.5\,(\text{Amount in Sample 1} + \text{Amount in Sample 2})} \text{ X } 100\ \%$$

12.3 COMPLETENESS ASSESSMENT

Completeness for this project is determined based on the number of sample results for each target analyte and each sample type that are usable as determined through data validation and data assessment. Data values rejected during data validation (indicated by an "R" or "UR" flag) will be considered unusable unless additional review and documentation by one or more technical team members demonstrates that the rejection was erroneous. To monitor completeness, the number of usable, valid results for each soil type and analyte will be counted and compared to the completeness objectives in Sections 3.3.2 and 3.3.3.

Percent completeness will be calculated using the following equation:

$$\%\ \text{Completeness} = \frac{(\text{Number of Valid Measurements})}{(\text{Number of Measurements Planned})} \text{ x } 100\%$$

Because the many parameters to be measured for a project are interrelated in many different ways, a single completeness criterion cannot be established for the project. Instead, the ability to attain project objectives will be evaluated at the end of each sampling round by how effectively the necessary decisions and data evaluations can be made.

12.4 DATA ASSESSMENT

The assessment of data obtained from an investigation is a critical part of determining the next step in data collection and decision making. It must be determined whether the data are of appropriate type, quality, quantity, and representativeness to support the project objectives. The effect of the loss of data deemed unacceptable for use, for whatever reason, will be evaluated.

12.4.1 Reconciliation with Data Quality Objectives

Field data will be examined immediately after generation for errors. Laboratory data will be examined upon receipt from the laboratory in a series of evaluations. The first step will be a data verification and validation as described in Section 9.0.

After data validation, the data will be reconciled with DQOs to determine whether sufficient data of acceptable quality are available for decision making. In addition to the evaluations described in Sections 12.1 through 12.3, a series of inspections and statistical analyses may be performed to estimate several of the data set characteristics. The statistical evaluations will include simple summary statistics for target analytes, such as the maximum concentration, minimum concentration, number of samples exhibiting no detectable analyte, the number of samples exhibiting detectable analytes, and the proportion of samples with detectable and undetectable analytes. These inspections and statistical analyses will be designed to do the following:

- Identify deviations, if any, from the field sampling SOPs (inspection).
- Identify deviations, if any, from the laboratory analytical SOPs (inspection).
- Identify deviations, if any, from the Master QAPP and project-specific QAPP addendum (inspection).
- Identify deviations, if any, from the data validation process (inspection).
- Identify and explain the impacts of elevated detection limits (inspection).
- Identify unusable data (i.e., data qualified as “R”) (inspection).
- Evaluate project assumptions such as “groundwater flow is to the northwest” (inspection).
- Characterize data set distributions (e.g., Shapiro-Wilk W test) if enough data are available (statistics).
- Identify unanticipated data set characteristics such as a laboratory variance greater than the sampling variance (e.g., *t*-test) if enough data are available (statistics).

- Identify and evaluate potential data outliers (95 percent confidence goodness-of-fit test on probability plot data). The plotted data will be transformed, if necessary, depending on the observed distribution (statistics).

- Evaluate adherence to investigation objectives and decision rules (inspection and statistics, as applicable).

- Ensure completion of corrective actions (inspection).

- Evaluate effects of deviations from planned procedures and processes on the interpretation and utility of the data (inspection and statistics, as applicable).

- Identify the existence of remaining data gaps (inspection/statistics).

For statistical comparisons and mathematical manipulations, analytes that are not detected at the applicable sample-specific MDLs will be represented by a concentration equal to one-half the sample-specific MDL.

If necessary, investigation objectives may be revised in anticipation of additional data collection.

The suitability of any given statistical test will be assessed based on the completeness of the data sets and the conditions observed at the site. For example, when a single data value is available for soils or water samples at a given sampling location, statistical tests cannot be conducted for that individual sampling location. However, pooling of data across sampling locations may be possible and, if logical to do so, may be implemented at the discretion of the contractor's Project Manager. For example, when evaluating constituents of potential concern, multiple soil sample results of a given depth and grain size within a depositional environment may be pooled for statistical comparison to the background data set from soil of the same depth, grain size, and depositional environment. Statistical testing will generally be conducted at the 5-percent significance level. Statistical testing at other significance levels may also be warranted to provide perspective on the results of testing a 5-percent significance. If other significance levels are used, they will be supported with rationales for their use.

13.0 CORRECTIVE ACTION

It is required that any and all personnel noting conditions adverse to quality report these conditions immediately to the contractor's Project Manager and CLEAN QAM. These parties, in turn, are charged with performing root-cause analyses and implementing appropriate corrective action in a timely manner. It is ultimately the responsibility of the QAM to document all findings and corrective actions taken and to monitor the effectiveness of the corrective measures performed.

13.1 FIELD CORRECTIVE ACTION

Field nonconformances or conditions adverse to quality must be identified and corrected as quickly as possible so that work integrity or quality of product is not compromised. The need for corrective action may arise based on deviations from project plans and procedures, adverse field conditions, or other unforeseen circumstances. Corrective action needs may become apparent during the performance of daily work tasks or as a consequence of internal or external field audits.

Corrective action may include resampling and may involve amending previously approved field procedures. If warranted by the severity of the problem (e.g., if a change in the approved project-specific WPs or SOPs is required), the Navy will be notified in writing via a field task modification request (FTMR), and Navy (in conjunction with USEPA Region III) approvals will be obtained. The FOL is responsible for initiating FTMRs; an FTMR will be initiated for all deviations from the project plan documents, as applicable. An FTMR form is provided as Figure 13-1. Copies of all FTMRs will be maintained with the onsite project planning documents and will be placed in the final evidence file.

Minor modifications to field activities such as a slight offset of a boring location will be initiated at the discretion of the FOL, subject to onsite approval by Facility personnel. Approval for major modifications (e.g., elimination of a sampling point) must be obtained via an FTMR.

13.2 LABORATORY CORRECTIVE ACTION

In general, laboratory corrective actions are warranted whenever an out-of-control event or potential out-of-control event is noted. The specific corrective action taken depends on the specific analysis and the nature of the event. Generally, the following occurrences alert laboratory personnel that corrective action may be necessary:

- QC data are outside established warning or control limits.
- Method blank analyses yield concentrations of target analytes greater than acceptable levels.

- Undesirable trends are detected in spike recoveries or in duplicate RPDs.
- There is an unexplained change in compound detection capability.
- Inquiries concerning data quality are received.
- Deficiencies are detected by laboratory QA staff audits or from performance evaluation sample test results.

Corrective actions are documented for non-routine out-of-control situations on a corrective action form. Figure 13-2 provides a blank of a typical corrective action form. A routine out-of-control situation is defined as one that is noted in the corrective action section of the method-specific SOP. Each SOP defines the routine out-of-control situations and the appropriate corrective action procedures for these situations. All out-of-control situations not addressed in the SOP must be treated as non-routine and documented in the corrective action logbook.

Using the corrective action form, any employee may notify the laboratory QA/QC Officer of a problem. The QA/QC Officer initiates the corrective action by relating the problem to the appropriate laboratory manager and/or internal coordinator, who then investigates or assigns responsibility for investigating the problem and its cause. After the cause is determined, an appropriate corrective action is approved by the QA/QC Officer. Its implementation is verified and documented on the corrective action form and is further documented through audits.

Information contained on corrective action forms is kept confidential within the laboratories and is generally limited to the individuals involved. Severe problems and difficulties may warrant special reports to the laboratory president, who will ensure that the appropriate corrective actions are taken.

13.3 CORRECTIVE ACTION DURING DATA VALIDATION AND DATA ASSESSMENT

As a means of oversight, the QAM may audit a percentage of the data validation, assessment, and evaluation deliverables generated/performed. Oversight audits may also be conducted directly by Navy personnel or by an independent data validation firm under contract to the Navy.

The need for corrective action may become apparent during data validation, interpretation, or presentation activities, or problems may be identified as a result of oversight findings. The performance of rework, instituting a change in work procedures, or providing additional/refresher training are possible corrective actions relevant to data evaluation activities. The contractor's Project Manager will be responsible for approving the implementation of corrective action.

13.4 CORRECTIVE ACTION FOR ADMINISTRATIVE ACTIVITIES

Findings identified by the conduct of office procedures and file audits may also necessitate the performance of corrective actions. Corrective actions involving file management and office procedures usually consist of correction of an isolated nonconformance or the performance of activities necessary to conform with clarified guidance.

FIGURE 13-1

FIELD TASK MODIFICATION REQUEST FORM
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Client Identification | Project Number | TMR Number

To_____ Location_____ Date_____

Description:

Reason for Change:

Recommended Disposition:

Field Operations Leader (Signature, if applicable) | Date

Disposition:

Project Manager (Signature, if required) | Date

Distribution:
Program Manager
Quality Assurance Officer
Project Manager
Field Operations Leader

Others as required_____

FIGURE 13-2

ANALYTICAL LABORATORY CORRECTIVE ACTION FORM
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Name:_____ Date:_____

Problem:

Samples Affected:

_____

Action Taken:

Name_____ Date:_____

_____

Action Taken:

Name_____ Date:_____

_____

Proof of Return to Control:

Supervisor:_____ QA/QC Officer:_____

Date:_____ Date:_____

14.0 QUALITY ASSURANCE REPORTS TO MANAGEMENT

QA reports to management will be provided in two primary formats during the course of NDW,IH investigations. Data validation letter reports will be prepared on a SDG-specific basis and will summarize QA/QC issues for the laboratory data. Monthly progress reports will be provided by the contractor's Project Manager.

14.1 CONTENTS OF PROJECT QUALITY ASSURANCE REPORTS

The data validation reports address all major and minor laboratory noncompliances, as well as noted sample matrix effects. In the event that major problems occur with the analytical laboratory (e.g., holding time exceedances or calibration noncompliances, etc.), the Data Validation Coordinator notifies the contractor's Project Manager, the Program Manager, and the Laboratory Services Coordinator. Such notifications (if necessary) are typically provided via internal memoranda and are placed in the project file. Such reports contain a summary of the noncompliance, a synopsis of the impact on individual projects, and recommendations regarding corrective action and compensational adjustments. Corrective actions are initiated at the program level.

The FOL will provide the contractor's Project Manager with weekly reports regarding accomplishments, deviations from the project-specific WP, upcoming activities, and a QA summary during the course of the field investigation. In addition, quarterly project review meetings are held for all active Navy CLEAN projects. Issues discussed at the project review meeting include all aspects of budget and schedule compliance and QA/QC problems. The contractor's Project Manager will provide a monthly progress report to the Navy that addresses the project budget, schedule, accomplishments, planned activities, required revisions of the QAPP, and QA/QC issues and intended corrective actions.

14.2 INDIVIDUALS RECEIVING/REVIEWING QUALITY ASSURANCE REPORTS

Data validation QA reports are provided to the contractor's Project Manager for inclusion in the project files. In the event that major problems are observed for a given laboratory, the Program Manager, Deputy Program Manager, QAM, contractor's Project Manager, and Laboratory Services Coordinator are provided with copies of the QA report. Weekly field progress reports are provided to the contractor's Project Manager. Monthly progress reports are provided to the Navy CLEAN Program Manager and the Navy.

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Master Work Plan

for

Installation Restoration Program Environmental Investigations

at

Naval District Washington, Indian Head

Indian Head, Maryland

Engineering Field Activity Chesapeake
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888

Contract Task Order 0805

June 2004

020404/P

MASTER WORK PLAN
FOR
INSTALLATION RESTORATION PROGRAM
ENVIRONMENTAL INVESTIGATIONS
AT
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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ACRONYMS

ACH	Air exchanges per hour
AOC	Area of Concern
ARAR	Applicable or Relevant and Appropriate Requirement
ARM	Anti-radiation missile
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient Water Quality Criteria
BAF	Bioaccumulation factor
BCF	Bioconcentration factor
BERA	Baseline ecological risk assessment
bgs	Below ground surface
BSAF	Biota-sediment accumulation factor
BTAG	Biological Technical Assistance Group
CAD	Cartridge-actuated device
Cal EPA	California Environmental Protection Agency
CDD	Chlorinated dibenzo-p-dioxin
CDF	Chlorinated dibenzofuran
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action Navy
cm^2	Square centimeter
CNI	Commander Navy Installations
COC	Chemical of concern
COMAR	Code of Maryland Regulations
COPC	Chemical of potential concern
CSF	Cancer slope factor
CSM	Conceptual site model
CTE	Central tendency exposure
CTO	Contract Task Order
CWA	Clean Water Act
DERP	Defense Environmental Restoration Program
DoD	Department of Defense
DQO	Data quality objective
EEQ	Ecological effects quotient
EFACHES	Engineering Field Activity Chesapeake
E/A&H	ENSAFE/Allen & Hoshall

EEQ	Ecological effects quotient
E.O.	Executive Order
EOD	Explosive ordnance disposal
EPC	Exposure point concentration
FFA	Federal Facility Agreement
FOL	Field Operations Leader
FS	Feasibility Study
FSP	Field Sampling Plan
GIS	Geographical information system
Hart	Fred C. Hart Associates, Inc.
HASP	Health and Safety Plan
HEAST	Health Effects Assessment Summary Tables
HHRA	Human health risk assessment
HI	Hazard index
HQ	Hazard quotient
HRS	Hazard Ranking System
HSWA	Hazardous and Solid Waste Amendments
IAS	Initial Assessment Study
ICR	Incremental cancer risk
IEUBK	Integrated Exposure Uptake Biokinetic
IHDIV-NSWC	Indian Head Division, Naval Surface Warfare Center
IR	Installation Restoration
IRIS	Integrated Risk Information System
L/kg	Liter per kilogram
L/m^3	Liter per cubic meter
LOAEL	Lowest-observed-adverse-effects-level
m^3/day	Cubic meter per day
MCL	Maximum contaminant levels
MCLG	Maximum contaminant level goal
MDE	Maryland Department of the Environment
MDNR	Maryland Department of Natural Resources
mg/cm^2	Milligrams per square centimeter
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
MRL	Minimal risk level
msl	Mean sea level
NAVEODTECHDIV	Naval Explosive Ordnance Disposal Technology Division

NAVSCOLEOD	Naval School Explosive Ordnance Disposal
NCEA	National Center for Environmental Assessment
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NDW	Naval District Washington
NDW,IH	Naval District Washington, Indian Head
NHANES	National Health and Nutrition Examination Survey
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No-observable-adverse-effects-level
NOS	Naval Ordnance Facility
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
OPPTS	Office of Prevention, Pesticides, and Toxic Substances
ORNL	Oak Ridge National Laboratory
OSWER	Office of Solid Waste and Emergency Response
PA	Preliminary Assessment
PAD	Propellant-actuated device
PAH	Polynuclear aromatic hydrocarbon
PCB	Polychlorinated biphenyl
POC	Point of Contact (NDW,IH)
POTW	Publicly owned treatment works
PPRTV	Provisional peer reviewed toxicity value
QAPP	Quality Assurance Project Plan
RA	Remedial Action
RAGS	Risk Assessment Guidance for Superfund
RBC	Risk-based concentration
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RDT&E	Research development testing and evaluation
RfD	Reference dose
RI	Remedial Investigation
RME	Reasonable maximum exposure
ROD	Record of Decision
RPM	Remedial Project Manager (Navy)
SARA	Superfund Amendments Reauthorization Act
SDWA	Safe Drinking Water Act
SEALOG	Naval Sea Logistics Center, Atlantic
SERA	Screening level ecological risk assessment

SI	Site Inspection
SMDP	Scientific management decision point
SMP	Site Management Plan
SOP	Standard operating procedure
SRA	Screening risk assessment
SSA	Site screening area
SSL	Soil screening level
SSP	Site screening process
SWMU	Solid waste management unit
TBC	To Be Considered
TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
TEF	Toxicity equivalence factor
TIC	Tentatively identified compound
TOC	Total organic carbon
TRV	Toxicity reference value
TRW	Technical Review Workgroup
TtNUS	Tetra Tech NUS, Inc.
UCL	Upper confidence limit
µg/dL	Microgram per deciliter
µg/L	Microgram per liter
UMD	University of Maryland
USACE	United States Army Corps of Engineers
USC	United States Code
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
VDEQ	Virginia Department of Environmental Quality
VF	Volatilization factor
WP	Work Plan
ºF	Degree Fahrenheit

1.0 INTRODUCTION

This Master Work Plan (WP) was prepared for the Naval District Washington, Indian Head[1] (NDW,IH) in Indian Head, Maryland and the Engineering Field Activity Chesapeake (EFACHES), under the Comprehensive Long-Term Environmental Action Navy (CLEAN), Contract Number N62467-94-D-0888, Contract Task Order (CTO) 0805. This Master WP presents general background and environmental information for the Facility (consisting of the main area on Cornwallis Peninsula and the Stump Neck Annex on Stump Neck Peninsula), describes development of this Master WP and its integration with project-specific planning documents, summarizes the overall scope and objectives of environmental investigations at the Facility, outlines the procedures for implementation of environmental investigations, and describes how sites will be evaluated in terms of risk. Project-specific planning documents will be written as supplements to this Master WP.

1.1 SUMMARY OF PLANNING DOCUMENTS

This Master WP is part of a set of master planning documents that define the procedures and policies for performing environmental investigations at the main area of the Facility. The other master planning documents include:

- Master Quality Assurance Project Plan (QAPP)
- Master Field Sampling Plan (FSP)
- Health and Safety Plan (HASP) Guidance Document (Master HASP)
- Facility Standard Operating Procedures (SOPs).

Project-specific planning documents will be prepared for individual tasks. They will refer to the master planning documents where appropriate and provide project-specific information and reference the Facility SOPs for proposed sampling and analysis methods and procedures.

The procedures and policies in the master planning documents are for conducting environmental investigations at the Facility as part of the Navy Installation Restoration (IR) Program. They were developed to comply with applicable tenants established in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as implemented through the National Oil and Hazardous

[1] On 1 October 2003, the installation management functions at Indian Head transferred from Indian Head Division/Naval Surface Warfare Center to Naval District Washington. References to this Installation will now be Naval District Washington, Indian Head.

Substances Pollution Contingency Plan (NCP). Additional guidance for conducting such activities is contained in the United States Environmental Protection Agency (USEPA) Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988c) and the Department of the Navy Installation Restoration Manual (Draft) (Navy, 2001). Further discussion of the Navy IR Program is presented in Section 1.4.

1.2 LOCATION AND GENERAL DESCRIPTION

NDW,IH is located in the northwestern section of Charles County, Maryland, approximately 25 miles south of Washington DC. The Facility consists of two areas: the main area and Stump Neck Annex. The areas are located on two separate peninsulas along the eastern shore of the Potomac River. The main area is on the Cornwallis Neck Peninsula, and the Annex is on the Stump Neck Peninsula. Figure 1-1 illustrates the general location of the Facility. The main area on Cornwallis Peninsula covers approximately 2,034 acres and is bounded by the Potomac River to the north and west, Mattawoman Creek to the south and east, and the Town of Indian Head to the east. The Stump Neck Annex covers approximately 1,100 acres and is bounded by the Potomac River to the north, Chicamuxen Creek to the south, and private residential property to the east.

On October 1, 2003, the Navy established a new Echelon II Navy Command, Commander Navy Installations (CNI). Under CNI, all shore installation management functions for Navy facilities in the National Capital area transferred to Naval District Washington (NDW). Shore installation management functions include buildings, roads, utilities, security and fire protection, childcare, and quality of life. As a result, the responsibility for providing these regional common operating support services at Indian Head has transferred to NDW. Therefore, NDW is now the landlord or "host" of the Facility. As of February 2004, the name of the Facility has yet to be officially assigned. In the interim, the Facility is referred to as NDW,IH.

As NDW,IH's largest tenant command, Indian Head Division, Naval Surface Warfare Center (IHDIV-NSWC) operations are primarily located on the main area of the Facility. IHDIV-NSWC's principal mission on the main area is to:

- Provide services in energetics for all warfare centers through engineering, fleet and operational support, manufacturing technology, limited production, and industrial base support.

- Provide research, development, testing, and evaluation of energetic materials, ordnance devices and components, and other related ordnance engineering standards including chemicals, propellants and their propulsion systems, explosives, pyrotechnics, warheads, and simulators.

- Provide support to all warfare centers, military departments, and the ordnance industry for special weapons, explosive safety, and ordnance environmental issues.

The Stump Neck Annex of NDW,IH is primarily occupied by the Naval School Explosive Ordnance Disposal (NAVSCOLEOD) and the Naval Explosive Ordnance Disposal Technology Division (NAVEODTECHDIV) tenant commands.

Currently, NAVEODTECHDIV is the primary tenant at the Stump Neck Annex. The mission of NAVEODTECHDIV is to:

- Provide explosive ordnance disposal (EOD) technology and logistics management.

- Develop war-essential elements of intelligence, equipment, and procedures to counter munitions, both United States and foreign, as required to support Department of Defense (DoD) components and the peacetime security needs of other agencies.

The mission of NAVSCOLEOD is to train active military personnel in performing EOD operations. In 1998, most operations at NAVSCOLEOD relocated to Pensacola, Florida, although a small detachment of the school remained and continues to operate at the Facility.

1.3 FACILITY HISTORY

The Facility was established in 1890 as the Naval Proving Ground on the 659 acres of the Cornwallis Neck Peninsula. One year later, an adjacent tract of 222.75 acres, known as Mount Pleasant Farm, was acquired. Powder, fuses, and cartridge casings purchased by the Navy and naval guns manufactured at the Washington Navy Yard were tested for quality assurance and control at the Naval Proving Ground. Projectiles were also field tested at the Naval Proving Ground. In 1900, the Facility began producing smokeless powder to supply the entire United States naval fleet.

In 1901, the 1,084 acres of Mason's Enlargement, now known as Stump Neck, were purchased. This property was often shelled for gun testing. Between 1904 and 1907, the powder factory on the Cornwallis Neck Peninsula was expanded, and a powder re-working facility was constructed. In 1915, plants were added for the production of sulfuric and nitric acid because of the escalating costs of commercial acid. An ammonium picrate plant was built in the same year and operated for the next 5 years. Ammonium picrate (Explosive D) was combined with black powder for use in projectiles and valued for its insensitivity to shock and friction.

During World War I, the Naval Proving Ground established extensive propellant manufacturing, experimental, and test programs. It produced 10 million pounds of smokeless powder and reworked 800,000 pounds of smokeless powder over the course of the war. In 1918, the Facility was enlarged by the purchase of 1,368 acres of adjacent land, and a 13.8-mile railroad spur was laid from the Naval Proving Ground to the Pennsylvania Railroad junction at White Plains, Maryland.

For a brief period in the early 1920s, Dr. Robert H. Goddard conducted research and development of rocket propellants at NDW,IH.

The proofing of all Naval guns continued at the Naval Proving Ground until 1921 when this activity was relocated to a NDW,IH-administered detachment at Dahlgren, Virginia. The activity was moved to Dahlgren because the safety limits for new shots and shrapnel exceeded the boundaries of the Facility. In 1932, the Facility was redesignated the Naval Powder Factory, and the facility at Dahlgren became the Naval Proving Ground.

With the onset of World War II, fundamental research was conducted in rocketry and rocket propellant grains for bombardment rockets, bazookas, and air-to-ground anti-tank weapons, beginning in 1940. A new Explosive D plant was completed in 1942, and an extrusion plant for the production of double-base propellants began operations in 1943. An ammonia oxidation plant came into operation in 1945 to improve nitric acid production. During World War II, the Naval Powder Factory produced an average of 48 tons of nitric acid a day and 4 million pounds of Explosive D a month.

As the war ended, the mission of the Facility was expanded into propellant research and development. A pilot plant constructed in 1949 was responsible for research and development of solid propellants for new rockets and guided missiles.

Beginning in 1950, the Naval Powder Factory returned to major production for the Korean War with an emphasis on double-base and high-energy casting powders. Four additional manufacturing plants for nitroglycerin, cast propellants, cordite, and nitroguanidine were constructed. In 1958, the Facility became known as the Naval Propellant Plant.

In support of the Polaris missile program, 23 new buildings were constructed in 1960 for base grain manufacturing. In the following year, a computer facility was completed for ballistic evaluation, and the first nitroplasticizers were produced for the program. In 1962, the Facility had the capability of manufacturing space rocket propellant and developed a new liquid monopropellant for use in the Mark 46 and 48 torpedoes. It also had developed inert-diluent and pneumatic mixing processes.

In 1966, the Facility was redesignated to the Naval Ordnance Station (NOS). It subsequently approached maximum production during the Vietnam War. Land on Bullitt's Neck (47 acres) and Rum Point (83 acres) was acquired in 1965 and 1966 to satisfy increased quantity distance arc requirements. In the late 1960s, the Facility began producing propellant and casting powder for the Poseidon missile, and the inert-diluent and pneumatic mix processes were added.

In 1971, the Department of the Navy was designated as the single manager for explosive ordnance disposal, which is conducted at NAVEODTECHDIV on Stump Neck Annex. In 1976, NOS was assigned the task of production of standard anti-radiation missile (ARM) motors.

In recent years, the Facility has been involved with the development of electronic missile simulators and air-crew escape propulsion systems. A resulting product line is the cartridge-actuated device (CAD)/propellant-actuated device (PAD) program. These devices provide the various energy sources to perform the many functions required to eject and parachute air crews to safe recovery. They also provide the energy for a myriad of other functions such as stores release, cable cutting, inflation, etc. The Facility is the DoD manager for CADs and PADs. The CAD/PAD program is designed to eliminate duplication of effort within DoD.

In 1992, the Facility became a division of the newly formed Naval Surface Warfare Center. As a result of the “BRAC 93” decision, the NDW,IH was established as the Navy's single-site, full-spectrum energetics center with the transfer of the Navy's principal research, development, test, and evaluation (RDT&E) capability for explosives, components, and warheads technology from White Oak to Indian Head. NDW,IH’s role is to provide expertise in the field of energetics to the other members of the center and the other warfare centers established in the underwater and air warfare areas. The NDW,IH is a facility able to synthesize propellants and explosives from design to full-scale production.

On October 1, 2003, the Navy established a new Echelon II Navy Command, CNI with the mission to provide consistent effective and efficient shore installation services and support to sustain and improve current and future fleet readiness and mission execution. Under CNI, National Capital area Navy facilities’ shore installation management functions transferred to NDW. Shore installation management functions include buildings, roads, utilities, security and fire protection, childcare, and quality of life. As a result, the responsibility for providing these regional common operating support services at Indian Head has transferred to NDW. Therefore, NDW is now the landlord or “host” of the Facility. As of February 2004, the name of the Facility has yet to be officially assigned. In the interim, the Facility is referred to as NDW,IH.

In this capacity, NDW,IH is host to a multi-mission military installation. NDW,IH’s major tenant commands performing critical missions for the military include:

- IHDIV-NSWC
- NAVEODTECHDIV
- Naval Ordnance Safety and Security Activity
- Naval Sea Logistics Center, Atlantic (SEALOG)
- Joint Interoperability Test Command
- United States Marine Corps Chemical Biological Incident Response Force

1.4 NAVY INSTALLATION RESTORATION PROGRAM/CERCLA HISTORY

Identification, investigation, and cleanup of hazardous waste sites at the Facility are conducted under the auspices of the Department of the Navy IR Program. This program is designed to identify, assess, characterize, and cleanup or control contamination from past hazardous waste disposal operations and hazardous materials spills at Navy and Marine Corps activities. CERCLA and its implementing regulation, NCP, established a series of programs for the cleanup of hazardous waste disposal and spill sites nationwide. One of these programs, the Defense Environmental Restoration Program (DERP), is codified in the Superfund Amendments Reauthorization Act (SARA) Section 211 [10 United States Code (USC) 2701]. The IR Program is a component of the DERP.

The IR Program provides a structured but flexible approach for identifying, evaluating, and cleaning up sites where hazardous substances have been released to the environment for which the Department of the Navy is responsible. Initial guidance for the Navy's IR Program was published in May 1988. The IR Manual was revised in 1992 to represent a compilation of DERP requirements, policy, and guidance for both the United States Navy and the United States Marine Corps and updated to incorporate the many changes that have occurred in the IR Program since 1988. The latest version of the manual is entitled Department of the Navy Installation Restoration Manual (Draft) (Navy, 2001).

The IR Program is comprised of three distinct phases: Preliminary Assessment (PA)/Site Inspection (SI), Remedial Investigation (RI)/Feasibility Study (FS), and Remedial Design (RD)/Remedial Action (RA).

- **PA/SI**. The PA is a basic record search and personnel interview process that locates sites on a base that may be candidates for inclusion in the IR Program. The SI is a more detailed investigation, which includes actual site inspection and sampling and laboratory analysis to determine if site contamination is present. Based on the results of the SI, a site may be included in the IR Program or removed from further consideration.

- **RI/FS**. The RI is a thorough, physical site investigation to determine the nature and extent of contamination at a site. This phase typically includes tasks for quantitative risk assessment. A risk assessment can be performed for both human and ecological receptors. The FS is an assessment of the possible engineering solutions for site remediation and a cost and benefit analysis of each of the alternatives. The FS recommends a single course of action and leads to a Record of Decision (ROD), which is the formal approval of the plan by the agencies involved.

- **RD/RA**. The RD provides a detailed, comprehensive design for implementation of the action recommended by the FS. The RA is the implementation of the RD. The goal of the RD/RA is that no further action is necessary except continued monitoring. An RA may be initiated at any time during the remedial process for expedition of cleanup.

Cleanup goals are determined on an individual site basis. All Applicable or Relevant and Appropriate Requirements (ARARs) of federal and State laws are considered in setting cleanup goals and selecting the methods for cleanup. Overall, CERCLA is, by regulation, risk driven, and requires the evaluation of human health and environmental risks.

1.5 GEOGRAPHIC INFORMATION SYSTEM

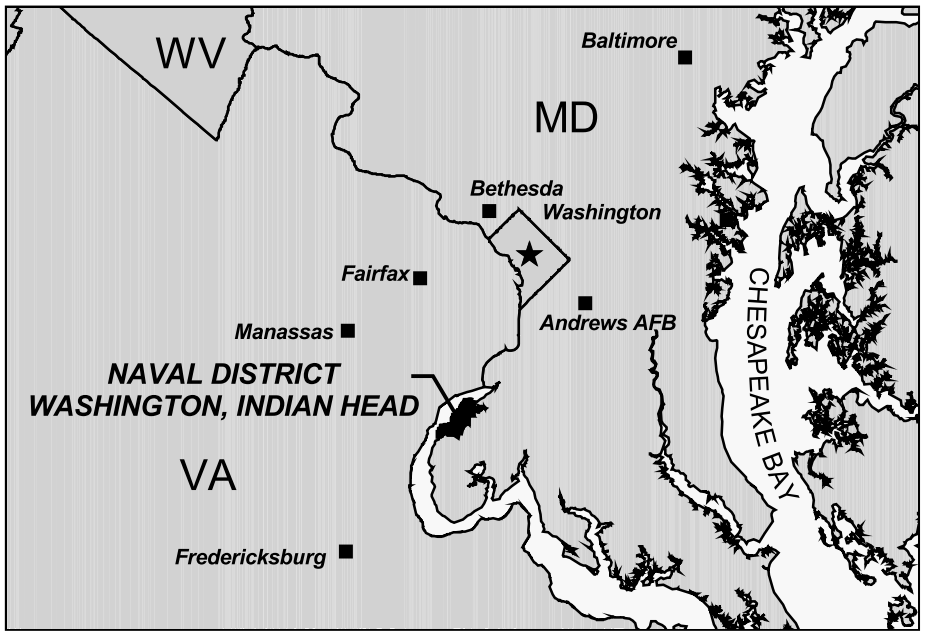
A geographical information system (GIS) has been developed and is maintained by the Facility. GIS integrates maps, tabular data, charts, and images from a variety of sources. These capabilities enable the user to analyze data and define relationships between tabular and geographic features. The products of GIS functions are detailed tables, maps, and charts based on specific, user-selected criteria.

The geographic extent of the NDW,IH GIS includes the main area, Stump Neck Annex, Nanjemoy Creek and land masses contained within the Mattawoman Creek study area. The GIS developed for NDW,IH is comprised of data obtained from NDW,IH, surveyors, and field studies. Types of coverages maintained by the Facility include buildings, roads, property boundaries, solid waste management unit (SWMU) boundaries, installation restoration (IR) site boundaries, flora, fauna, hydrology, topology, groundwater monitoring well locations, and utilities. The GIS system also provides a retrievable record of areas on the Facility that are subject to use restrictions due to the presence of contamination. Contractors commonly maintain databases that include soil and water chemical analytical data and the locations of environmental samples (soil, sediment, and surface water).

1.6 WORK PLAN ORGANIZATION

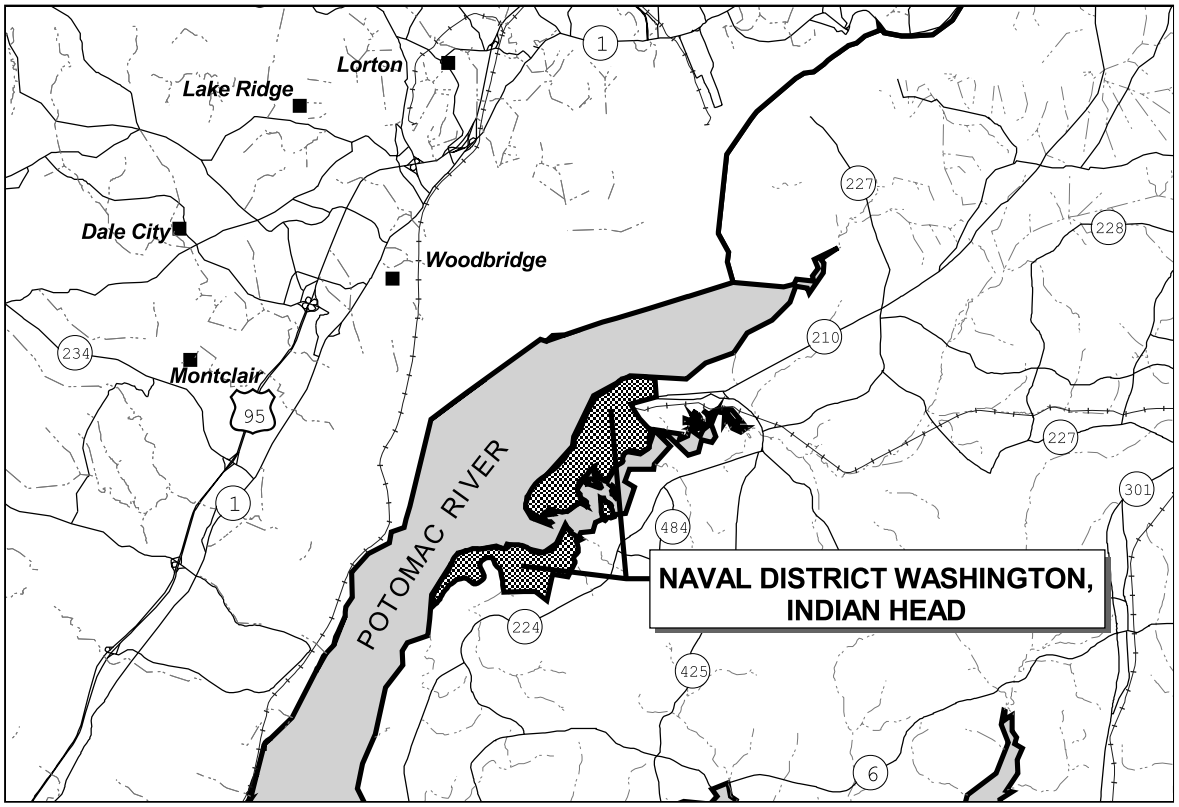
This Master WP is organized into seven sections. Section 1 provides a brief discussion of the planning documents in the set of master documents, a general description of the Facility and its history, and issues

concerning the environment. Section 2 provides a detailed physical description of the Facility. Sections 3 and 4 describe how human health and ecological risk assessments, respectively, will be performed for the Facility. Section 5 describes the development of the Master WP and its integration with project-specific WPs and the process of development of data quality objectives (DQOs). Section 6 outlines the regulatory requirements for the history of environmental study at the Facility. Section 7 outlines the management and execution of various aspects of the environmental investigations and actions.



LEGEND

- City
- Highway
- Railroad
- River



DRAWN BY K. PEILA — DATE 2/4/04	Tetra Tech NUS, Inc.	CONTRACT NUMBER 4020	OWNER NO. CTO 0805
CHECKED BY G. LATULIPPE — DATE 2/2/04	FACILITY LOCATION MAP NAVAL DISTRICT WASHINGTON, INDIAN HEAD INDIAN HEAD, MARYLAND	APPROVED BY GJL — DATE 6/4/04	
COST/SCHEDULE-AREA		APPROVED BY — — DATE —	
SCALE AS NOTED		DRAWING NO. FIGURE 1-1	REV 0

P:\GIS\NSWC_INDIAN_HEAD\WORKPLAN_SITELOCATION.APR FACILITY LOCATION MAP 8/2/04 KMP

2.0 BACKGROUND INFORMATION

This section provides background information about the Facility and surrounding region in the following areas:

- Land use
- Water sources and usage
- Population
- Facility access
- Regional geology
- Regional hydrogeology
- Facility hydrology
- Facility ecology
- Meteorology

2.1 LAND USE

According to the Initial Assessment Study (IAS) (Hart, 1983), NDW,IH covers approximately 2,034 acres on the Cornwallis Neck peninsula in Charles County. Of this area, explosive production and storage activities occupy 1,494 acres, EOD classrooms and field training areas occupy 60 acres, administrative operations occupy 280 acres, and military housing and personnel support occupy 200 acres. There are approximately 1,040 buildings on the Facility. There are also over 30 miles of steam distribution lines, a power plant, and a water and sewage treatment plant on the Facility.

Also according to the IAS, Stump Neck covers approximately 1,162 acres. Of that total, 635 acres are devoted to explosive operations, 486 acres are utilized as a military training area, and 41 acres are occupied by housing and personnel support facilities.

The area adjoining the Facility to the northeast is residential and under the authority of the Town of Indian Head.

2.2 WATER SOURCES AND USAGE

The Facility is the largest user of groundwater in the area with average daily withdrawals of approximately 1 to 2 million gallons (Hiortdahl, 1990). Drinking water and industrial process water are supplied by production wells screened in either the Patapsco Formation or the Arundel or Patuxent Formations,

ranging in depth from 190 to 450 feet. Currently, 10 production wells are in use at the Facility (eight on the Main Area and two on Stump Neck). The locations of those wells are shown on Figures 2-1 and 2-2.

Two principal waterways bound the Cornwallis Neck peninsula, the Potomac River and Mattawoman Creek. The Potomac River is the major waterway in the area and lies west of the Facility. It is classified by the State of Maryland for Class I (Water Contact Recreation and Aquatic Life) use in the area of the Facility and Class II (Shellfish Harvesting Waters) use downstream of the Facility. The Facility draws water from the Potomac River to charge the onsite fire protection system. According to the IAS (Hart, 1983), the Facility withdraws up to 3 million gallons of water a day from the Potomac River. Mattawoman Creek is a tributary to the Potomac River and is east of the Facility. It is classified for Class I use by the State of Maryland.

2.3 POPULATION

The population of NDW,IH is approximately 4,050. This includes approximately 2,200 civilian employees, 500 military personnel, 800 contractor personnel, and 550 military dependants. Based on the 2000 United States Census Bureau estimates, the population of the Town of Indian Head is approximately 3,422, and the total population of Charles County is 120,546.

2.4 FACILITY ACCESS

The Facility is accessible from Washington DC. by Maryland State Route 210. Air service is from Ronald Reagan Washington National Airport, Baltimore-Washington DC. International Airport, or Dulles International Airport. A railroad connected the Facility to White Plains, Maryland, for shipment of products and bulk deliveries. There were rail connections from the main spur to all parts of the Facility. The Facility also had docking facilities along the Potomac River for river service. Both the railway and docking facilities are inactive.

2.5 REGIONAL GEOLOGY

2.5.1 Physiography and Topography

The facility is located in the western portion of Charles County, which lies within the Atlantic Coastal Plain Physiographic Province, approximately 8 to 10 miles east of the Fall Line that marks the western extent of the physiographic province. NDW,IH has gently rolling to undulating topography with elevations ranging from sea level to greater than 100 feet above mean sea level (msl). The higher elevations exist in the western portion of the Facility. Generally, the land surface slopes to the southwest and southeast. The

western side of the Facility, along the Potomac River, is characterized by 20- to 100-foot bluffs, and the eastern side, along Mattawoman Creek, is more gently sloping.

2.5.2 Geology

The regional geology consists of a sedimentary wedge of Cretaceous to Quaternary fluvial and marine deposits overlying crystalline Precambrian metamorphic and igneous bedrock. The sedimentary wedge dips and thickens eastward and ranges in thickness from 650 to 900 feet (Vroblesky, 1991). It lies unconformably on the crystalline basement rock surface, which dips to the east. In stratigraphically ascending order, the sedimentary units underlying NDW,IH are the Cretaceous Potomac Group, the Tertiary Aquia and Park Hall Formations, and Quaternary fluvial and estuarine deposits.

The Potomac Group consists of three units (in descending stratigraphic order): the Patapsco Formation, the Arundel Formation, and the Patuxent Formation. The Potomac Group consists of interbedded clay, silt, sand, and gravel deposited in fluviodeltaic environments (Hiortdahl, 1990) and ranges in thickness from 650 to 750 feet (Vroblesky, 1991; Harsh, 1990). The upper 100 feet of the Patapsco Formation outcrops along the western bluffs of the peninsula along the Potomac River. The middle and lower units of the Patapsco subcrop below the Potomac River (Hiortdahl, 1990). The Arundel Formation and Patuxent Formation consist of clays with interbedded sand units.

The Aquia Formation consists of glauconitic sand interbedded with sand, silt, and clay. The unit is Tertiary in age and generally less than 20 feet in thickness. The other Tertiary unit in the area is the Park Hall Formation. It is fluvial and estuarine deposits of sand and clay interbedded with sand with gravel and is overlain unconformably by Quaternary deposits (McCartan, 1989).

Quaternary deposits at NDW,IH consist of Pleistocene paleochannel deposits and Holocene alluvial deposits (Hiortdahl, 1990). These deposits are not expected to exceed 40 feet in thickness (AWARE, 1982) and consist of sand, silt, and clay mixtures with irregular bedding (Hart, 1983).

2.5.3 Soils

The dominant soil series on the Cornwallis Neck peninsula are the Beltsville, Keyport, and Elkton Silt Loams (Hart, 1983; USDA, 1974). The Beltsville Silt Loam is found primarily in the upland elevations of the northern end of the Facility, roughly north of Bronson Road. The Beltsville series consists of silt and sand with moderate amounts of clay. These soils are nearly level to moderately sloping and slowly permeable but well drained (USDA, 1974). In addition to the Beltsville Silt Loam, areas of cut-and-fill soils are found in the northern end of the Facility. Cut-and-fill lands are areas where the native soils have been removed and graded or filled with other material or soil. The Keyport and Elkton Silt Loams are

found in the lower elevations of the southern end of the Facility, roughly south of Bronson Road. They are both clayey silt loam soils. Both series are slowly permeable; however, the Elkton series is less permeable than the Keyport series.

The areas along streams and bordering the major waterways are predominantly cut-and-fill lands, gravelly lands, and tidal marshes. The gravelly lands consist of gravelly deposits with soil types unidentifiable due to erosion. Tidal marshes consist of sand to clay and some peat (Hart, 1983).

2.6 REGIONAL HYDROGEOLOGY

The Patapsco and Patuxent Formations of the Potomac Group are the main groundwater aquifers used in the area. The Patapsco Formation is the principal aquifer for Charles County. The three principal water-bearing zones within the formation are the Lower, Middle, and Upper Sands. They are under confined conditions. The Lower Sand outcrops in Virginia; the Middle Sand outcrops below the Potomac River and in Virginia; and, the Upper Sand outcrops beneath the Potomac River. The water-bearing zones of the Patuxent Formation are laterally discontinuous sand zones. Recharge of the Patuxent Formation occurs in Virginia, where it outcrops.

Groundwater elevations of the Potomac Group measured in 1990 indicate a cone of depression in the Cornwallis Neck peninsula area (Hiortdahl, 1990). The area of influence extends for approximately 6 miles in the northeastern and southwestern direction and approximately 2 to 3 miles in the northwestern and southeastern direction. The cone of depression is a result of the heavy pumping on the peninsula for the past 90 years. Under natural conditions, groundwater would flow east-southeast, following the dip of the formations in the area.

2.7 FACILITY HYDROLOGY

The three principal waterways in the vicinity of the Facility are the Potomac River, Mattawoman Creek, and Chicamuxen Creek. The Potomac River is a tidally influenced estuary and slightly brackish. Mattawoman Creek and Chicamuxen Creek are tributaries to the Potomac River and are also tidally influenced. Tidal marshes exist along Mattawoman Creek and Chicamuxen Creek.

Natural drainage from the Facility is predominately to Mattawoman Creek with the remaining drainage flowing to the Potomac River. A drainage divide extends down the length of the peninsula and roughly parallels Route 210. Drainages east of the divide flow to Mattawoman Creek; drainages west of the divide flow into the Potomac River.

Some facility waste waters are discharged directly to the Potomac River or Mattawoman Creek from outfalls throughout the facility to tributaries of the Potomac River or to Mattwoman Creek. The waste waters consist of industrial (generally non-contact cooling water) and storm effluents. A majority of the process waste waters that previously discharged directly to the Potomac River or Mattawoman Creek either no longer exist, or are now treated at the sewage treatment plant, which discharges to the Potomac River.

Shallow, unconfined to semiconfined groundwater at the Cornwallis Neck peninsula occurs from near surface to approximately 45 feet below ground surface (bgs), with water-table elevations ranging from sea level to approximately 65 feet above msl. Typically, the shallow groundwater occurs in perched water-bearing zones and is recharged from infiltration (Hart, 1983; Slaughter and Otton, 1968). In some lowland areas, surface water intrusion may be an additional source of recharge of the shallow aquifer along the edges of water bodies and during periods of high tide. It is assumed that shallow groundwater flow follows topography and discharges into local water bodies.

2.8 FACILITY ECOLOGY

The information in the following section was obtained from the IAS (Hart, 1983) and University of Maryland State Climatologist Office (UMD, 2002), except where noted.

2.8.1 Flora

Approximately 35 percent of the Facility is wooded. The forests consist of hardwoods, including oak and hickory, and Loblolly and Virginia pines. The upland areas are characterized by older growth pines and oaks, whereas the lower elevations are composed of sycamore, ash, elm, and sweet gum.

About 53 percent of the Facility is open field and shrub vegetation. Loblolly pine, sweet gum, red cedar, and black locust are typical of these communities.

Along the shoreline and beaches of the Potomac River, black persimmon, false indigo, poison ivy, sea myrtle, grape and Virginia creeper are present along with phlox, gama grass, panic grass, Bermuda grass, or finger grass. Marsh areas predominate Mattawoman Creek and are characterized by jewelweed, alger, marsh cattail, weedgrass, sedge, three square bulrush, wild rice, saltmarsh cordgrass, smartweed, and marsh mallow.

2.8.2 Wildlife

The ecosystem at the Facility supports a variety of animal life. Deer are abundant on the Facility. Other common mammals include possum, bats, squirrels, mice, raccoon, woodchuck, rabbits, and other burrowing rodents such as voles and shrews. The birds found within Charles County include grebes, herons, ducks, geese, hawks, kestrels, osprey, eagles, gulls, owls, gulls, and perching birds such as robins, warblers, and jays. Common reptiles and amphibians of Charles County include lizards, snakes, turtles, salamanders, frogs, and toads.

2.8.3 Aquatic Life

The area of the Potomac River adjacent to the Facility is part of the spawning and nursery area for striped bass, white perch, herring, and shad. Bay anchovies and three species of silversides also spawn and nurse within this area. The area is the upstream limit of the nursery area for estuarine-dependent species including the Atlantic menhaden and Atlantic croaker. Mattawoman Creek is a spawning area for blueback herring, white and yellow perch, and gizzard shad.

2.8.4 Threatened and Endangered Species

A rare, threatened, and endangered species and natural area survey was performed at NDW,IH by the Maryland Natural Heritage Program (MDNR, 1992). More current lists (July 5, 2001), but covering all of Charles County, are found on the Maryland Department of Natural Resources (MDNR) Wildlife and Heritage Service internet site at http://www.dnr.state.md.us/wildlife/espaa.html. A comparison of the rare, threatened, and endangered species found on the Facility during the 1992 survey with the more current Charles County survey dated 2001 yields the following:

- Threatened animal species are limited to the bald eagle (*Haliaeetos leucocephalus*).

- Endangered animal species are limited to the frosted elfin (*Incisalia irus*).

- Rare animal species include the treetop emerald (*Somatochlora provocans*) and the Carolina satyr (*Hermeuptychia sosybius*).

- Threatened plant species are limited to the narrow melicgrass (*Melica mutica*).

- Rare plant species include the tickseed sunflower (*Bidens coronata*), the large-seeded forget-me-not (*Myosotis macrosperma*), and the small-flowered baby-blue-eyes (*Nemophilia aphylla*).

2.9 METEOROLOGY

NDW,IH is located in the Atlantic Coastal Plain on the eastern bank of the Potomac River, midway between the rigorous climate of the north and the mild climate of the south. Because NDW,IH is located in the middle latitudes where the general atmospheric flow is from west to east across North America, it has a continental-type climate with four well-defined seasons. However, the proximity of the Potomac River and its tributaries has a considerable modifying effect on the climate, especially in moderating extreme temperatures.

Indian Head experiences a modified moist, humid continental climate with warm and wet summers and cool winters. The Appalachian and Blue Ridge Mountain Ranges to the west obstruct cold, continental air in the winter, and the Potomac River and Atlantic Ocean contribute to more moderate temperatures and higher humidity.

The annual average temperature (1971 to 2000) is 56 degrees Farenheit (°F) (UMD, 2002). The warmest month is typically July, with an average temperature of 76 ºF, and January is the coldest month, with an average temperature of 35 ºF. The average annual precipitation is approximately 44 inches, and the average monthly precipitation varies from 2.85 (in February) to 4.60 (in August) inches.

Prevailing surface winds are from the west-northwest to northwest except during the warm months of the year, when they become more southerly. The periods with most wind occur in late winter and early spring. The growing season is approximately 187 days long.

More detailed data are presented in Tables 2-1, 2-2, and 2-3.

TABLE 2-1

TEMPERATURE DATA FOR LAPLATA, CHARLES COUNTY, MARYLAND
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Month	Average[1] Maximum Temperature[2]	Average[1] Minimum Temperature[2]	Average[1] Temperature[2]	Average[1] Monthly Precipitation	Extreme[3] Maximum Temperature	Most Recent Date of Extreme Maximum	Extreme[4] Minimum Temperature	Most Recent Date of Extreme Minimum
January	44	26	35	3.42	79	1/26/1950	(8)	1/22/1984
February	48.5	28.4	38.5	2.85	81	2/24/1985	(2)	2/18/1979
March	57.8	35.4	46.6	3.96	91	3/30/1998	1	3/11/1960
April	68.4	43.2	55.8	3.11	95	4/18/1976	20	4/7/1982
May	74.6	53.2	63.9	4.13	96	5/20/1996	29	5/9/1956
June	81.2	61.9	71.6	3.81	100	6/26/1952	39	6/2/1966
July	84.8	66.8	75.8	4.12	103	7/31/1954	46	7/1/1988
August	83.4	65.4	74.4	4.6	102	8/31/1953	45	8/29/1986
September	77.9	58.7	68.3	4.31	103	9/10/1983	31	9/21/1956
October	68	47.1	57.6	3.36	96	10/4/1954	19	10/24/1969
November	58.6	38.1	48.4	3.21	86	11/2/1971	9	11/29/1955
December	48.2	30.1	39.2	3.16	77	12/16/1971	1	12/26/1980
Annual	66.3	46.2	56.3	44.04	--	--	--	--

1 Averages are calculated using data collected from 1971 through 2000.
2 Temperatures in degrees Fahrenheit. Temperatures below zero degrees Fahrenheit presented in parentheses.
3 Extreme Maximum Temperatures from 1948 through 1998.
4 Extreme Minimum Temperatures from 1948 through 1998.

Source: Maryland State Climatologist Office, University of Maryland College Park, Department of Meteorology, November 2002.
http://www.atmos.umd.edu/~climate/

TABLE 2-2

PRECIPITATION DATA FOR LAPLATA, CHARLES COUNTY, MARYLAND
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Month	Average[1] Monthly Precipitation[2]	Maximum[3] Daily Precipitation	Most Recent Date of Maximum Daily Precipitation
January	3.42	2.37	1/27/1976
February	2.85	2.2	2/23/1994
March	3.96	2.38	3/26/1978
April	3.11	2.16	4/14/1970
May	4.13	2.23	5/16/1983
June	3.81	7.49	6/22/1972
July	4.12	4.2	7/13/1975
August	4.60	9.8	8/27/1971
September	4.31	5.21	9/13/1989
October	3.36	5.45	10/14/1955
November	3.21	2.64	11/28/1993
December	3.16	2.4	12/21/1951
Annual	44.04	9.8	8/27/1971

1 Averages are calculated using data collected from 1971 through 2000.
2 Precipitation in inches.
3 Maximum daily precipitation from 1948 through 1998.

Source: Maryland State Climatologist Office, University of Maryland College Park, Department of Meteorology, November 2002. http://www.atmos.umd.edu/~climate/

TABLE 2-3

MISCELLANEOUS WEATHER DATA FOR LAPLATA, CHARLES COUNTY, MARYLAND
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Data Category	Average Number of Days	Average Date of First Occurrence	Average Date of Last Occurrence
Minimum Temperature[1] Less Than or Equal to 32 Degrees	96	October 24	April 20
Maximum Temperature[1] Less Than or Equal to 32 Degrees	8	December 21	February 11
Maximum Temperature[1] Greater Than or Equal to 90 Degrees	24	May 25	September 3
Growing Season [2]	187	N/A	N/A

1 Temperatures in degrees Fahrenheit.
2 The growing season is defined as the number of days between the last 32 degrees Fahrenheit temperature in the spring and first in the fall.
N/A Not applicable.

Source: Maryland State Climatologist Office, University of Maryland College Park, Department of Meteorology, November 2002. http://www.atmos.umd.edu/~climate/

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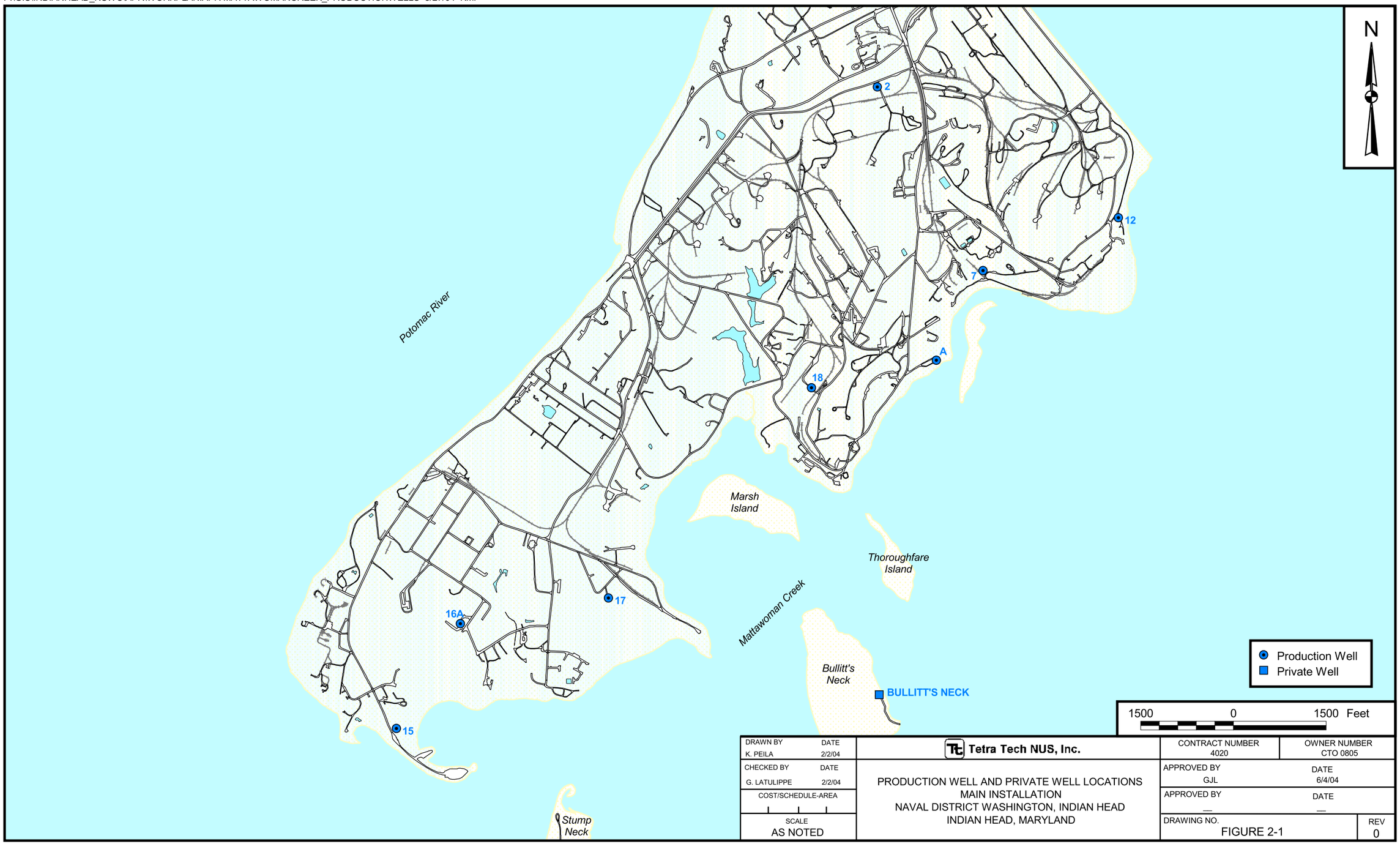

DRAWN BY K. PEILA	DATE 2/2/04	Tetra Tech NUS, Inc.	CONTRACT NUMBER 4020	OWNER NUMBER CTO 0805
CHECKED BY G. LATULIPPE	DATE 2/2/04	PRODUCTION WELL AND PRIVATE WELL LOCATIONS MAIN INSTALLATION NAVAL DISTRICT WASHINGTON, INDIAN HEAD INDIAN HEAD, MARYLAND	APPROVED BY GJL	DATE 6/4/04
COST/SCHEDULE-AREA			APPROVED BY —	DATE —
SCALE AS NOTED			DRAWING NO. FIGURE 2-1	REV 0

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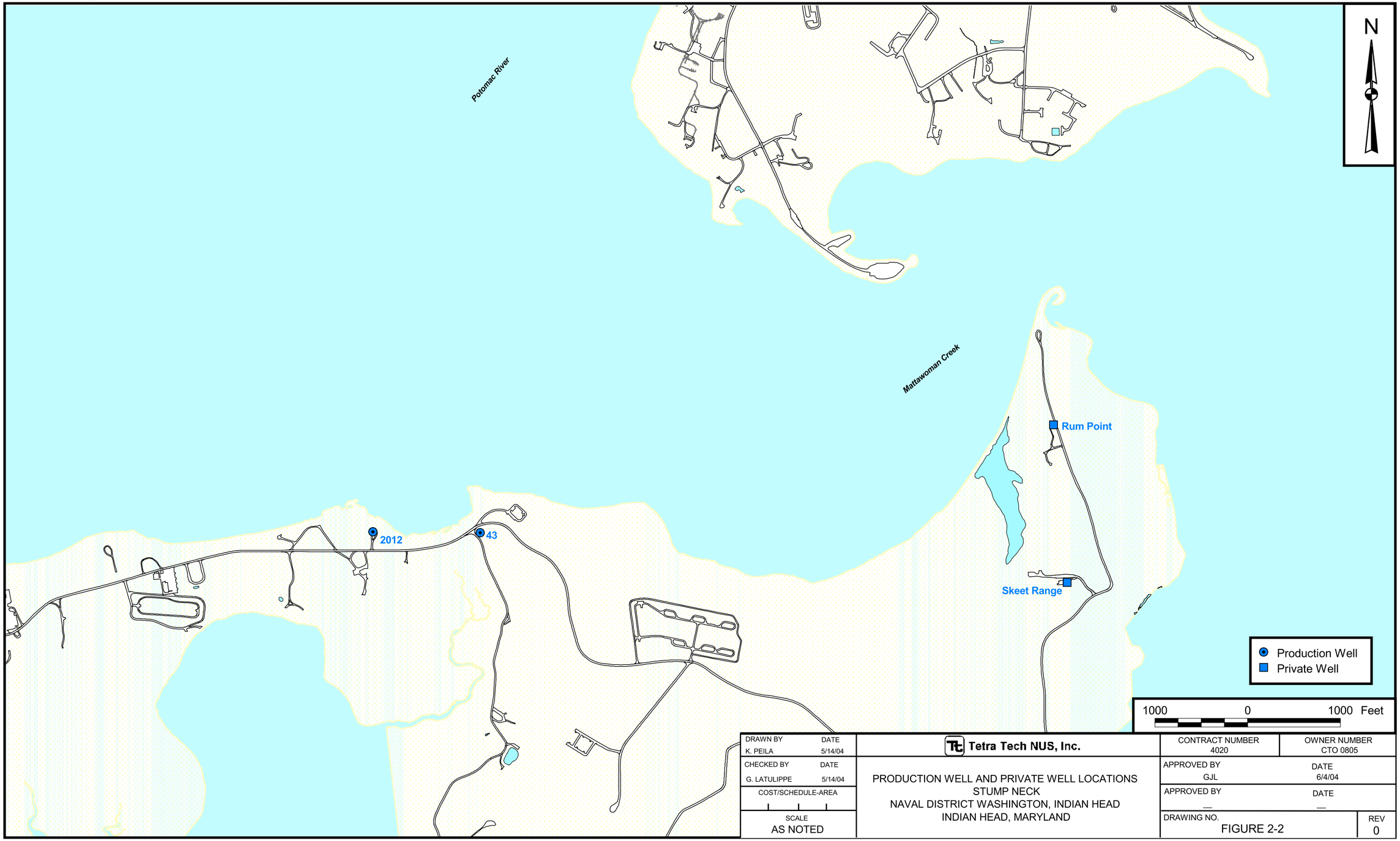


DRAWN BY K. PEILA	DATE 5/14/04	Tetra Tech NUS, Inc.	CONTRACT NUMBER 4020 / OWNER NUMBER CTO 0805
CHECKED BY G. LATULIPPE	DATE 5/14/04	PRODUCTION WELL AND PRIVATE WELL LOCATIONS STUMP NECK NAVAL DISTRICT WASHINGTON, INDIAN HEAD INDIAN HEAD, MARYLAND	APPROVED BY GJL / DATE 6/4/04
COST/SCHEDULE-AREA			APPROVED BY — / DATE —
SCALE AS NOTED			DRAWING NO. FIGURE 2-2 / REV 0

3.0 HUMAN HEALTH RISK ASSESSMENT METHODOLOGY

A human health risk assessment (HHRA) will be performed for those sites where contamination levels indicate that the site may pose a risk to human health. The evaluation process is described in this section of the Master WP.

The objective of an HHRA is to determine whether detected concentrations of chemicals pose a significant threat to potential human receptors under current and/or future land use. The potential risks to human health at sites under investigation at the Facility will be estimated based on the assumption that no actions are taken to control contaminant releases.

This section of the Master WP contains the general methodologies that will be used to evaluate project-specific human health risks at the Facility. Detailed site information will be provided in project-specific WPs. The use of the framework provided will ensure continuity between project-specific assessments and allow for the streamlined development of future risk assessments. The following current USEPA risk assessment guidance and USEPA Region III supplements were primarily used to develop the framework contained in this section of the Master WP:

- USEPA, December 1989. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A) Interim Final. Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002.

- USEPA, March 25, 1991. Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors. Washington, DC. Office of Solid Waste and Emergency Response (OSWER) Directive 9285.6-03.

- USEPA, August 1997. Exposure Factors Handbook. Office of Research and Development, Washington, DC. EPA/600/P-95/002Fa.

- USEPA, September 2001. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim, Review Draft for Public Comment. Office of Emergency and Remedial Response, Washington, DC. EPA/540/R99/005, OSWER 9285.7-02EP, PB99-963312.

- USEPA, December 2001. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments) Final. Office of Emergency and Remedial Response, Washington, DC.

- USEPA, December 2002. Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites. Office of Emergency and Remedial Response, Washington, DC. OSWER 9285.6-10.

- USEPA Region III, January 1993. Selecting Exposure Routes and Contaminants by Risk-Based Screening. Hazardous Waste Management Division, Philadelphia, Pennsylvania. EPA/903/R-93-001.

- USEPA Region III, June 2003. Technical Guidance Manual, Risk Assessment, Updated Dermal Exposure Assessment Guidance.

An HHRA consists of five components: (1) Data Evaluation; (2) Exposure Assessment; (3) Toxicity Assessment; (4) Risk Characterization, and (5) Uncertainty Analysis. Sections 3.1 through 3.5 of the Master WP contain detailed discussions of the methodologies to be followed for each component of an HHRA. A schematic diagram of the general risk assessment process is provided as Figure 3-1. The results of the HHRA will be presented in USEPA's Risk Assessment Guidance for Superfund (RAGS) Part D (USEPA, 2001b) reporting format.

Three major aspects of chemical contamination and environmental fate and transport must be considered to evaluate potential risks: (1) contaminants with toxic characteristics must be found in environmental media and must be released by either natural processes or by human action; (2) potential exposure points must exist; and (3) human receptors must be present at the point of exposure. Risk is a function of both toxicity and exposure. If any one of these factors are absent for a specific site, the exposure route is regarded as incomplete, and no potential risks will be considered for human receptors.

3.1 DATA EVALUATION

Data evaluation, the first component of an HHRA, is a project-specific task involving the compilation and evaluation of the analytical data set. Prior collection, the proposed samples for each site have been be defined (e.g., type, location, analytes, tests, etc.) with the goal of satisfying the objectives of each environmental investigation. Frequently, the sample locations are biased so as to target likely occurrences of contamination in an effort to ensure that, if contamination is present on the site, it is detected in the data set for that investigation. The main objective of data evaluation is to develop a

media-specific list of chemicals of potential concern (COPCs) that will be used to quantitatively determine potential human health risks represented by the assembled data set.

3.1.1 Quantitative versus Qualitative Use of Analytical Data

Current site data, as well as historical data, may be used to assess risks to potential human receptors at a site. All analytical data employed in the quantitative estimation of potential risks will be subjected to data validation. A discussion of data validation protocol to be followed for data generated for the Facility is provided in the associated Master QAPP.

Fixed-based analytical results from the targeted analyte lists only are generally used in the quantitative risk evaluation. Typically, unfiltered results for groundwater and surface water will be used to assess risks associated with these media. Field screening results, data regarded as unreliable (i.e., qualified as "R" during the data validation process), results of tentatively identified compound (TIC) analyses, and filtered sample results will not be used. However, these data may be used to substantiate the conclusions of the quantitative risk analysis.

3.1.2 Chemicals of Potential Concern Selection

The selection of COPCs is a qualitative screening process used to limit the number of chemicals and exposure routes quantitatively evaluated in an HHRA to those site-related constituents that dominate overall potential risks. Screening by risk-based and background concentrations will be employed to focus the risk assessment on meaningful chemicals and exposure routes.

In general, a chemical will be selected as a COPC and retained for further risk evaluation if: (1) the maximum detection in a sampled medium exceeds the risk-based concentration (RBC), referred to as the COPC screening level; (2) the chemical is determined to be present at concentrations greater than background levels; and (3) if the chemical is infrequently detected (i.e., in less than 10 percent of the samples available for risk assessment). Frequency of detection will be used to exclude chemicals when data sets of 20 samples or greater are available. Chemicals eliminated from further evaluation at this time are assumed to present minimal risks to potential human receptors.

COPC Screening Level Development

The RBC screen developed by USEPA Region III (USEPA Region III, 1993), along with the most recent version of the USEPA Region III's RBC table, will be used to develop risk-based COPC screening levels for a site. The risk-based COPC screening levels will correspond to a systemic hazard quotient (HQ) of 0.1 (for noncarcinogens) or a lifetime cancer risk of 1E-6 (for carcinogens). USEPA Region III RBCs are

based on an HQ of 1.0, and the screening concentrations are based on an HQ of 0.1. Conservatively, RBCs used as screening levels for noncarcinogenic chemicals have been divided by a factor of 10 to further account for the potential cumulative effects of several chemicals affecting the same target organ or producing the same adverse noncarcinogenic health effect.

Risk-based COPC screening levels for tap water ingestion, which are based on daily, residential exposure assumptions, will be used to select COPCs for groundwater and surface water. As discussed in the recent RBC Table (USEPA Region III, 2003b), direct ingestion and inhalation exposure routes will be considered for various volatile organic compounds. In general, the use of tap water screening levels is regarded as an extremely conservative approach to COPC selection at the Facility because shallow groundwater at the Facility is not used as a potable drinking water source (i.e., drinking water supplies are obtained from relatively deep aquifers, approximately 190 to 240 feet below ground surface), and potential human exposure to surface water is expected to be limited to incidental exposures such as recreational activities and trespassing. However, it should be recognized that the use of scenarios which are less stringent than residential scenarios chances the need to impose use restrictions on the site under study. Sites for which contaminant concentrations are low enough to meet the requirements of a residential scenario should be noted as such to enhance the potential for avoiding the need to apply use restrictions to the site.

Risk-based COPC screening levels for soil ingestion and soil screening levels (SSLs) for transfers from soil to air will be used to select COPCs for soil. Depending on the current and projected future land use at a particular site, soil ingestion screening levels for residential or industrial/commercial land use will be employed. Industrial soil ingestion screening levels will be used at sites where a potential future residential scenario is highly unlikely. SSLs will be used to screen out chemicals detected at insignificant concentrations and to justify the elimination of the inhalation exposure pathway, which involves the generation of fugitive dust and volatile emissions.

For sediment, COPCs will be selected by comparing detected site concentrations to soil ingestion (residential or industrial/commercial) screening levels only. SSLs for transfers from soil to air are not considered to be appropriate for sediment screening because of high moisture content associated with sediment matrices. The use of soil ingestion screening levels for sediment COPC identification is regarded as a conservative approach because anticipated exposure to sediment is less than anticipated exposure to soil.

If fish tissue and ambient air sample data are available for a site, COPC screening levels will also be developed for these matrices based on input parameters presented in the current USEPA Region III RBC table. Estimated fish tissue concentrations may also be calculated by multiplying measured surface

water concentrations in milligrams per liter (mg/L) by the bioconcentration factor (BCF) in liters per kilogram (L/kg), obtained from literature sources.

Lead as a COPC

RBCs are not calculated for lead because the USEPA has not derived toxicity values for this chemical. However, recommended screening levels are available for lead in soil that are used to indicate the need for response activities. Guidance from the Office of Prevention, Pesticides, and Toxic Substances (OPPTS) and the OSWER recommend 400 milligrams per kilogram (mg/kg) as the lowest screening level for lead-contaminated soil in a residential setting where children are frequently present (USEPA, 1994a and USEPA, 1994b).

A value of 400 mg/kg will be used as a screening level for soil and sediment at sites where a future residential scenario is considered to be a likely potential land use. For those sites where industrial/commercial land use only is anticipated, a screening level of 800 mg/kg will be used. This value is currently recommended by the Technical Review Workgroup (TRW) for Lead for commercial/industrial exposures (USEPA, 2004). The Safe Drinking Water Act (SDWA) action level of 15 micrograms per liter (µg/L) will used as the screening level for lead in groundwater and surface water. However, the use of screening concentrations greater than those required for residential scenarios is likely to result in the need to apply use restrictions to the site. Sites for which contaminant concentrations are low enough to meet the requirements of a residential scenario should be noted as such to enhance the potential for avoiding the need to apply use restrictions to the site.

Essential Nutrients and Chemicals Without Toxicity Criteria

The essential nutrients calcium, magnesium, potassium, and sodium will not be identified as COPCs at a site. These inorganic chemicals are naturally abundant in environmental matrices and are only toxic at high doses. In addition, because of the lack of toxicity criteria, risk-based COPC screening levels may not be calculable for some chemicals commonly detected at sites (i.e., acenaphthylene, benzo(g,h,i)perylene, and phenanthrene). Surrogates will be selected based on similar chemical structures for those chemicals for which risk-based screening levels are not available.

Determination of Site-Related Chemicals

In accordance with Navy policy (Navy, 2000) inorganic chemicals found at concentrations indicative of background levels are not considered to be site-related contaminants and will not be retained as COPCs. The use of site-specific background data will determine if detected chemicals are present at naturally occurring levels. Conventional statistical methods (e.g., Wilcoxon Rank-Sum Test, etc.) will be employed

to compare site concentrations to background concentrations or site-specific (or Base-wide) background data. For soils, the background data will be obtained from the Background Soil Investigation Report (TtNUS, 2002). Potential risks associated with exposures to any chemical eliminated as a COPC on the basis of background will be discussed in the uncertainty analysis.

The elimination of detected chemicals based on background data will be limited to inorganics only. Although some organic compounds [primarily polynuclear aromatic hydrocarbons (PAHs), pesticides, and polychlorinated biphenyls (PCBs)] can be a result of anthropogenic sources, organics are not considered to represent "true" background levels. All detected organic compounds will be regarded as site-related for purposes of COPC selection. However, historical information for a site will be reviewed to determine if the presence of organics are attributable to site-related activities or anthropogenic sources.

3.2 EXPOSURE ASSESSMENT

This portion of the risk assessment defines and evaluates, quantitatively or qualitatively, the type and magnitude of human exposure to the chemicals present at or migrating from a site. The exposure assessment is designed to depict the physical setting of the site, identify potentially exposed populations and applicable exposure pathways, calculate concentrations of COPCs to which receptors might be exposed, and estimate chemical intakes under the identified exposure scenarios.

Actual or potential exposures at the Facility will be determined based on the most likely pathways of contaminant release and transport, as well as human activity patterns. A complete exposure pathway has three components: (1) a source of chemicals that can be released to the environment; (2) a route of contaminant transport through an environmental medium; and (3) an exposure or contact point for a human receptor.

3.2.1 Conceptual Site Model

The development of a conceptual site model (CSM) is an essential component of the exposure assessment. The CSM will integrate information regarding the physical characteristics of the site, exposed populations, sources of contamination, and contaminant mobility (fate and transport) to identify potential exposure routes and receptors to be evaluated in the risk assessment. A well-defined CSM will allow for a better understanding of the risks at a site and will aid risk managers in the identification of the potential need for remediation.

Exposure Setting

The exposure setting will consist of a description of the physical characteristics (climate, meteorology, geology, groundwater hydrology, vegetation, and nearby surface water bodies) of a site, as well as the identification of potentially exposed populations at or near the site. Exposed populations will be identified with respect to both current and future land uses. Information on the population (or nearby population) at a site, the average tour of duty for military personnel, and identification of residential areas at the Facility will be provided. Section 2.0 of the Master WP contains general Facility-specific information that will be used to develop the site-specific exposure setting for a site.

Potential Exposure Pathways/Receptors

The course that a chemical takes from the source to the exposed individual is defined as the exposure pathway. Several factors regarding exposure (chemical sources, environmental release mechanisms, contact points, likely exposure routes, and potential receptors) will be considered during the development of applicable exposure pathways at a site. The characterization of these factors is necessary so that only potentially complete exposure pathways are evaluated in the risk assessment.

Potential receptors can be exposed to site contaminants, directly or indirectly, via five environmental media: air, soil, groundwater, surface water, and sediment. Potential exposure routes for these media include ingestion (swallowing), dermal contact (skin or eye), and/or inhalation (through breathing passages).

In general, the following exposure scenarios may be applicable under current and/or future land use for sites under investigation at the Facility:

- **Maintenance workers and full-time employees** may be exposed to site media while performing maintenance activities (e.g., mowing, landscaping), site inspections, or daily duties. Typically, these two classes of receptors will be evaluated for exposure to surface soil only. Exposure to groundwater will not be evaluated for this receptor because shallow groundwater at the Facility is not used as a potable water supply under current conditions and is not anticipated to be used for this purpose under potential projected future land use. Exposure to surface water and sediment is expected to be minimal for these receptors. Indoor, full-time employees may also be exposed to COPCs that have volatilized from subsurface soil/groundwater and migrated through building foundations into indoor air.

- Unless a site is physically restricted or located in a highly remote or secured area, individuals may trespass on the site and come in contact with site media. **Adolescent trespassers** from ages 6 to

16 years will be evaluated for infrequent exposure to surface soil, surface water, and sediment. Small children (6 years or younger) are not included in this receptor group because they are expected to be supervised by an adult and would not be allowed to trespass onto a site.

- As discussed in Section 2.2, Potomac River and Mattawoman Creek, which bound the Facility, are Maryland Class I and/or II waterways, indicating that they are protected resources for aquatic life, recreational activities involving water contact, and/or shellfish harvesting. **Adult recreational users** will be considered as potential receptors at a site, if applicable. This receptor group will be evaluated for exposure to surface water, sediment, and contaminated finfish/shellfish. Anticipated exposure to surface soil is assumed to be relatively insignificant for this receptor.

- For sites involving current or potential future construction or excavation activities, **construction workers** will be evaluated for exposure to surface and subsurface soil. Dermal exposure to shallow groundwater may also be likely for this receptor. The determination of whether this exposure will be evaluated in the quantitative risk assessment will be made on a site-by-site basis using information on the depth to groundwater and detected groundwater chemicals.

- If applicable, **onsite/offsite residents** will be evaluated as potential receptors. Future onsite residents will be assumed to be exposed to surface soil and groundwater on a daily basis. A future residential scenario will not be considered likely at sites located in secured production areas at the Facility or at sites containing land use restrictions. However, a hypothetical residential scenario may be applied to these sites so as to evaluate the potential for the site to avoid use restrictions (i.e., either because contamination concentrations are low enough, or because a nominal effort will reduce the concentrations sufficiently). Offsite residents may be exposed to site media indirectly through the generation of fugitive dust and/or volatile emissions and through migration of groundwater. Onsite/offsite residents may also be exposed to COPCs that have volatilized from subsurface soil/groundwater.

A summary of the exposure routes that may be addressed quantitatively for a particular receptor are provided in Table 3-1.

The CSM for a site will be presented in an illustrative fashion in addition to a textual discussion. Figure 3-2 is an example format of an illustrative CSM.

3.2.2 Central Tendency Exposure versus Reasonable Maximum Exposure

Traditionally, exposures evaluated in the HHRA were based on the concept of a reasonable maximum exposure (RME) only, which is defined as "the maximum exposure that is reasonably expected to occur at a site" (USEPA, 1989c). However, recent risk assessment guidance (USEPA, 1992a) indicates the need to address an average case or central tendency exposure (CTE) as well.

In order to provide a full characterization of potential exposure, both RME and CTE scenarios will be evaluated in the project-specific risk assessments for the Facility. It should be noted that the available guidance (USEPA, 1993a) concerning the evaluation of CTE is limited and at times vague. Therefore, professional judgment may be exercised when defining CTE conditions for a particular receptor at a site.

3.2.3 Exposure Concentrations

The exposure point concentration (EPC) is a conservative estimate of the average concentration in an environmental medium. Because of the uncertainty associated with estimating the true average concentration at a site, the 95-percent upper confidence limit (UCL), which is based on the distribution of a data set, is considered to be the best estimate of the exposure concentration for data sets with 10 or more samples (USEPA, 1992b). For normally distributed data, USEPA recommends an UCL based on the Student's *t*-statistic. For lognormally distributed data USEPA recommends that the UCL be based on the Land method using the *H*-statistic. For data that is neither normally nor lognormally distributed, the UCL will be based on non-parametric statistics (e.g., bootstrap). The UCLs will be calculated following the methodology presented in USEPA's Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites (USEPA, 2002c). The 95-percent UCL will be used as the exposure concentration to assess RME and CTE risks (USEPA, 1993a). For data sets with less than 10 samples, the UCL is considered to be a poor estimate of the mean, and the exposure concentration will be defined as the arithmetic mean or maximum detection, depending on the exposure scenario to be evaluated.

The EPC is determined for each individual exposure unit within a site. An exposure unit is the area throughout which a receptor moves and encounters an environmental medium for the duration of the exposure. Unless there is site-specific evidence to the contrary, an individual receptor is assumed to be exposed equally to media within all portions of the exposure unit over the time frame of the risk assessment.

Detailed sample calculations, as well as general methodology for the statistical evaluation, will be presented in the site-specific risk assessment. Sample and duplicate analytical results will be averaged for statistical use. Nondetected data points will be utilized; in general, one-half the sample-specific

detection limit will be employed for these analytical results. If the calculated 95-percent UCL exceeds the maximum detected concentration, the maximum will be used as the exposure concentration in place of the UCL. RAGS Part D tables for the EPCs will be included in appendices to the HHRA.

3.2.4 Chemical Intake Estimation

The methodologies and techniques that will be used to estimate exposure intakes are presented in this section of the Master WP. Intakes for the identified potential receptor groups will be calculated using current USEPA risk assessment guidance (USEPA, 1989c and USEPA, 2001a) and presented in the risk assessment spreadsheets. These spreadsheets, in RAGS Part D format, will be appended to the site-specific assessment as support documentation.

Noncarcinogenic intakes will be estimated using the concept of an average annual exposure. Carcinogenic intakes will be calculated as an incremental lifetime exposure, which will assume a life expectancy of 70 years. Equations that will used to calculate estimated intakes are provided below. Assumptions regarding exposure are presented at the end of this section.

Inhalation of Air and Fugitive Dust/Volatile Emissions

The amount of a chemical a receptor takes in as a result of inhalation is determined using the concentration of the contaminant in air. Intakes of both particulates and vapors/gases will be calculated using the same equation, as follows (USEPA, 1989c):

$$\text{Intake}_{ai} = \frac{(C_{ai})(IR_a)(ET)(EF)(ED)}{(BW)(AT)}$$

where:

Intake_{ai}	=	intake of chemical "i" from air via inhalation (mg/kg/day)
C_{ai}	=	concentration of chemical "i" in air (mg/m^3)
IR_a	=	inhalation rate (m^3/hr)
ET	=	exposure time (hours/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (year)
BW	=	body weight (kg)
AT	=	averaging time (days);
		for noncarcinogens, AT = ED x 365 days/year;
		for carcinogens, AT = 70 year x 365 days/year

The concentration of a chemical in air will be developed using modeling techniques presented in current SSL guidance, measured soil concentrations, and additional site-specific information.

As mentioned in Section 3.1.2, the need for a quantitative evaluation of the inhalation pathway may not be warranted for all sites at the Facility. A qualitative evaluation of exposure (i.e., comparisons of maximum site soil concentrations to SSLs for transfers from soil to air) will be used to identify whether a quantitative analysis of this exposure pathway is warranted.

Dermal Contact with Soil/Sediment

Direct physical contact with soil (and sediment) may result in the dermal absorption of chemicals. Exposure associated with the dermal route are estimated in the following manner (USEPA, 1989c and USEPA, 2001a):

$$Intake_{si} = \frac{(C_{si})(SA)(AF)(ABS)(CF)(EF)(ED)}{(BW)(AT)}$$

where: $Intake_{si}$ = amount of chemical "i" absorbed during contact with soil/sediment (mg/kg/day)

C_{si} = concentration of chemical "i" in soil/sediment (mg/kg)

SA = skin surface area available for contact (cm^2/day)

AF = skin adherence factor (mg/cm^2)

ABS = absorption factor (dimensionless)

CF = conversion factor (1E-6 kg/mg)

EF = exposure frequency (days/year)

ED = exposure duration (year)

BW = body weight (kg)

AT = averaging time (days);
for noncarcinogens, AT = ED x 365 days/year;
for carcinogens, AT = 70 year x 365 days/year

Exposed surface areas of the body available for dermal contact are determined on a receptor-specific basis because they correspond with assumed human activities and clothing worn during exposure events. Current guidance (USEPA, 2001a) was used to develop the following default assumptions concerning the amount of skin surface area available for contact for a receptor:

- For maintenance workers, full-time employees, and construction workers, the USEPA (USEPA, 2001a and USEPA, 2002c) currently recommends that an area of 3,300 square centimeters (cm^2) be

assumed available for dermal contact. This assumes that the worker wears a short-sleeved shirt, long pants, and shoes. Therefore, the exposed skin surface area is limited to the head, hands, and forearms.

- For adolescent trespassers (3,720 cm^2) and adult recreational users (5,400 cm^2), 30 percent of the total body surface area will be assumed to be available for soil and/or sediment contact.

- For future onsite child residents, the hands, forearms, lower legs, feet, and face (2,800 cm^2) are assumed to be available for soil contact (USEPA, 2001a).

- For future onsite adult residents, the head, hands, forearms, and lower legs (5,700 cm^2) are assumed to be available for soil contact (USEPA, 2001a).

Current USEPA guidance is used to determine soil adherence factors and chemical-specific absorption factors. For COPCs in soil/sediment, the following soil adherence factors will be used for the RME and CTE exposure scenarios:

- Construction workers – 0.3 mg/cm^2 for the RME and 0.1 mg/cm^2 for the CTE (Exhibit 3.3, USEPA, 2002c).

- Onsite workers and future occupational workers – 0.2 mg/cm^2 for the RME and 0.02 mg/cm^2 for the CTE (USEPA, 2001b).

- Adolescent trespassers – 0.3 mg/cm^2 for the RME and 0.04 mg/cm^2 for the CTE. This is based on the assumption of teens playing in moist conditions (USEPA, 2001a).

- Adult recreational users – 0.2 mg/cm^2 for the RME and 0.02 mg/cm^2 for the CTE (Exhibit 3.3, USEPA, 2001a).

- Future child residents – 0.2 mg/cm^2 for the RME and 0.04 mg/cm^2 for the CTE (Exhibit 3.5, USEPA, 2001a).

- Future adult residents – 0.07 mg/cm^2 for the RME and 0.01 mg/cm^2 for the CTE (Exhibit 3.5, USEPA, 2001a).

Current USEPA guidance (USEPA, 2001a and USEPA, 2003a) will be used to determine chemical-specific absorption factors.

Incidental Ingestion of Soil/Sediment

Incidental ingestion of soil (and sediment) by potential receptors coincides with dermal exposure based on the following equation:

$$\text{Intake}_{si} = \frac{(C_{si})(IR_s)(FI)(EF)(ED)(CF)}{(BW)(AT)}$$

where:

Intake_{si}	=	intake of contaminant "i" from soil or sediment (mg/kg/day)
C_{si}	=	concentration of contaminant "i" in soil or sediment (mg/kg)
IR_s	=	ingestion rate (mg/day)
FI	=	fraction ingested from contaminated source (dimensionless)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (year)
CF	=	conversion factor (1E-6 kg/mg)
BW	=	body weight (kg)
AT	=	averaging time (days);
		for noncarcinogens, AT = ED x 365 days/year;
		for carcinogens, AT = 70 year x 365 days/year

The same exposure frequencies and durations used in the estimation of dermal intakes will be used to estimate exposure via incidental ingestion. The fraction of soil ingested from the source is based on assumed human activity patterns and may be determined on a site-specific basis.

Dermal Contact with Groundwater/Surface Water

The same equation is used to estimate intakes for dermal contact with groundwater and surface water. Residential receptors are assumed to use groundwater for domestic purposes (i.e., bathing, showering, washing dishes) that can result in a dermal exposure. It is also possible under future land use conditions that deep excavations at the Facility for activities such as utility maintenance and construction could result in a dermal exposure to the shallow groundwater. Dermal contact with surface water may also occur while receptors are involved in certain activities such as fishing and trespassing. As discussed previously, the need for an evaluation of these exposure scenarios will be determined on a site-by-site basis.

The following equation will be used to assess exposures resulting from dermal contact with water (USEPA, 2001a):

$$DAD_{wi} = \frac{(DA_{event})(EV)(ED)(EF)(A)}{(BW)(AT)}$$

where: DAD_{wi} = dermally absorbed dose of chemical "i" from water (mg/kg/day)

DA_{event} = absorbed dose per event (mg/cm^2-event)

EV = event frequency (events/day)

ED = exposure duration (year)

EF = exposure frequency (days/year)

A = skin surface area available for contact (cm^2)

BW = body weight (kg)

AT = averaging time (days);
for noncarcinogens, AT = ED x 365 days/year;
for carcinogens, AT = 70 year x 365 days/year

Groundwater exposure for residential receptors will be assumed to occur on a daily basis, while exposure for other receptor groups will be limited to infrequent, site-specific exposure events. Dermal intakes for residents and select recreational users (i.e., water skiers, swimmers) will assume total body exposure. For other receptor groups such as trespassers, fishermen, and construction workers, the exposed surface area of the body available for contact will be determined based on assumed activities and will be similar to the assumptions outlined for dermal contact with soil and sediment.

The absorbed dose per event (DA_{event}) will be estimated using a nonsteady-state approach for organic compounds and a traditional steady-state approach for inorganics. For organics, the following equations apply:

$$\text{If } t_{event} < t^*, \text{ then : } DA_{event} = (2)(K_p)(FA)(C_{wi})(CF)\left(\sqrt{\frac{6\,\tau\, t_{event}}{\pi}}\right)$$

$$\text{If } t_{event} > t^*, \text{ then : } DA_{event} = (K_p)(FA)(C_w)(CF)\left(\frac{t_{event}}{1+B} + 2\,\tau\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right)$$

where: t_{event} = duration of event (hour/event)

t^* = time it takes to reach steady-state conditions (hour)

FA = fraction absorbed (chemical specific)

K_p = permeability coefficient from water through skin (cm/hour)

C_{wi} = concentration of chemical "i" in water (mg/L)

τ	=	lag time (hour)
π	=	constant (dimensionless; equal to 3.141592654)
CF	=	conversion factor (1E-3 L/cm^3)
B	=	partitioning constant derived by Bunge Model (dimensionless)

Values for the chemical-specific parameters (t^*, K_p, τ, and B) will be obtained from the current dermal guidance (USEPA, 2001a). If no published values are available for a particular compound, they will be calculated using equations provided in the cited guidance.

The following steady-state equation will be used to estimate DA_{event} for inorganics:

$$DA_{event} = (K_p)(C_{wi})(t_{event})$$

The dermal permeability (K_p) values recommended in the USEPA dermal guidance (USEPA, 2001a) will be used to calculate DA_{event} for inorganic COPCs.

Incidental/Direct Ingestion of Groundwater/Surface Water

Residents may be exposed to groundwater via direct ingestion. Direct contact with surface waters while swimming or exploring could also result in the inadvertent ingestion of small amounts of water. Intakes associated with ingestion of water will be evaluated using the following equations (USEPA, 1989c):

$$\text{Intake}_{wi} = \frac{(C_{wi})(IR_w)(EF)(ED)}{(BW)(AT)} \quad \text{for groundwater}$$

$$\text{Intake}_{wi} = \frac{(C_{wi})(CR)(ET)(EF)(ED)}{(BW)(AT)} \quad \text{for surface water}$$

where:	Intake_{wi}	=	intake of chemical "i" from water (mg/kg/day)
	C_{wi}	=	concentration of chemical "i" in water (mg/L)
	IR_w	=	ingestion rate for groundwater (L/day)
	CR	=	contact rate for surface water (L/hour)
	ET	=	exposure time for surface water (hour/day)
	EF	=	exposure frequency (days/year)
	ED	=	exposure duration (year)
	BW	=	body weight (kg)
	AT	=	averaging time (days);
			for noncarcinogens, AT = ED x 365 days/year;

for carcinogens, AT = 70 year x 365 days/year

The same exposure times, frequencies, and durations used to assess dermal exposure to water will be used to estimate intakes for ingestion of water.

Inhalation of Volatiles Released During Household Use of Water

Volatilization of chemicals into indoor air from groundwater used as a source of domestic water may occur, thereby exposing individuals inside residential dwellings. Therefore, it is necessary to evaluate the potential risks associated with indoor air concentrations of chemicals as a result of vapor migration from impacted groundwater. Inhalation exposures during household use of water will be estimated using the methodology provided in RAGS Part B (USEPA, 1991b). This method considers all uses of household water (e.g., showering, laundering, dish washing, etc.) by means of a volatilization constant (K) equal to 0.0005 x 1,000 liters per cubic meter (L/m^3).

The following equation is used to evaluate inhalation exposure from household use of water:

$$\text{Intake}_i = \frac{(C_{wi})(K)(IR_a)(EF)(ED)}{(BW)(AT)}$$

where:

Intake_i	=	inhalation intake of chemical "i" (mg/kg/day)
C_{wi}	=	concentration of chemical "i" in water (mg/L)
IR_a	=	inhalation rate (m^3/day)
K	=	volatilization constant (L/m^3)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (year)
BW	=	body weight (kg)
AT	=	averaging time (days)
		for noncarcinogens, AT = ED x 365 days/year;
		for carcinogens, AT = 70 year x 365 days/year

The indoor inhalation rates are assumed to be 15 cubic meters per day (m^3/day) for adults (USEPA, 1991a) and 10 m^3/day for children (USEPA, 1997b).

Inhalation of Chemicals Volatilized from Groundwater by Construction Workers

Construction workers may be exposed to COPCs that have volatilized from groundwater when excavation exposes the shallow water table. Exposures for construction workers associated with the inhalation route are estimated in the following manner (USEPA, 1989c):

$$\text{Intake}_{ai} = \frac{(C_{ai})(IR_a)(ET)(EF)(ED)}{(BW)(AT)}$$

where: Intake_{ai} = intake of chemical "i" from air via inhalation (mg/kg/day)
C_{ai} = concentration of chemical "i" in air (mg/m^3)
IR_a = inhalation rate (m^3/hr)
ET = exposure time (hours/day)
EF = exposure frequency (days/year)
ED = exposure duration (year)
BW = body weight (kg)
AT = averaging time (days);
for noncarcinogens, AT = ED x 365 days/year;
for carcinogens, AT = 70 year x 365 days/year

There are no well-established models available for estimating migration of volatiles from groundwater into a construction/utility trench. The risk assessments will use an approach suggested by the Virginia Department of Environmental Quality (VDEQ, 2003) that is based on a combination of a vadose zone model to estimate volatilization of gases from contaminated groundwater into a trench and a box model to estimate dispersion of the contaminants from the air inside the trench into the above-ground atmosphere to estimate the EPC for air in a construction trench. The VDEQ methodology is described in the following sections.

Airborne concentrations of a contaminant in a trench are estimated using the following equation:

$$C_{ai} = C_{GW} \times VF \times CF$$

where: C_{ai} = air concentration of contaminant in the trench (mg/m^3)
C_{GW} = concentration of contaminant in groundwater (µg/L)
VF = volatilization factor (L/m^3)
CF = conversion factor (0.001 mg/µg)

The model assumes that a construction project could result in an excavation to 15 feet bgs or less. If the depth to groundwater at a site is less than 15 feet, the VDEQ model assumes that a worker would encounter groundwater when digging an excavation or trench. The worker would then have direct exposure to the groundwater. The worker would also be exposed to contaminants in the air inside the trench that would result from volatilization from the groundwater pooling at the bottom of the trench.

The following equation is used to calculate the volatilization factor (VF) for a trench less than 15 feet deep:

$$VF = (K_i \times A \times F \times 10^{-3} \times 10^{4} \times 3{,}600) / (ACH \times V)$$

where: K_i = overall mass transfer coefficient of contaminant (cm/s)
A = area of the trench (m^2)
F = fraction of floor through which contaminant can enter (unitless)
ACH = air changes per hour (h^{-1})(360 h^{-1})
V = volume of trench (m^3)
10^{-3} = conversion factor (L/cm^3)
10^{4} = conversion factor (cm^2/m^2)
3,600 = conversion factor (seconds/hour)

Studies of urban canyons suggest that if the ratio of trench width relative to wind direction to trench depth is less than or equal to 1, a circulation cell or cells will be set up within the trench that limits the degree of gas exchange with the atmosphere and the air exchanges per hour (ACHs) are assumed to be two based on measured ventilation rates of buildings. If the ratio of trench width to trench depth is greater than 1, air exchange between the trench and above-ground atmosphere is not restricted, thus ACHs are assumed to be 360 based on the ratio of trench depth to the average wind speed. It will be assumed that the width to trench depth ratio is greater than 1; therefore, ACHs will be assumed to be 360.

$$K_i = 1 / \{(1/k_iL) + [(RT) / (H_i\, k_iG)]\}$$

where: k_iL = liquid-phase mass transfer coefficient of “i” (cm/s)
R = ideal gas constant (atm-m^3/mole-°K = 8.2×10^{-5})
T = average system absolute temperature °K (Default = 298°K)
H_i = Henry's Law constant of “i” (atm-m^3/mol)
k_iG = gas-phase mass transfer coefficient of i (cm/s)

$$k_iL = (MWO_2/MWi)^{0.5} \times (T/298) \times kL,O_2$$

where: k_iL = liquid-phase mass transfer coefficient of component “i” (cm/s)

MWO_2 = molecular weight of oxygen (g/mol)

MW_i = molecular weight of component i (g/mol)

kL,O_2 = liquid-phase mass transfer coefficient of oxygen at 25°C (cm/s)

= 0.002 cm/s

$$k_iG = (MWH_2O/MW_i)^{0.335} \times (T/298)^{1.005} \times kG, H_2O$$

where: k_iG = gas-phase mass transfer coefficient of component “i” (cm/s)

MWH_2O = molecular weight of water (g/mol)

kG,H_2O = gas-phase mass transfer coefficient of water vapor at 25°C (cm/s)

= 0.833 (cm/s)

The same exposure frequency and exposure time used to estimate intake from dermal contact with groundwater will be used to evaluate intake from inhalation of volatile organic compounds (VOCs) from groundwater during construction activities.

Ingestion of Finfish/Shellfish

Indirect chemical exposure may also occur via the ingestion of finfish or shellfish from the Potomac River or Mattawoman Creek. This exposure route will be evaluated under an adult recreational user exposure scenario using the following model (USEPA, 1989c):

$$Intake_{fi} = \frac{(C_{fi} \times IR_f \times FI \times EF \times ED)}{(BW \times AT)}$$

where: $Intake_{fi}$ = intake of chemical "i" from shellfish/finfish (mg/kg/day)

C_{fi} = concentration of chemical "i" in shellfish/finfish (mg/kg)

IR_f = ingestion rate (kg/day)

EF = exposure frequency (days/year)

ED = exposure duration (year)

FI = fraction ingested from contaminated source (dimensionless)

BW = body weight (kg)

AT = averaging time (days);

for noncarcinogens, AT = ED x 365 days/year;

for carcinogens, AT = 70 year x 365 days/year

If actual fish tissue samples are available for a site, the tissue analytical data will be used to estimate intakes. If they are not available, finfish tissue concentrations will be estimated using surface water data and chemical-specific BCFs, as discussed in Section 3.1.2.

Summary of Exposure Parameters

In general, standard default parameters (USEPA, 1991a), which combine mid-range and upper-end exposure factors, will be used to assess RME scenarios. CTE scenarios will be assessed primarily by the use of mid-range exposure factors presented in current risk assessment guidance (USEPA, 1989c and USEPA, 1993a). Age-adjusted factors will be used to assess RME and CTE risks for residential receptors. General exposure input parameters for the identified potential receptor groups at the Facility are presented in Table 3-2. These input parameters may be updated according to new risk assessment guidance, as it becomes available.

3.2.5 Exposure to Lead

The equations and methodology presented in the previous section cannot be used to evaluate exposure to lead because of the absence of published dose-response parameters. Exposure to lead will be assessed using the latest version of the USEPA's Integrated Exposure Uptake Biokinetic (IEUBK) Model for lead (USEPA, 2002a). This model is designed to estimate blood levels of lead in children (under 7 years of age) based on either default or site-specific input values for air, drinking water, diet, dust, and soil exposure.

Studies indicate that infants and young children are extremely susceptible to adverse effects from exposure to lead. Considerable behavioral and developmental impairments have been noted in children with elevated blood lead levels. The threshold for toxic effects from this chemical is believed to be in the range of 10 micrograms per deciliter (µg/dL) to 15 µg/dL. Blood lead levels greater than 10 µg/dL are considered to be a "concern."

For sites under investigation at the Facility, the IEUBK Model for lead will be used to address exposure to lead in children when detected groundwater and surface water concentrations exceed the 15 µg/L federal action level promulgated under the SDWA and when detected soil and sediment concentrations exceed the OSWER soil screening level of 400 mg/kg for residential land use (USEPA, 1994a). Average chemical concentrations, as well as default parameters for some input parameters, will be employed. Estimated blood lead levels and probability density histograms will be presented as support documentation for this analysis and appended to the site-specific risk assessment.

The TRW Lead Model for Adult Exposure (USEPA, 2003a) will be used to address exposure to lead in adult recreational users and workers exposed to lead in contaminated soils. In this model, adult exposure to lead in soil is addressed by an evaluation of the relationship between the site soil lead concentration and the blood lead concentration in the developing fetuses of adult women. The adult lead model will generate a spreadsheet for each exposure scenario evaluated (i.e., industrial, recreational). The output of the spreadsheet is the probability that the blood lead concentration in the fetus exceeds 10 µg/L.

3.3 TOXICITY ASSESSMENT

The objective of the toxicity assessment is to identify the potential health hazards and adverse effects in exposed populations. Quantitative estimates of the relationship between the magnitude and type of exposures and the severity or probability of human health effects will be defined for the identified COPCs. Quantitative toxicity values determined during this component of the risk assessment will be integrated with outputs of the exposure assessment to characterize the potential for the occurrence of adverse health effects for each receptor group.

The toxicity value used to evaluate noncarcinogenic health effects is the reference dose (RfD). Carcinogenic effects are quantified using the cancer slope factor (CSF).

3.3.1 Toxicity Criteria for Oral and Inhalation Exposures

Oral and inhalation RfDs and CSFs to be used in the site-specific risk assessments for the Facility will be obtained from the following primary literature sources:

- Integrated Risk Information System (IRIS) (http://www.epa.gov/iris/)

- USEPA provisional peer reviewed toxicity values (PPRTVs) – The Office of Research and Development/National Center for Environmental Assessment (NCEA) Superfund Health Risk Technical Support Center develops PPRTVs on a chemical-specific basis when requested by USEPA's Superfund program.

- Other Toxicity Values – These sources include but are not limited to California Environmental Protection Agency (Cal EPA) toxicity values, the Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs), and the Annual Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997d)

Although RfDs and CSFs can be found in several toxicological sources, USEPA's IRIS online database is the preferred source of toxicity values. This database is continuously updated, and values presented have been verified by USEPA.

3.3.2 Toxicity Criteria for Dermal Exposure

RfDs and CSFs found in literature may be expressed as administered doses; therefore, these values are considered to be inappropriate for estimating the risks associated with dermal routes of exposure. Oral dose-response parameters based on administered doses must be adjusted to absorbed doses before the comparison to estimated dermal exposure intakes is made. Because this information is not always readily available, all oral dose-response parameters will be adjusted.

The adjustment to an absorbed dose will be made using chemical-specific absorption efficiencies published in available guidance (USEPA, 2001a and USEPA Region III, 2003a) and the following equations:

$$RfD_{dermal} = (RfD_{oral})(ABS_{GI})$$

$$CSF_{dermal} = (CSF_{oral}) / (ABS_{GI})$$

where: ABS_{GI} = absorption efficiency in the gastrointestinal tract

Current USEPA guidance (USEPA, 2001a and USEPA Region III, 2003a) will be used to determine chemical-specific absorption efficiencies.

3.3.3 Toxicity Criteria for Carcinogenic Effects of PAHs

Limited toxicity values are available to evaluate the carcinogenic effects from exposure to PAHs. The most extensively studied PAH is benzo(a)pyrene, which is classified by the USEPA as a known human carcinogen. Although CSFs are available for benzo(a)pyrene, insufficient data are available to calculate CSFs for other carcinogenic PAHs. Toxic effects for these chemicals will be evaluated using the concept of estimated orders of potential potency, as presented in current USEPA guidance (USEPA, 1993b). These parameters are based on the carcinogenicity of benzo(a)pyrene and are available for select carcinogenic PAHs. The equivalent oral and inhalation CSFs for these chemicals are derived by multiplying the CSF for benzo(a)pyrene by the order of potential potency.

3.3.4 Toxicity Criteria for Carcinogenic Effects of Dioxins/Furans

Similar to the concept of estimated orders of potential potency for PAHs, chlorinated dibenzo-p-dioxins (CDDs) and chlorinated-dibenzofurans (CDFs) will be evaluated using toxicity equivalence factors (TEFs) relative to the toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) (USEPA, 1989a). Based on a variety of approaches that generate toxicities relative to 2,3,7,8-TCDD, the USEPA developed TEFs for other dioxins/furans from structure-activity relationships and the available toxicological information. The equivalent oral CSFs for these chemicals are derived by multiplying the CSF for 2,3,7,8-TCDD by the TEF.

3.3.5 Toxicity Criteria for Chromium

Toxicity criteria are available for different forms of chromium, which is considered to be more toxic in the hexavalent state. Unless chromium speciation is performed at a site, risks associated with this chemical will be assessed by conservatively assuming that 100 percent of the reported total chromium result is attributable to hexavalent chromium.

3.3.6 Toxicity Criteria for Iron

There are no toxicity values for iron available in USEPA's IRIS database. Iron is an essential nutrient, and deriving a toxicity value for such a chemical poses a special problem in that the dose adversity curve is "U-shaped." Thus, the toxicity value must be protective against deficiency as well as toxicity. USEPA's NCEA has derived a provisional RfD of 0.3 mg/kg/day for iron using data obtained from the second National Health and Nutrition Examination Survey (NHANES) database (USEPA, 1996). The NCEA provisional RfD is based on the average adult daily intake of iron and not on any adverse health effects. The provisional RfD will be used to evaluate exposures to iron in the HHRAs. Although there are studies that indicate exposure to high levels of iron will have adverse health effects on the liver, blood, and gastrointestinal system, these organs will not be considered target organs for iron in the HHRAs because, as noted above, the RfD for iron is not based on adverse health effects to these organs.

3.3.7 Identification of Other Human Health-Based Criteria

Media-specific regulatory and human health-based criteria for COPCs, other than dose-response parameters, will also be provided in the site-specific risk assessments. These criteria, which consist of ARARs and To Be Considered (TBC) values, can also be used to indicate the potential for adverse health effects in human receptors. ARARs (i.e., drinking water and ambient water quality criteria) are cleanup standards and other environmental protection requirements and criteria promulgated under federal or State law. TBCs (i.e. health advisories for drinking water) are nonpromulgated, nonenforceable

standards or criteria that may be helpful in determining what concentration of a particular chemical is protective of human health.

3.4 RISK CHARACTERIZATION

Potential risks (noncarcinogenic and carcinogenic) for human receptors resulting from the exposures outlined in the exposure assessment are quantitatively determined during the risk characterization component of the HHRA.

A summary and interpretive discussion of the quantitative risk estimates will be provided in the text of the site-specific risk assessments. COPCs that contribute significantly to elevated risks will be identified as "risk drivers" during the interpretive risk discussion. All of the numeric estimates of risk will be contained in the risk assessment spreadsheets, which will appended to the assessment as support documentation.

3.4.1 Risk Estimation Methods

Quantitative estimates of risk will be calculated according to risk assessment methods outlined in current USEPA guidance (USEPA, 1989c). Lifetime cancer risks will be expressed in the form of dimensionless probabilities referred to as incremental cancer risks (ICRs), based on CSFs. Noncarcinogenic risk estimates will be presented in the form of HQs that are determined through a comparison of intakes with published RfDs.

ICR estimates are generated for each COPC using estimated exposure intakes and published CSFs, as follows:

$$ICR = (\text{Estimated Exposure Intake})(CSF)$$

If the above equation results in an ICR greater than 0.01, the following equation will be used:

$$ICR = 1 - [\exp(-\text{Estimated Exposure Intake})(CSF)]$$

An ICR of 1E-6 indicates that the exposed receptor has a one-in-one-million chance of developing cancer under the defined exposure scenario.

As mentioned previously, noncarcinogenic risks will be assessed using the concept of HQs and hazard indices (HIs). The HQ for a COPC is the ratio of the estimated intake to the RfD, as follows:

$$HQ = (\text{Estimated Exposure Intake}) / (RfD)$$

An HI will be generated by summing the individual HQs for all of the COPCs. It should be noted that HI is not a mathematical prediction of the severity of toxic effects and therefore is not a true "risk"; it is simply a numerical indicator of the possibility of the occurrence of noncarcinogenic (threshold) effects.

3.4.2 Comparison of Quantitative Risk Estimates to Benchmarks

To interpret the quantitative risks and to aid risk managers in determining the need for remediation at a site, quantitative risk estimates will be compared to typical benchmarks. Calculated ICRs will be interpreted using the USEPA's "target range" (1E-4 to 1E-6), while HIs will be evaluated using a value of 1.0.

The USEPA has defined the range of 1E-4 to 1E-6 as the ICR target range for most hazardous waste facilities addressed under CERCLA. Individual or cumulative ICRs greater than 1E-4 will not be considered as protective of human health, while ICRs below 1E-6 will be regarded as protective.

An HI exceeding unity (1.0) indicates that there may be potential noncarcinogenic health risks associated with exposure. If an HI exceeds unity, a segregation of target organ effects associated with exposure to COPCs will be performed. Only those chemicals that impact the same target organ(s) or exhibit similar critical effect(s) will be regarded as truly additive.

3.5 UNCERTAINTY ANALYSIS

The goal of the uncertainty analysis is to identify important uncertainties and limitations associated with the HHRA. Uncertainties related to each component of the assessment (i.e., data evaluation, exposure assessment, toxicity assessment, and risk characterization) will be presented. In addition, the effect of a particular uncertainty on the outcome of the assessment (i.e., risk estimates) will also be indicated, where possible.

TABLE 3-1

POTENTIALLY COMPLETE EXPOSURE ROUTES FOR QUANTITATIVE EVALUATION
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Receptors	Exposure Routes
Maintenance Workers/Full-Time Employees	• Soil Dermal Contact (surface) • Soil Ingestion (surface) • Inhalation of Air/Dust/Emissions (surface) • Inhalation of Vapors Intruding into a Building from the Subsurface
Adolescent Trespassers	• Soil Dermal Contact (surface) • Soil Ingestion (surface) • Inhalation of Air/Dust/Emissions (surface) • Surface Water/Sediment Dermal Contact • Surface Water/Sediment Ingestion
Adult Recreational User (swimmers, water skiers, fishermen)	• Surface Water/Sediment Dermal Contact • Surface Water/Sediment Ingestion • Ingestion of Finfish/Shellfish
Construction Workers	• Soil Dermal Contact (surface and subsurface) • Soil Ingestion (surface and subsurface) • Inhalation of Air/Dust/Emissions (surface and subsurface) • Groundwater Dermal Contact (shallow groundwater)
Onsite Resident	• Soil Dermal Contact (surface) • Soil Ingestion (surface) • Inhalation of Air/Dust/Emissions (surface) • Direct Ingestion of Groundwater • Groundwater Dermal Contact (showering/bathing) • Inhalation of Volatiles in Groundwater (showering/bathing) • Inhalation of Vapors Intruding into a Building from the Subsurface
Offsite Resident	• Inhalation of Air/Dust/Emissions (surface) • Direct Ingestion of Groundwater • Groundwater Dermal Contact (showering/bathing) • Inhalation of Volatiles in Groundwater (showering/bathing) • Inhalation of Vapors Intruding into a Building from the Subsurface

TABLE 3-2

SUMMARY OF EXPOSURE INPUT PARAMETERS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND
PAGE 1 OF 2

Exposure Parameter	Construction Workers		Full-Time Workers		Maintenance Workers		Adolescent Trespassers		Adult Recreational Users		On/Offsite Child Residents		On/Offsite Adult Residents	
	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE
All Exposures														
C_{soil}/C_{sed} (mg/kg)	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]
C_{gw}/C_{sw} (ug/L)	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]	Maximum or 95% UCL[1]
ED (years)	1[2]	1[2]	25[1]	9[1]	25[1]	9[1]	10[3]	10[3]	30[1]	9[1]	6[1]	2[1]	24[1]	7[1]
BW (kg)	70[3]	70[3]	70[3]	70[3]	70[3]	70[3]	43[4]	43[4]	70[3]	70[3]	15[3]	15[3]	70[3]	70[3]
AT_n (days)	365[3]	365[3]	9,125[3]	3,285[3]	9,125[3]	3,285[3]	3,650[3]	3,650[3]	10,950[3]	3,285[3]	2,190[3]	730[3]	8,760[3]	2,555[3]
AT_c (days)	25,550[3]	25,550[3]	25,550[3]	25,550[3]	25,550[3]	25,550[3]	25,550[3]	25,550[3]	25,550[3]	25,550[3]	25,550[3]	25,550[3]	25,550[3]	25,550[3]
Incidental Ingestion/Dermal Contact with Soil														
IR (mg/day)	330[5]	165[6]	100[1]	50[1]	100[1]	50[1]	100[2]	50[6]	NA	NA	200[1]	100[1]	100[1]	50[1]
EF-Soil (days/year)	250[1]	219[1]	250[1]	219[1]	30[2]	15[6]	52[2]	26[6]	NA	NA	350[1]	234[1]	350[1]	234[1]
FI (unitless)	1[1]	1[1]	1[1]	1[1]	1[1]	1[1]	1[1]	1[1]	NA	NA	1[1]	1[1]	1[1]	1[1]
SA (cm^2/day)	3,300[5]	3,300[5]	3,300[7]	3,300[7]	3,300[7]	3,300[7]	3,720[8]	3,720[8]	NA	NA	2,800[7]	2,800[7]	5,700[7]	5,700[7]
AF (mg/cm^2)	0.3[5]	0.1[7]	0.2[7]	0.02[7]	0.2[7]	0.02[7]	0.3[7]	0.04[7]	NA	NA	0.2[7]	0.04[7]	0.07[7]	0.01[7]
ABS (unitless)	chemical-specific[7,9]	chemical-specific[7,9]	chemical-specific[7,9]	chemical-specific[7,9]	chemical-specific[7,9]	chemical-specific[7,9]	chemical-specific[7,9]	chemical-specific[7,9]	NA	NA	chemical-specific[7,9]	chemical-specific[7,9]	chemical-specific[7,9]	chemical-specific[7,9]
CF (kg/mg)	1.E-06	1.E-06	1.E-06	1.E-06	1.E-06	1.E-06	1.E-06	1.E-06	NA	NA	1.E-06	1.E-06	1.E-06	1.E-06
Inhalation of Fugitive Dust/Volatiles														
IRa (m^3/hour)	3.3[4]	3.3[4]	2.5[1]	2.5[1]	2.5[1]	2.5[1]	3.2[4]	3.2[4]	NA	NA	0.83[1]	0.83[1]	0.83[1]	0.83[1]
ET (hour)	8[2]	4[6]	8[2]	4[6]	8[2]	4[6]	4[2]	2[2]	NA	NA	24[1]	24[1]	24[1]	24[1]
PEF (m^3/kg)	2.64E+06[5]	2.64E+06[5]	3.34E+09[10]	3.34E+09[10]	3.34E+09[10]	3.34E+09[10]	3.34E+09[10]	3.34E+09[10]	NA	NA	3.34E+09[10]	3.34E+09[10]	3.34E+09[10]	3.34E+09[10]
Q/C (g/m^2-s per kg/m^3)	14.31[5]	14.31[5]	90.24[10]	90.24[10]	90.24[10]	90.24[10]	90.24[10]	90.24[10]	NA	NA	90.24[10]	90.24[10]	90.24[10]	90.24[10]
Ingestion/Dermal Contact with Groundwater														
IR_{gw} (L/day)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1[11]	1[11]	2[1]	1.4[1]
EF (days/year)	30[2]	15[6]	NA	NA	NA	NA	NA	NA	NA	NA	350[1]	234[1]	350[1]	234[1]
ET (hours/day) and t_{event} (hours/event)	8[2]	4[6]	NA	NA	NA	NA	NA	NA	NA	NA	0.2[9]	0.2[9]	0.33[9]	0.33[9]
EV (events/day)	1[2]	1[2]	NA	NA	NA	NA	NA	NA	NA	NA	1[9]	0.4[15]	1[9]	1[9]
A (cm^2/day)	3,300[5]	3,300[5]	NA	NA	NA	NA	NA	NA	NA	NA	6,600[7]	6,600[7]	18,000[7]	18,000[7]
K_p (cm/hour)	chemical-specific[7]	chemical-specific[7]	NA	NA	NA	NA	NA	NA	NA	NA	chemical-specific[7]	chemical-specific[7]	chemical-specific[7]	chemical-specific[7]
t* (hour/event), τ (hour), and B (unitless)	chemical-specific[7]	chemical-specific[7]	NA	NA	NA	NA	NA	NA	NA	NA	chemical-specific[7]	chemical-specific[7]	chemical-specific[7]	chemical-specific[7]
Inhalation of Volatile Emissions from Groundwater														
C_{air} (mg/m^3)	calculated[12]	calculated[12]	NA	NA	NA	NA	NA	NA	NA	NA	Calculated[13]	Calculated[13]	Calculated[13]	Calculated[13]
InhR (m^3/hour)	3.3[4]	3.3[4]	NA	NA	NA	NA	NA	NA	NA	NA	0.83[1]	0.83[1]	0.83[1]	0.83[1]
ET (hours/day)	8[2]	4[6]	NA	NA	NA	NA	NA	NA	NA	NA	24[1]	24[1]	24[1]	24[1]
EF (days/year)	30[2]	15[6]	NA	NA	NA	NA	NA	NA	NA	NA	350[1]	234[1]	350[1]	234[1]
Incidental Ingestion/Dermal Contact with Surface Water														
CR (L/hour)	NA	NA	NA	NA	NA	NA	0.05[14]	0.05[14]	0.05[14]	0.05[14]	NA	NA	NA	NA
ET (hours/day) and t_{event} (hours/event)	NA	NA	NA	NA	NA	NA	4[2]	2[2]	4[2]	2[2]	NA	NA	NA	NA
A (cm^2/day)	NA	NA	NA	NA	NA	NA	3,720[8]	3,720[8]	18,000[7]	18,000[7]	NA	NA	NA	NA
K_p (cm/hour)	NA	NA	NA	NA	NA	NA	chemical-specific[7]	chemical-specific[7]	chemical-specific[7]	chemical-specific[7]	NA	NA	NA	NA
t* (hour/event), T (hour), and B (unitless)	NA	NA	NA	NA	NA	NA	chemical-specific[7]	chemical-specific[7]	chemical-specific[7]	chemical-specific[7]	NA	NA	NA	NA
CF (L/cm^3)	NA	NA	NA	NA	NA	NA	1E-03	1E-03	1E-03	1E-03	NA	NA	NA	NA
Incidental Ingestion/Dermal Contact with Sediment														
IR (mg/day)	NA	NA	NA	NA	NA	NA	100[2]	50[6]	100[1]	50[1]	NA	NA	NA	NA
EF-Sediment (days/year)	NA	NA	NA	NA	NA	NA	52[2]	26[6]	16[2]	8[2]	NA	NA	NA	NA
FI (unitless)	NA	NA	NA	NA	NA	NA	1[1]	1[1]	1[1]	1[1]	NA	NA	NA	NA
SA (cm^2/day)	NA	NA	NA	NA	NA	NA	3,720[8]	3,720[8]	5,400[8]	5,400[8]	NA	NA	NA	NA
AF (mg/cm^2)	NA	NA	NA	NA	NA	NA	0.3[7]	0.04[7]	0.02[7]	0.02[7]	NA	NA	NA	NA
ABS (unitless)	NA	NA	NA	NA	NA	NA	chemical-specific[7,9]	chemical-specific[7,9]	chemical-specific[7,9]	chemical-specific[7,9]	NA	NA	NA	NA
CF (kg/mg)	NA	NA	NA	NA	NA	NA	1.E-06	1.E-06	1.E-06	1.E-06	NA	NA	NA	NA
Ingestion of Fish														
IRf (kg/meal)	NA	NA	NA	NA	NA	NA	NA	NA	0.129[4]	0.129[4]	NA	NA	NA	NA
EF (meals/year)	NA	NA	NA	NA	NA	NA	NA	NA	62[4]	31[6]	NA	NA	NA	NA

TABLE 3-2

SUMMARY OF EXPOSURE INPUT PARAMETERS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Notes:

A	Skin surface area available for contact	ET	Exposure time
ABS	Absorption factor	EV	Event frequency
AF	Soil-to-skin adherence factor	FI	Fraction ingested from contaminated source
AT_c	Averaging time for carcinogenic effects	IRa	Inhalation rate for fugitive dust and volatilization from soil
AT_n	Averaging time for noncarcinogenic effects	InhR	Inhalation rate for volatilization from groundwater.
B	Bunge Model partitioning coefficient	IR	Ingestion rate (soil, sediment, groundwater, or fish)
BW	Body weight	K_p	Permeability coefficient from water through skin
CF	Conversion factor	PEF	Particulate emission factor
CR	Contact rate	Q/C	Inverse of mean concentration at center of source
$C_{soil/sed}$	Exposure concentration for soil/sediment	SA	Skin surface area available for contact
$C_{gw/sw}$	Exposure concentration for groundwater/surface water	τ	Lag time
C_{air}	Exposure concentration for air	t^*	Time it takes to reach steady-state conditions
ED	Exposure duration	t_{event}	Duration of event
EF	Exposure frequency		

1 - USEPA, 1993a: Superfund's Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure.
2 - Professional judgement.
3 - USEPA, 1989c: Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A) Interim Final. EPA/9285.7-01/FS.
4 - USEPA, 1997b: Exposure Factors Handbook. EPA/600/P-95/002FA.
5 - USEPA, 2002c: Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24.
6 - CTE value is assumed to be 50 percent of the RME value.
7 - USEPA, 2001a: Risk Assessment Guidance for Superfund (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim. EPA/540/R/99/005.
8 - Assumes that 30 percent of total body surface area is available for contact.
9 - USEPA Region III, 2003a: Technical Guidance Manual, Risk Assessment, Updated Dermal Exposure Assessment Guidance. June
10 - Site-specific value for Philadelphia, PA obtained from USEPA's Soil Screening Guidance Internet site (http://risk.lsd.ornl.gov/calc_start.shtml).
11 - USEPA Region III, 2003b: Risk-Based Concentration Table, October.
12 - VDEQ, 2003: Virginia Department of Environmental Quality (VDEQ, online- http://www.deq.state.va.ua/brownfield/vrp.html).
13 - USEPA, 1991b: Human Health Evaluation Manual, Part B: Development of Risk-based Preliminary Remediation Goals. OSWER Directive 9285.7-01B.
14 - USEPA, 1988a: Superfund Exposure Assessment Manual, April. EPA/540/1-88/001.
15 - USEPA, 2002b: Child-Specific Exposure Factors Handbook, Interim Report. EPA/600/P/00/002B.

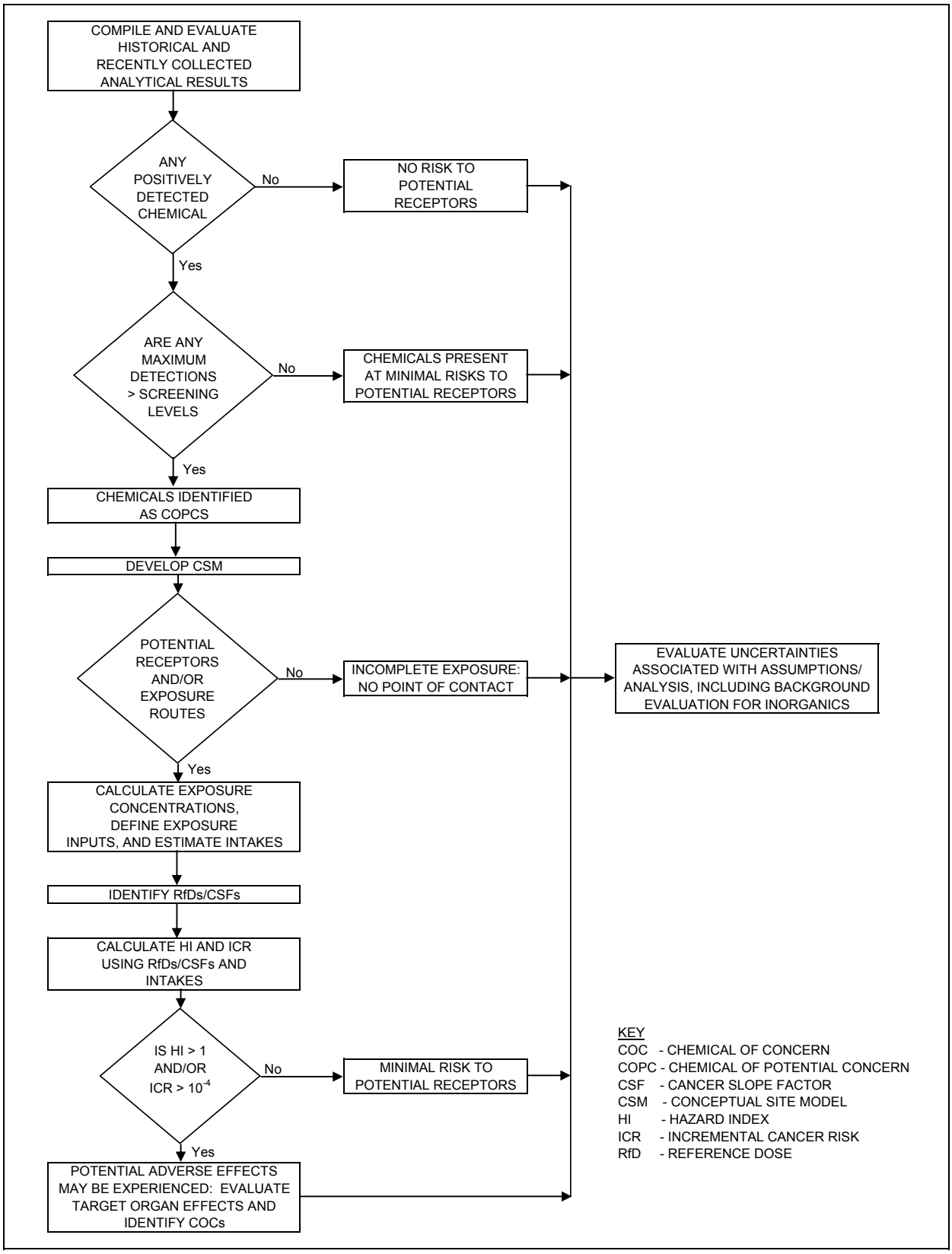


FIGURE 3-1

SUMMARY OF HUMAN HEALTH RISK ASSESSMENT PROCESS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

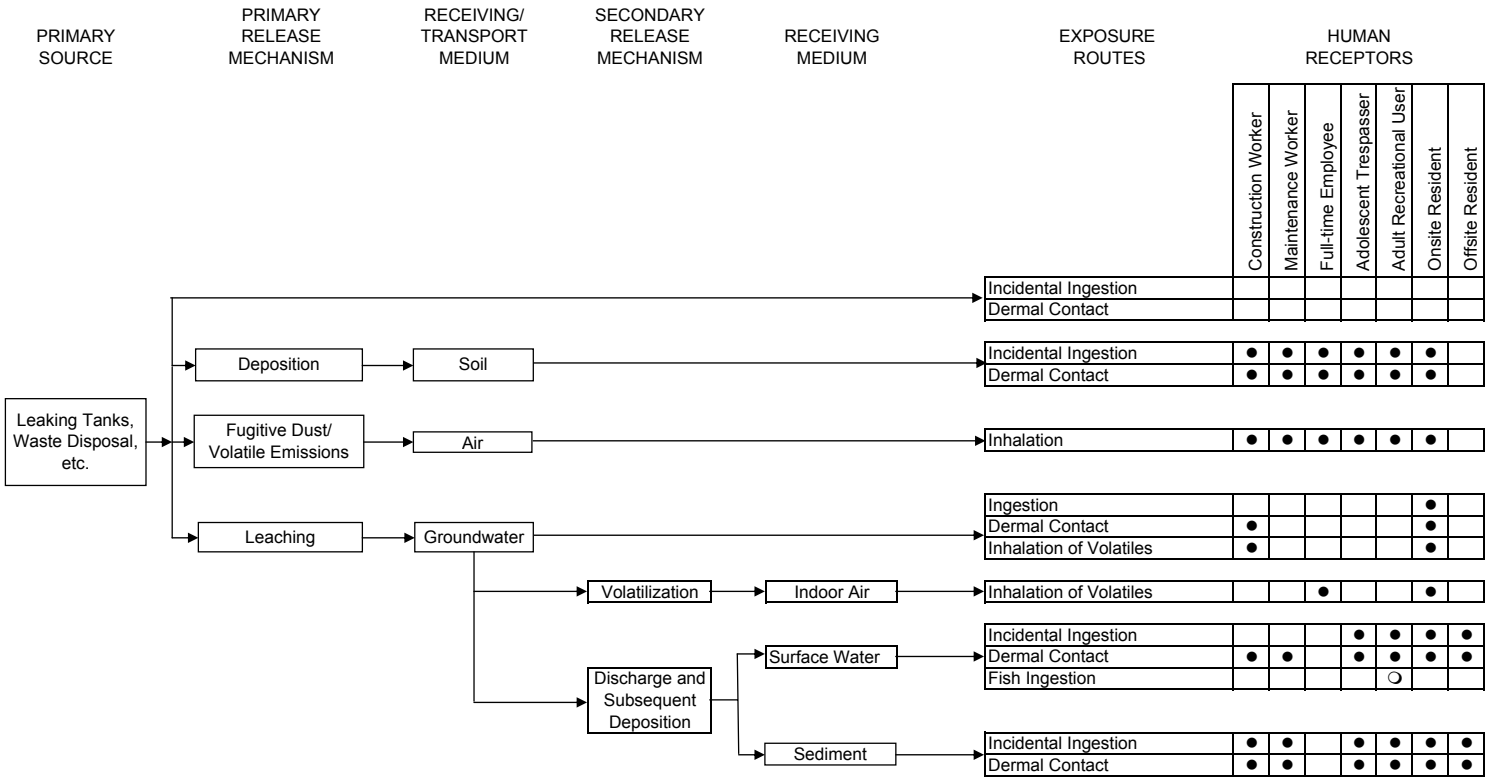


FIGURE 3-2

EXAMPLE CONCEPTUAL SITE MODEL
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

4.0 ECOLOGICAL RISK ASSESSMENT METHODOLOGY

4.1 INTRODUCTION

This section of the Master WP presents the general methodology that will be followed when conducting screening level ecological risk assessments (SERAs) (including Step 3a) at NDW,IH. This section does not include the methodology for conducting baseline ecological risk assessments (BERAs) (excluding Step 3a) because that methodology is project-specific depending on the risk drivers and ecological receptors of concern.

The goal of a SERA is to determine whether adverse ecological impacts are present as a result of exposure to chemicals released to the environment through past operations at IR sites. The SERA provides information to scientists and managers that will enable them to conclude either that ecological risks at a site are most likely negligible or that further information is necessary to evaluate potential ecological risks at a site. The SERA methodology that will be used at NDW,IH follows the guidance presented in the Navy Policy for Conducting Ecological Risk Assessments (Navy, 1999), the Final Guidelines for Ecological Risk Assessment (USEPA, 1998), and the Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (USEPA, 1997a).

A SERA (as defined in this Master WP) will consist of the first two of the eight steps (plus Step 3a) required by the USEPA guidance (USEPA, 1997a and USEPA, 1998) and the Navy Policy for Conducting Ecological Risk Assessments. Figure 4-1 presents the Navy's ecological risk assessment tiered approach. The first two steps are the screening level assessment. Step 3a is technically the first step of the BERA and consists of refining the list of COPCs that are retained following the SERA. However, this step will be included in the SERAs for NDW,IH because it is part of the Navy process and helps to further refine the SERA. Steps 3b through 7 are conducted if additional evaluations or investigations are necessary. Note that these steps are not presented as part of this Master WP. Finally, Step 8, Risk Management, is incorporated throughout the SERA process, in cooperation with USEPA Region III Biological Technical Assistance Group (BTAG).

4.2 PROBLEM FORMULATION

Problem formulation is the first step in the SERA process and includes identification of potential receptor groups, contaminants, and the mechanisms for fate and transport and toxicity. Determination of the complete exposure pathways that exist at a site is accomplished at this point to facilitate receptor selection. As part of receptor identification, site habitats and potential ecological receptors are described.

4.2.1 Site Description and Physical Features

The first step in preliminary problem definition will be a general NDW,IH Facility description, or Facility characterization, discussing the overall ecology of the Facility. This will also include geological, hydrogeological, and climatologic descriptions of the NDW,IH area as they relate to the ecological setting at the Facility. The ecological setting will include descriptions of habitat types and ecological receptors potentially present at the site. This will encompass aquatic habitats and receptors, terrestrial habitats and wildlife, and terrestrial vegetation. The Facility Natural Resources Office will be contacted for information regarding State- and federally listed rare, threatened, and endangered species or sensitive habitats such as wetlands on or around each IR site. Wetland delineations or other biological sampling typically will not be conducted as part of the SERA. If wetland delineations are done, they would be performed using the United States Army Corps of Engineers (USACE) Wetlands Delineation Manual (1987).

4.2.2 Potential Exposure Pathways

The potential pathways by which ecological receptors may be exposed to COPCs at each site will be identified, along with the species that could be adversely affected by these chemicals. Several potential exposure pathways may exist at each site. These pathways are described in the following sections.

4.2.2.1 Surface Soil

Several groups of terrestrial ecological receptors can be exposed to contaminants in the surface soil. Invertebrates, such as earthworms, are exposed to the contaminants as they move through the soil and ingest soil particles while searching for food. Plants are exposed to the contaminants via direct contact as contaminants are absorbed through the roots, which may then translocate to different parts of the plants (i.e., leaves, seeds).

Small mammals and birds are exposed to contaminants in the soil via several exposure routes. They may be exposed by direct contact as they search for food or burrow into the soil. Exposure of terrestrial wildlife to contaminants in the soil via dermal contact is unlikely to represent a major exposure pathway because fur, feathers, and chitinous exoskeletons are expected to minimize transfer of contaminants across dermal tissue. Therefore, the dermal pathway will not be evaluated for terrestrial wildlife in the SERAs. Small mammals and birds also may be exposed to contaminants in the soil via incidental ingestion of soil and ingestion of plants and/or invertebrates that have accumulated contaminants from the soil. These pathways will be evaluated in the SERA, as appropriate.

Larger predatory species, such as the red fox and red-tailed hawk, can be exposed (indirectly) to site contaminants in the soil by ingesting small mammals that have accumulated contaminants from the soil.

4.2.2.2 Groundwater

Ecological receptors typically are not directly exposed to contaminants in the groundwater, so this exposure pathway is not complete. Exposure to groundwater after it discharges to a surface water body will be evaluated as part of the surface water pathway.

4.2.2.3 Surface Water/Sediment

Contaminated groundwater may discharge as a seep that drains to a surface water body or may discharge directly to a surface water body. Contaminants in the soil may enter the water bodies via overland flow. Several water bodies at NDW,IH may support small invertebrates, fish, and other aquatic receptors. These receptors could be exposed to contaminants in the water or sediment by direct contact and incidental ingestion of water, and piscivorous wildlife may consume fish that have accumulated contaminants from the surface water or sediment.

4.2.2.4 Air

Although inhalation of particulates may be a complete pathway, it is expected to be insignificant compared to other pathways such as ingestion of food items that have accumulated contaminants from soil. Also, inhalation pathways typically are not evaluated in SERAs because of the uncertainty in exposures and effects concentrations. Therefore, this pathway will not be evaluated.

4.2.3 <u>Endpoints</u>

4.2.3.1 Assessment Endpoints

Assessment endpoints are explicit expressions of the environmental value that is to be protected (USEPA, 1997a). The selection of these endpoints is based on the habitats present, the migration pathways of probable contaminants, and the routes that contaminants may take to enter receptors. The habitats at NDW,IH are very diverse and consist of forested areas, open fields with grasses, and aquatic habitats. For the SERAs, the assessment endpoints are the protection of the following groups of receptors from adverse effects of contaminants on their growth, survival, and reproduction:

- Soil invertebrates
- Aquatic vegetation
- Terrestrial vegetation

- Herbivorous mammals
- Herbivorous birds
- Carnivorous mammals
- Carnivorous birds
- Omnivorous mammals
- Omnivorous birds
- Benthic invertebrates
- Fish

The specific endpoints selected for each site will differ from site to site depending on the habitat and potential receptors that may be present. The following paragraphs discuss why the above assessment endpoints may be selected for the SERAs.

Soil Invertebrates - Soil invertebrates are expected to be present in the soil at the Facility. They aid in the formation of soil and redistribution and decomposition of organic matter in the soil and serve as a food source for higher trophic level organisms. They also can accumulate contaminants that can then be transferred to the higher trophic level organisms that consume invertebrates.

Terrestrial Vegetation - Terrestrial vegetation at the Facility consists of grasses, shrubs, and trees. They serve as a food source and provide shade and cover for many organisms and help prevent soil erosion, among other important functions. They also can accumulate contaminants that can then be transferred to the higher trophic level organisms that consume plants.

Herbivorous Birds and Mammals - Herbivorous birds and mammals (animals that consume only plant tissue) may be present at the Facility because of the vegetative habitats. Their role in the community is essential because, without them, higher trophic levels could not exist. They may be exposed to and accumulate contaminants present in the plants they consume.

Carnivorous Birds and Mammals - Carnivorous birds and mammals consist of birds and mammals that consume invertebrates, fish, and other mammals and birds. Soil invertebrate-eating birds and mammals are present throughout the Facility in different terrestrial habitats (i.e., forested, open field). These are considered first-level carnivores, and they serve as a food source for higher trophic level carnivores. Piscivorous birds and mammals may be present along some of the larger water bodies, if significant fish populations are present in the creeks. Finally, carnivorous birds and mammals that feed on other birds and mammals are at the top of the food chain. The top carnivores typically are less densely distributed than the herbivores and first-level carnivores because they require a larger area to hunt for their food. All

of the carnivores may be exposed to and accumulate contaminants present in the food items they consume.

Omnivorous Birds and Mammals - Omnivorous birds and mammals, which consume both plant and animal tissue, are present throughout the Facility in different terrestrial habitats (i.e., forested, open field). They may be exposed to and accumulate contaminants present in the plants and animals they consume.

Benthic Macroinvertebrates - Benthic macroinvertebrates are similar to the soil invertebrates in that they serve as a food source for higher trophic level organisms (i.e., fish, amphibians, birds, mammals). They also can accumulate some contaminants that can then be transferred to the higher trophic level organisms that consume invertebrates.

Fish - Fish are present in some of the creeks on and adjacent to the Facility. Fish are exposed to contaminants and can accumulate contaminants from the food items they consume or from the surface water in which they live.

All the initial assessment endpoints may not be evaluated in the SERAs. As indicated in USEPA guidance (USEPA, 1997a), "it is not practical or possible to directly evaluate risks to all of the individual components of the ecosystem at a site. Instead, assessment endpoints focus the risk assessment on particular components of the ecosystem that could be adversely affected by contaminants from the site." Therefore, the SERAs will focus on the endpoints that will tend to yield the highest risks, which should then account for endpoints that will have lower risks.

4.2.3.2 Measurement Endpoints

Measurement endpoints are estimates of biological impacts (i.e., mortality, reproduction) used to evaluate the assessment endpoints. The selection of measurement endpoints for the SERAs is based on the data that will be available to evaluate the assessment endpoints (i.e., typically only chemical data). The following measures of effects will be used to evaluate the assessment endpoints in the SERAs:

- Decreases in survival, growth, and/or reproduction of benthic invertebrates and fish will be evaluated by comparing the measured concentrations of chemicals in the sediment and/or surface water to screening values designed to be protective of ecological receptors.

- Decreases in survival, growth, and/or reproduction of terrestrial plants and soil invertebrates will be evaluated by comparing the measured concentrations of chemicals in the surface soil to screening values designed to be protective of ecological receptors.

- Decreases in survival, reproduction, and/or increases in developmental effects of birds and mammals will be evaluated by comparing the estimated ingested dose of contaminants in the invertebrates, fish, surface water and/or sediment to no-observable-adverse-effects-levels (NOAELs) and lowest-observed-adverse-effects-levels (LOAELs) for surrogate wildlife species.

4.2.3.3 Selection of Receptor Species

Many receptors in soil and aquatic environments are adequately described in general categories such as soil invertebrates, vegetation, and sediment-dwelling (benthic) invertebrates. This is due to the nature of the threshold values, effects values, or water-quality criteria typically used to characterize risk for such organisms.

For vertebrate receptors, selection of particular species is required so that intake through eating, drinking, and other routes can be estimated. As previously mentioned, for most wildlife species, ingestion is the primary route of exposure. Surrogate species are selected for their preferred habitat, body size, sensitivity, home range, abundance, commercial or sport utilization, legal status, and functional role (e.g., predators). To be conservative, surrogate species are typically small and have small home ranges. The availability of exposure parameters such as body mass, feeding rate, and drinking rate also are factors in selecting surrogate species. The following surrogate species will be used for the food chain modeling, where appropriate:

- Herbivorous mammal: meadow vole
- Herbivorous bird: bobwhite quail
- Carnivorous bird: American robin
- Carnivorous mammals: short tail shrew
- Piscivorous mammal: Mink
- Piscivorous bird: Great blue heron or belted kingfisher (depending on habitat)

4.2.4 <u>Conceptual Site Model</u>

A CSM in SERA problem formulation is a written description of predicted relationships between ecological entities and the stressors to which they may be exposed. The CSM consists of two primary components: predicted relationships among stressors, exposures, and assessment endpoint responses and a diagram that illustrates the relationships (USEPA, 1998). A CSM will be prepared for each site depending on the site-specific conditions.

4.3 ECOLOGICAL EFFECTS ASSESSMENT

4.3.1 Terrestrial Plants and Invertebrates and Aquatic Receptors

Potential risks to terrestrial and aquatic receptors (excluding wildlife) resulting from exposure to chemicals first will be evaluated by comparing chemical concentrations to ecological screening levels. The USEPA Region III BTAG screening levels (USEPA Region III, 1995) will be used to screen the parameters as COPCs because they were developed specifically for USEPA Region III to evaluate potential risks to ecological receptors. The USEPA Region III BTAG criteria are considered to be conservative values protective of the most sensitive organisms. These criteria will be supplemented with other values when BTAG criteria are not available. Also, alternate values will be used when values used as the BTAG values are updated (i.e., when new USEPA Water Quality Criteria or ecological soil screening levels are published). These toxicity values are expressed in units of concentration because the media of concern are in intimate contact (direct exposure) with terrestrial plants/invertebrates and aquatic receptors.

4.3.2 Terrestrial Wildlife

The BTAG screening levels are not designed to evaluate risks to terrestrial wildlife. Instead, risk for terrestrial wildlife through ingestion of surface water, sediment, and biota will be evaluated through food chain modeling. Only chemicals considered to be important bioaccumulative chemicals by USEPA (USEPA, 2000a) will be included in the food chain models.

Risk to terrestrial receptors from exposure to chemicals will be determined by estimating the dose and comparing the dose to toxicity reference values (TRVs) representing acceptable daily doses in mg/kg-day. TRVs are developed from NOAELs and LOAELs obtained from wildlife studies, when available. The majority of the TRVs will be obtained from the Oak Ridge National Laboratory (ORNL) Toxicological Benchmarks for Wildlife: 1996 Revision (Sample et al., 1996) and supplemented with other toxicity information when necessary.

4.4 CHARACTERIZATION OF EXPOSURE

This portion of the SERA includes identification of contaminant concentration data used as EPCs to represent ecological exposure in various media. Terrestrial soil invertebrates and plants are exposed to contaminants in the surface soil through direct contact and/or ingestion. Aquatic organisms are exposed to contaminants in the surface water and sediment through direct contact and/or ingestion. Maximum concentrations will be used as the EPCs for comparison to the screening values in order to select COPCs.

Exposure of terrestrial receptors to contaminants in surface soil, sediment, and surface water is determined by estimating the daily doses in mg/kg-day using exposure equations. The contaminant concentrations in the surface soil, sediment, and surface water are used to calculate the doses. The following equations will be used to calculate doses for the surrogate species selected for modeling:

For terrestrial wildlife:

$$\text{Dose} = \frac{[(\text{Cs} * \text{BAF} * \text{If}) + (\text{Cs} * \text{Is}) + (\text{Cw} * \text{Iw})] * \text{H}}{\text{BW}}$$

For piscivorous wildlife:

$$\text{Dose} = \frac{[(\text{Cs} * \text{BAF (or BSAF} * \frac{\%\text{L}}{\%\text{TOC}}) * \text{If}) + (\text{Cs} * \text{Is}) + (\text{Cw} * \text{Iw})] * \text{H}}{\text{BW}}$$

where:

Dose	=	Daily intake (mg/kg-day)
Cs	=	Contaminant concentration in soil or sediment (mg/kg)
BAF	=	For herbivorous wildlife: Soil-to-plant bioaccumulation factor
		For invertivorous wildlife: Soil-to-worm bioaccumulation factor
		For piscivorous wildlife: Sediment-to-biota bioaccumulation factor (for inorganics)
BSAF	=	Biota-to-sediment bioaccumulation factor (for organics) (unitless)
%L	=	Percent lipids [4 percent (dry weight) for fish]
%TOC	=	Percent total organic carbon (TOC) (average TOC for each area)
If	=	Ingestion rate of food (kg/day)
Is	=	Rate of incidental soil or sediment ingestion (kg/day)
Cw	=	Contaminant concentration in water (mg/L)
Iw	=	Ingestion rate of water (L/day)
H	=	Contaminated area/home area range area ratio (unitless)
BW	=	Body weight (kg)

The exposure assumptions (i.e., ingestion rate, body weight) will be obtained primarily from the Wildlife Exposure Factors Handbook (USEPA, 1993c) with other sources used as necessary. Dry-weight food ingestion rates will be used for the SERAs. The percent lipid value of 4 percent (dry weight) is based on an average of 1 percent lipid (wet weight) found in the whole body fish samples collected from

Mattawoman Creek (TtNUS, 2004) divided by 25 percent (0.25), which is the percent solids of fish (Sample et al., 1997).

As presented in the equations above, the SERA will use various BAF, biota-sediment accumulation factors (BSAFs), and/or BCF to estimate contaminant loading in plants, soil invertebrates, fish, and sediment invertebrates from chemical concentrations in surface soil, sediment, or surface water. The following list presents the sources of the BAFs, BSAFs, and BCFs that may be used in the SERA:

- Plant BAFs - organics: Toxicity and Chemical-Specific Factors Database (ORNL, 2003). These BAFs are used to estimate plant concentrations from chemical concentrations in soil. Only one value is available for use in the conservative and average food chain model.

- Plant BAFs - inorganics: Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants (ORNL, 1998). These BAFs are used to estimate plant concentrations from chemical concentrations in soil. The 90-percent BAF will be used for the conservative food chain model, and the median value will be used for the average food chain model.

- Soil invertebrate BAFs - PCBs and inorganics: Development and Validation of Bioaccumulation Models for Earthworms (Sample et al., 1998). These BAFs are used to estimate earthworm concentrations from chemical concentrations in soil. The 90-percent BAF will be used for the conservative food chain model, and the median value will be used for the average food chain model.

- Fish BSAFs - PCBs, PAHs, dioxins, and pesticides: The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, Volume 1: National Sediment Quality Survey (USEPA, 1997c). These BSAFs are used to estimate fish concentrations from chemical concentrations in the sediment. These are used as the primary estimators of fish concentrations when the chemical is detected in both the sediment and surface water. When a bioaccumulative chemical is only detected in the surface water, the BCF will be used to estimate the fish concentration (see below).

- Aquatic BCFs - Organics: Toxicity and Chemical-Specific Factors Database (ORNL, 2003). These BCFs are used to estimate fish concentrations from chemical concentrations in surface water. Only one value is available for use in the conservative and average food chain model. These values will only be used when a chemical is detected in the surface water but not the sediment.

Some of the accumulation factors presented in the documents listed above (or in other references) estimate the tissue concentrations in wet weight. These values will be converted to dry weight for use in

exposure estimation in the food chain models by dividing the accumulation factor by the proportion of dry matter content of the organism. Other accumulation factors may be obtained from the literature for chemicals not listed in the above reference sources. Contaminants that do not have BAFs or BSAFs are assigned a default value of 1.

The following input parameters will be used in the dose equations for the initial screening:

- Maximum surface water or sediment concentrations
- Conservative receptor body weights
- Conservative receptor ingestion rates
- Ratio of contaminated area to home range equal to 1.0 (i.e., receptors ingest 100 percent of their food from the site)

4.5 RISK CHARACTERIZATION

The risk characterization is the final phase of a SERA that compares exposure to ecological effects. It is at this phase that the likelihood of adverse effects occurring as a result of exposure to a stressor is evaluated. An ecological effects quotient (EEQ) approach will be used to characterize the risk to potential terrestrial receptors. This approach characterizes the potential effects by comparing exposure concentrations with the effects data. When EEQ values exceed 1.0, it is an indication that ecological receptors are potentially at risk. Additional evaluation or data may be necessary to confirm with greater certainty whether ecological receptors are actually at risk, especially because most benchmarks are developed using conservative exposure assumptions and/or studies. The EEQ value should not be construed as being probabilistic, rather, it is a numerical indicator of the extent to which an EPC exceeds or is less than a benchmark.

EEQs for aquatic receptors will be calculated as follows:

$$EEQ = \frac{C_{sw}}{SWSL} \text{ or } \frac{C_{sd}}{SSL}$$

Where: EEQ = ecological effects quotient (unitless)

C_{sw} = contaminant concentration in surface water (µg/L)

C_{sd} = contaminant concentration in sediment (µg/kg or mg/kg)

SWSL = surface water screening level (µg/L)

SSL = sediment screening level (µg/kg or mg/kg)

EEQs for terrestrial plants and invertebrates will be calculated as follows:

$$EEQ = \frac{C_{ss}}{SSSL}$$

Where: EEQ = ecological effects quotient (unitless)

C_{ss} = contaminant concentration in surface soil (µg/kg or mg/kg)

SSSL = plant or invertebrate screening level in soil (µg/kg or mg/kg)

EEQs for terrestrial wildlife model will be calculated as follows:

$$EEQ = \frac{Dose}{TRV}$$

Where: EEQ = ecological effects quotient (unitless)

Dose = daily intake dose (mg/kg-day)

TRV = toxicity reference value (NOAEL or LOAEL) (mg/kg-day)

Selection of Contaminants of Potential Concern

Prior collection, the proposed samples for each site have been be defined (e.g., type, location, analytes, tests, etc.) with the goal of satisfying the objectives of each environmental investigation. Frequently, the sample locations are biased so as to target likely occurrences of contamination in an effort to ensure that, if contamination is present on the site, it is detected in the data set for that investigation. The final part of the screening evaluation is to evaluate the data set and select COPCs. Chemicals not selected as COPCs are assumed to present negligible risk to ecological receptors and are not considered for further evaluation in the SERA. Chemicals retained as COPCs will be evaluated further in Step 3a to determine if they are carried through as chemicals of concern (COC). Ecological COPCs will be selected by the following procedures:

- Chemicals with EEQs greater than 1.0 (using screening values) will be retained as COPCs for further evaluation because they have a potential to cause risk to ecological receptors.

- Chemicals with EEQs greater than 1.0 based on the food chain model using NOAELs will be selected as COPCs because they have the potential to cause risks to mammals and birds.

- Chemicals without screening levels will be retained as COPCs but will only be evaluated qualitatively.

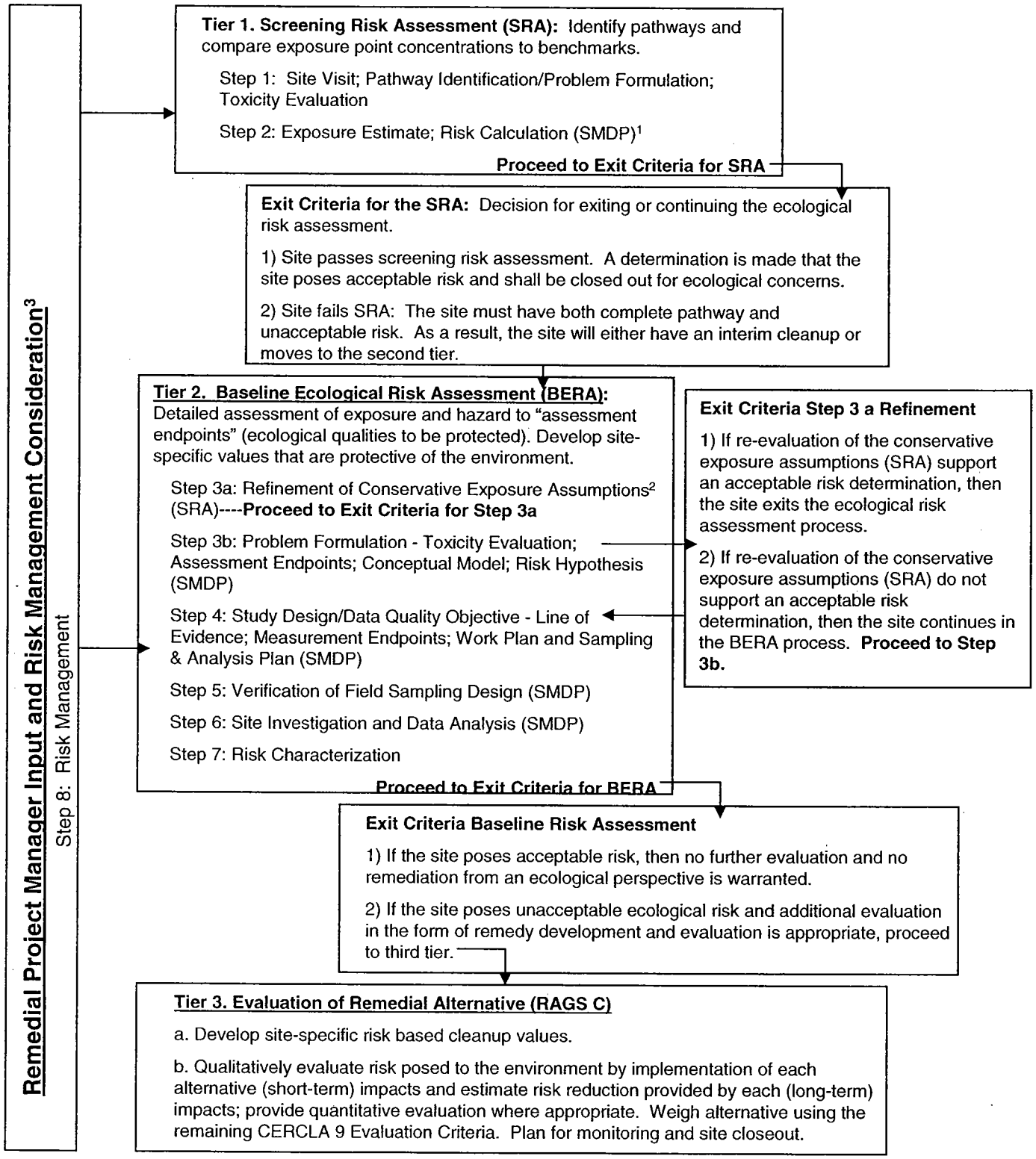
- Calcium, magnesium, potassium, and sodium will not be retained as COPCs because they are essential nutrients that can be tolerated by living systems even at high concentrations.

4.6 STEP 3A - REFINEMENT OF CONSERVATIVE EXPOSURE ASSUMPTIONS

Step 3a consists of a refinement of the conservative exposure assumptions/concentrations to evaluate potential risks to ecological receptors (i.e., plants, invertebrates, and wildlife receptors). The objective of the Step 3a evaluation is to refine the CSM based on all the available data, including the spatial distribution of the chemicals in the media, potential bioavailability of the chemicals, and background considerations. A goal of the Step 3a is to further reduce the number of chemicals retained as COPCs in order to focus any additional efforts on those chemicals causing ecological concern.

FIGURE 4-1

NAVY ECOLOGICAL RISK ASSESSMENT TIERED APPROACH
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND



Notes: 1) See USEPA's 8-Step ERA Process for requirements for each Scientific Management Decision Point (SMDP).

2) Refinement includes but is not limited to background, bioavailability, detection frequency, etc.

3) Risk Management is incorporated throughout the tiered approach.

5.0 WORK PLAN DEVELOPMENT

The Navy has the responsibility for ensuring that site environmental projects are performed efficiently in the most cost-effective and timely manner, considering pertinent constraints such as the need to protect human health and the environment, site closure requirements, regulatory compliance, and funding limitations. Clearly focused environmental projects are necessary to meet that responsibility. Therefore, the Navy has developed an approach to improve the planning and implementation of environmental projects through the appropriate application of guidance from USEPA, data and information from previous environmental work at NDW, IH and other facilities, and the use of innovative technologies when warranted. Taken together, these elements will improve the focus and cost effectiveness of environmental projects.

This Master Work Plan is intended to be applicable to a range of environmental projects including investigations (e.g., remedial, ecological, background, etc.), studies (e.g., pilot studies), and remedial actions (e.g., for verification sampling). The planning considerations discussed in the following sections apply equally to traditional investigation approaches (i.e., sample collection, fixed-base laboratory analysis, data evaluation), or to more innovative investigative approaches such as the Triad approach (EPA, 2001c; EPA, 2003c) which relies heavily on on-site data acquisition and real-time data evaluation.

This Master WP and the other master planning documents present general procedures and methods to plan environmental projects at the NDW, IH in a consistent manner. In addition, a project-specific WP will be prepared for each environmental project to be implemented at NDW, IH.

5.1 OBJECTIVES

The typical overall objective of environmental investigative work at NDW,IH is to efficiently characterize environmental contamination to determine whether there is a risk to human health and the environment. Based on the results of the risk evaluations, typical secondary objectives include: (1) determining whether no further action is required; (2) determining whether further investigation and characterization is needed; and/or (3) defining the nature and extent of contamination such that appropriate RAs can be developed and designed. Overall objectives may be modified to accommodate non-environmental investigations such as pilot studies. Each environmental project will have more objectives that are specific to that project. In each case, the project-specific objectives will be presented in the project-specific WP along with the rationale for developing the objectives.

5.2 DATA QUALITY OBJECTIVES

The project-specific WPs will generally conform to the DQO process, which consists of seven steps. The following paragraphs describe the generic processes and requirements for implementing the DQO process. Each project-specific WP will utilize the fundamental concepts of the DQO process to guide the planning stage of the project.

The DQO process is a systematic procedure, based on the Scientific Method that defines the criteria by which data collection activities are performed. The goal is to make the best use of limited resources by collecting data of sufficient quality and quantity to support defensible decision making while eliminating unnecessary precision. The most efficient way to accomplish these goals is to establish criteria for defensible decision making during the planning stages (before the study begins) and then develop a data collection approach based on these criteria.

The complete DQO process consists of seven steps. The USEPA provides guidance for the DQO process in Guidance for the Data Quality Objectives Process (QA/G-4) (2000b). The seven-step DQO process and where they can be addressed in the planning documents is presented on Table 5-1.

The following is a brief description of each step of the DQO process.

Step 1: **State the Problem** - Concisely describe the problem to be studied. Review prior studies and existing information to gain a sufficient understanding to define the problem.

Step 2: **Identify the Decision** - Identify what questions the study will attempt to resolve and what actions may result.

Step 3: **Identify the Inputs to the Decision** - Identify the information that needs to be obtained and the measurements that need to be taken to resolve the decision statement.

Step 4: **Define the Study Boundary** - Specify the time periods and spatial areas to which decisions will apply. Determine when and where data should be collected.

Step 5: **Develop a Decision Rule** - Define the statistical parameter(s) of interest, specify the action level, and integrate the previous DQO outputs into a single statement that describes the logical basis for choosing among alternative actions.

Step 6: **Specify Tolerable Limits on Decision Errors** - Define the decision maker's tolerable decision error rates based on a consideration of the consequences of making an incorrect decision.

Step 7: **Optimize the Design for Obtaining Data** - Evaluate information from the previous steps and generate a sampling design. Choose the most resource-effective design that meets all DQOs.

The aforementioned steps are often related in a downward decision flow. However, during development of the DQOs, the answers to subsequent questions may require a review of one or more of the previous steps. The DQO steps also will be reviewed during the data collection activities to allow for changes to the proposed project-specific WP that can better optimize the design. Therefore, the DQO process is an iterative process requiring dynamic project-specific WPs and input from decision makers to qualify all decisions made before and during the design and implementation of the data collection activities.

To ensure effective use of limited resources, EFACHES has determined that before data are collected, the DQO process will be used during the planning stages of all projects requiring substantial data collection. The depth and detail of the process will vary with the complexity of the particular study. For projects in which the likelihood of making decision errors is small, where decision errors are not critical, or where prescriptive procedures/remedies are mandated, the DQO process can be used less intensively. For example, on many small projects involving presumptive procedures/remedies, it is often not necessary to determine quantitative limits on decision errors to optimize the investigation or remedial design. Also, the DQO process is naturally less stringent for those projects for which little information is known about a site and the objective is to determine whether or not gross levels of contamination exist.

For project-specific WPs, the DQO process may be described in either text or tabular form or both. Tables 5-2 and 5-3 offer examples of tabular formats. DQO-related discussions need not follow the precise order of the DQO steps 1 through 7; however if they do not, a cross-walk table similar to Table 5-1 is suggested for inclusion in the project-specific WP.

TABLE 5-1

INTEGRATION OF DQO PROCESS INTO PROJECT-SPECIFIC PLANNING DOCUMENTS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

DQO Step [1]	Typical Location in Project-Specific Planning Documents
1. State the Problem	Section XXX, Site Background Section XXX, Previous Site Investigations Table X-2, Development of Data Needs Columns (see Table 5-2 in this Master Work Plan): • Identified or Suspected Contamination • Potential Transport Pathways • Potential Receptors • Qualitative Potential for Risk Human Health Ecological
2. Identify the Decision	Section XXX, Objectives Table X-2, Development of Data Needs Columns (see Table 5-2 in this Master Work Plan): • Potential Remedial Objectives • Potential Cleanup Criteria • Potential Response Action • Potential Remedial Technologies • Data Needs
3. Identify the Inputs to the Decision	Table X-3, Investigation Scoping Column (see Table 5-3 in this Master Work Plan): • Investigation Objectives - Human Health Risk - Ecological Risk - Engineering • Investigative Technique • Location • Work Plan Figure • Quantity of Samples • Matrix • Analytical Parameters

TABLE 5-1

INTEGRATION OF DQO PROCESS INTO PROJECT-SPECIFIC PLANNING DOCUMENTS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

DQO Step [1]	Typical Location in Project-Specific Planning Documents
4. Define the Boundaries of the Study	Section XXX, Background Section XXX, Previous Site Investigations Table X-3, Investigation Scoping Column (see Table 5-3 in this Master Work Plan): • Population: Contaminant Source/Media/Path • Spatial Description • Temporal Description • Data Needs
5. Develop a Decision Rule	Table X-3, Investigation Scoping Columns (see Table 5-3 in this Master Work Plan): • Decision Rule
6. Specify Tolerable Limits on Decision Efforts	Quality Assurance Project Plan
7. Optimize the Design for Obtaining Data	Field Sampling Plan Table X-3, Investigation Scoping (see Table 5-3 in this Master Work Plan)

1 Source: USEPA, 2000b.
X Denotes Section or Table number to be determined.

TABLE 5-2

DEVELOPMENT OF DATA NEEDS
EXAMPLE COLUMN HEADINGS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

STUDY BOUNDARY			STATEMENT OF THE PROBLEM					IDENTIFY THE DECISION				DATA NEEDS		
						Qualitative Potential for Risk								
Population: Contaminant Source/ Medium/Path	**Spatial**	**Temporal**	**Identified Contamination**	**Potential Transport Mechanisms**	**Potential Receptors**	**Human Health**	**Ecological**	**Potential Remedial Objectives**	**Potential Cleanup Criteria**	**Potential Response Actions**	**Potential Remedial Technologies**	**Human Health Risk**	**Ecological Risk**	**Engineering**
Identify the suspected or actual contaminant sources (e.g., leaking drums), media (e.g., groundwater), pathways (e.g., swale to a wetland).	Identify the area to be investigated (e.g., upgradient of the site, wetland east of the site, north-south swale).	Identify those aspects of the timing of the investigation that are important (e.g., conduct during drilling operations, sample during spring growing season, measure during high tide).	Identify the contaminants that are suspected or have been determined to be present to date.	Identify the potential mechanisms for contaminant transport (e.g., from soil via leaching, stormwater to groundwater, groundwater to stream, surface soil via storm runoff to stream).	Identify the potential receptors (e.g., human, ecological).	Provide a qualitative indication of human health risk. Provide a quantitative indication if determined during previous studies.	Provide a qualitative indication of ecological risk. Provide a more definitive indication if determined during previous studies.	Identify any potential remedial objectives that may be pursued if the suspected or previously identified contamination is determined to require remediation (e.g., protect humans from direct contact with contaminated surface soil, mitigate the transfer of surface soil contamination to other media).	Identify potential cleanup criteria that may be applied to remedial actions (e.g., MCLs, site - specific clean-up levels based on human health ICR<10E-6 and HI<1).	Identify potential response actions that seem to be appropriate if the site requires remediation (e.g., remove the contaminated media, treat the contaminated media insitu, install a barrier between the contaminated media and the receptors).	Identify potential remedial technology(ies) that may be applied to the contaminated media to achieve the potential response action(s).	Enter questions that express the data gaps with respect to human health risk. For example, "Does the arsenic concentration in downgradient groundwater pose a human health risk?".	Enter questions that express the data gaps with respect to ecological risk. For example, "Are the sediments in the downgradient stream toxic to benthic organisms?".	Enter questions that express the data gaps with respect to engineering data needed to more completely evaluate each potential remedial technology. For example, "What is the horizontal extent of the surface soil requiring remediation?".

MCL Maximum Contaminant Levels
ICR Incremental Cancer Risk
HI Hazard Index

TABLE 5-3

INVESTIGATION SCOPING
EXAMPLE COLUMN HEADINGS
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

STUDY BOUNDARY			INVESTIGATION OBJECTIVES			IDENTIFY INPUTS TO THE DECISION						DECISION RULE
Population: Contaminant Source/ Medium/Path	**Spatial**	**Temporal**	**Human Health Risk**	**Ecological Risk**	**Engineering**	**Investigative Technique**	**Location**	**Work Plan Figure**	**Quantity of Samples**	**Matrix**	**Analytical Parameters**	
For these three columns, repeat the entries from Table 5-2 to serve as a reference for the reader and to set the horizontal format of Table 5-3 to match Table 5-2.			For these three columns, refer to the questions entered into the Data Needs columns on Table 5-2 and rephrase the questions here as statements (i.e., objectives). For example, if the human health data need in Table 5-2 asks, "Does the arsenic concentration in downgradient groundwater pose a human health risk?"; the human health statement under Investigation Objectives in this table could read, "Determine the risk posed by arsenic concentrations in the downgradient groundwater."			Identify the investigative technique(s) that will be utilized to address each of the investigation objectives (e.g., monitoring wells and groundwater sampling, cone penetrometer tests, in-situ bioremediation pilot study).	Identify the location where the investigative techniques will be applied. This may, for example, be an area (e.g., wetland southwest of Building 2), or a sampling location shown on a figure.	Identify the work plan figure that illustrates the location identified in the previous column.	Show the quantity of samples planned for collection from the location(s) shown in the previous column for the media shown in the following column.	Identify the matrix to be sampled as indicated in the preceding columns.	Identify the analytical parameters for which the samples identified in the previous columns will be analyzed.	Enter an if-then statement that indicates the conditions under which certain actions will be taken. For example, "If the arsenic concentration in the downgradient groundwater exceeds USEPA Region III RBCs, then perform a human health risk assessment."

RBC Risk-based Concentration

6.0 REGULATORY BACKGROUND

This section describes how the site is being regulated, and its current status under CERCLA and includes a summary of ARARs.

6.1 REGULATORY OVERVIEW

The NDW,IH was placed on the National Priorities List (NPL) in 1995. The lead regulatory agency for the project is the USEPA. The Maryland Department of the Environment (MDE) also provides input into the regulatory process. In addition, there are other regulatory programs that affect the Facility including the Resource Conservation and Recovery Act (RCRA), the National Pollution Discharge Elimination System (NPDES), and wetland regulations.

6.1.1 Resource Conservation and Recovery Act

Federal regulations under RCRA establish minimum national standards defining the acceptable management of hazardous waste. States, including Maryland, can be authorized by USEPA to administer and enforce all or part of the RCRA hazardous waste management program. RCRA regulations include standards for hazardous waste generators, transporters, and treatment, storage, and disposal facilities. The Hazardous and Solid Waste Amendments (HSWA) expanded the scope of RCRA by adding new corrective action requirements, land disposal restrictions, and technical requirements. NDW,IH is classified as a large quantity generator and also has a RCRA permit to store hazardous waste generated at the Facility. Many of the IR Program sites at the Facility were identified as part of the HSWA corrective action requirements.

6.1.2 National Pollution Discharge Elimination System

The Facility participates in the NPDES permit process in compliance with the Clean Water Act (CWA). The NPDES permit process identifies national goals to eliminate the introduction or discharge of pollutants and toxic substances into waters of the United States, thus restoring and maintaining biological and chemical integrity.

To attain goals established by the CWA, the USEPA identifies different types of pollutants and the degrees of technology that must be applied to remove pollutants from point sources of wastewater. Point source means any discernible, confined and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, or landfill leachate collection system. All discharges of pollutants to waters of the United States from point sources must have a NPDES permit, including stormwater associated with industrial activities. Point source discharge requirements are implemented through the

NPDES, a nationwide permit program administered by the USEPA or USEPA-approved state programs. This program issues, modifies, revokes and reissues, terminates, monitors, and enforces permits. The CWA also authorizes the USEPA to promulgate pretreatment standards for industrial sources discharging effluents to publicly owned treatment works (POTWs).

6.1.3 Wetlands

Activities in tidal and nontidal wetlands are regulated by the USACE and the State of Maryland. The goal of the tidal wetlands program is to manage tidal wetlands to provide reasonable use while furnishing essential resource protection. The tidal wetland program regulates filling of open water and vegetated wetlands, construction of structures, and dredging. The goal of the nontidal wetlands and waterways program is to manage nontidal wetlands and to provide essential resource protection by authorizing only necessary and unavoidable impacts. The nontidal wetland and waterways program regulates grading or filling, excavating or dredging, changing existing drainage patterns, disturbing the water level or water, and destroying or removing vegetation. Activities in the 100-year floodplain are also regulated.

6.2 FACILITY CERCLA STATUS

CERCLA, as amended by SARA in 1986, was promulgated to identify contamination resulting from past operations at closed or abandoned facilities and to institute corrective measures as appropriate. In addition to requiring investigation and cleanup of sites, CERCLA also mandates reporting releases or threatened releases of hazardous substances from both current and past operations.

In addition, the USEPA has published regulations for responding to oil and hazardous spills in the NCP. The NCP established a phased approach to address potential emergency responses or removal situations. The response process consists of the preparation of a PA and SI. When the PA and SI are completed, the site is scored using the hazard ranking system (HRS). A site with an HRS score of 28.50 or greater becomes eligible for the NPL.

Sites placed on the NPL are subject to a further, more detailed, RI. The objective of the remedial phase is to eliminate, reduce, or control risks to human health and the environment. Following the final listing of a federal facility on the NPL, the negotiation of a Federal Facility Agreement (FFA) is required. The FFA is a legal document between the USEPA, the State, and the Facility. Those geographical areas listed in the FFA as posing a potential risk to human health or the environment are designated as site screening areas (SSAs). SSAs may be RCRA SWMUs, areas of concern (AOCs), or current IR Program sites.

Each SSA is investigated to confirm that it does or does not pose a potential risk to human health or the environment. The investigation process is referred to as the site screening process (SSP). The SSP

investigation and resulting SSP report determine the fate of each SSA. The SSP report makes recommendations as to whether the site should be further investigated under CERCLA or whether the site does not pose a risk to human health or the environment and therefore should be removed from the CERCLA program.

The remaining investigative/remedial steps of the CERCLA process include the RI/FS, ROD, and RD/RA. Throughout the SSP, each site is continuously reviewed to determine if site conditions are appropriate for a Removal Action, or an Interim Remedial Action. A Removal Action is usually a short-term action undertaken to mitigate or minimize adverse impacts to human health or the environment. An RA is usually a long-term action consistent with a permanent remedy taken instead of, or in addition to, a Removal Action. Interim Remedial Actions are implemented prior to a full-scale FS to temporarily mitigate risks until the final RA can be selected.

This Master WP and corresponding master planning documents provide standard procedures and guidance for performing environmental investigations at IR Program sites at the Facility.

6.3 SITE MANAGEMENT PLAN SUMMARY

An updated Site Management Plan (SMP) was prepared for the Facility in May 2003 (EFACHES, 2003). The SMP summarized the status of the sites at the Facility and their various studies or investigations.

6.4 SUMMARY OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

The assessment of ARARs is an integral part of the remediation process mandated under CERCLA and SARA (42 USC § 9601-9675). As the preamble of CERCLA states, the purpose of the law is "to provide for liability, compensation, cleanup, and emergency response for hazardous substances released into the environment and the cleanup of inactive hazardous waste disposal sites." In addressing hazardous substances and sites, CERCLA provides that onsite RAs must meet the standards and criteria that are otherwise legally applicable to the substance, pollutant, or contaminant or that are relevant and appropriate under the circumstances (42 USC § 9621 [d][2][A]).

Guidance for assessing and selecting ARARs is provided in the USEPA manual CERCLA Compliance With Other Laws Manual (USEPA, 1988b) and CERCLA Compliance with Other Laws Manual: Part II. Clean Air Act and Other Environmental Statutes and State Requirements (USEPA, 1989b). These guidance documents were used to identify potential federal ARARs.

CERCLA RAs may trigger several different types of requirements or ARARs. These are organized into three categories: chemical-specific, action-specific, and location-specific. However, these categories are

not always mutually exclusive. Chemical-specific ARARs are numerical requirements typically derived from health- or risk-based values for various chemical substances (USEPA, 1988b). Action-specific ARARs are usually technology- or activity-based requirements or limitations based on the type of RA (USEPA, 1988b). Location-specific ARARs are requirements or limitations based on the physical setting of the site (e.g., wetlands, floodplains).

To be classified as an ARAR, a requirement must be **applicable** or **relevant and appropriate**. As defined in the NCP, **applicable requirements** are "those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site" [40 Code of Federal Regulations (CFR) §300.5].

Relevant and appropriate requirements are "those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site" (40 CFR § 300.5).

In either case, an applicable or a relevant and appropriate requirement for onsite RA must be substantive. Compliance with administrative requirements is not mandated for onsite actions (USEPA, 1988b), Administrative requirements are those procedures "that facilitate the implementation of the substantive requirements of a statute or regulation" (USEPA, 1988b). For example, CERCLA specifically exempts on-site actions from federal, state, and local permitting requirements (42 USC § 9621 [e][1]). Furthermore, only those state requirements that are more stringent than federal requirements are ARARs (40 CFR § 300.5). "More stringent" would also necessarily include those state laws or programs that have no federal counterpart as, "they add to the federal law requirements that are specific to the environmental conditions in the State" (USEPA, 1989b).

Finally, there is a category of requirements titled TBC guidance. These are guidelines or advisories issued by the federal or state government but that are neither legally binding nor promulgated (USEPA, 1988b). However, these guidelines may be used when they are necessary to ensure protection of public health and the environment and when they have not been superseded (USEPA, 1988b). If no ARARs address a particular circumstance at a CERCLA site (such as soil standards), then TBCs can be used to establish remedial guidelines or targets. Even when TBCs are used, the other requirements imposed on the remedy, including cost-effectiveness, still apply.

The following sections discuss potential ARARs that could apply to RAs at NDW,IH. The information may or may not apply to a particular RA at a particular site but is provided as examples of information that needs to be considered or situations that may be encountered. Also, ARARs and TBC criteria are periodically amended by regulatory agencies. The evaluation of ARARs and TBC criteria is site specific.

6.4.1 Chemical-Specific ARARs and TBC Criteria

The following sections discuss ARARs that can potentially be used to develop remediation goals or determine areas of a site that may require RA to protect human health or the environment.

6.4.1.1 USEPA Region III Screening Levels

USEPA Region III has developed tables that provide screening levels for human health risk and ecological risk. The human health screening tables are presented in the RBC Tables provided by USEPA Office of RCRA Technical and Programs Support branch (see http://www.epa.gov/reg3hwmd/risk/index.htm). The RBCs correspond to a systemic HQ of 1.0 (for noncarcinogens) or a lifetime cancer risk of 1E-6 (for carcinogens). The TBCs can be used for screening out contaminants prior to conducting a risk assessment. In general, RBCs are not used to select contamination cleanup levels.

Screening levels developed by the USEPA Region III BTAG can be used to screen out contaminants prior to an ecological risk assessment. This table is presented in the Revised USEPA Region III BTAG Screening Levels from the USEPA Technical Support System (USEPA Region III, 1995).

These USEPA Region III screening levels are TBC criteria.

6.4.1.2 Maximum Contaminant Levels

Maximum contaminant levels (MCLs) are promulgated under the SDWA National Primary Drinking Water Regulations [40 CFR 141.11 through 141.136 and 40 CFR 141.60 through 141.66 and Code of Maryland Regulations (COMAR) 26.04.01] and are designed for the protection of human health. MCLs are applicable to drinking water suppliers that provide water to a minimum of 25 persons. They also reflect the technical and economic feasibility of removing particular contaminants from the water. MCLs may be relevant and appropriate for developing groundwater remediation goals.

6.4.1.3 Maximum Contaminant Level Goals (MCLGs)

Maximum contaminant level goals (MCLGs) (40 CFR 141.50 to 141.53) are generally specified as zero for carcinogenic chemicals, based on the assumption of nonthreshold toxicity, and do not consider either the technical or economic feasibility of achieving these goals. MCLGs are nonenforceable guidelines based entirely on health effects. The MCLs are set as closely to the MCLGs as is considered technically and economically feasible. MCLGs are TBC criteria that may be pertinent for developing groundwater remediation goals.

6.4.1.4 Health Advisories

Health advisories are guidelines developed by the USEPA Office of Drinking Water for nonregulated contaminants that may be intermittently encountered in drinking water. These guidelines are designed to consider both acute and chronic toxic effects in children (with an assumed body weight of 10 kg) who consume 1 liter of water per day or in adults (with an assumed body weight of 70 kg) who consume 2 liters of water per day. Health advisories are generally available for acute (1-day), subchronic (10-day), and chronic (longer-term or lifetime) exposure scenarios. These guidelines are designed to consider only threshold effects and, as such, are not used to set acceptable levels of known or probable human carcinogens. Health advisories are TBC criteria that may be pertinent for developing groundwater remediation goals.

6.4.1.4 Water Quality Criteria

USEPA Ambient Water Quality Criteria (AWQC) were developed pursuant to the CWA for pollutants in surface water. Although AWQC are not legal enforceable, they can be used by states to develop enforceable water quality standards. AWQC are available for the protection of human health from exposure to both drinking water and consuming aquatic organisms (primarily fish) and from consumption of organisms alone. AWQC are also available for the protection of freshwater and saltwater aquatic life. These guidelines should be considered as potential ARARs, as specified by CERCLA, for RAs that involve or affect surface water.

Maryland Surface Water Quality Criteria (COMAR 26.08.02.03) establish minimum standards for surface quality for each designated use. Standards are available for protection of human health and protection of aquatic life. These standards may be applicable for RAs that involve or affect surface water.

6.4.1.5 USEPA Generic Soil Screening Levels

SSLs are guidance values that provides soil concentrations for protection of human health and for protection of groundwater. SSLs are TBC criteria that can be used to estimate areas of a site where soil may be a continuing source of groundwater contamination.

6.4.1.6 Maryland Cleanup Standards for Soil and Groundwater

Maryland cleanup standards are TBC criteria that are intended to represent concentration levels at which no further RA would be required at a property based on potential harm posed by hazardous substances to human health. The cleanup standards have been developed by incorporating applicable land uses and the current or projected use of groundwater for potable use.

6.4.2 Action-Specific ARARs and TBC Criteria

The discussion of action-specific ARARs is based on some of the remedial alternatives that have been evaluated and/or implemented to date. The discussion does not include all potential alternatives that may be evaluated in an FS or implemented at a particular site; therefore, a site-specific evaluation of action-specific ARARs will be needed in the FS for each site. These remedial alternatives include the following:

- Capping
- Excavation and offsite disposal
- In-situ groundwater treatment
- Groundwater extraction, treatment, and discharge to surface water

These remedial alternatives and examples of associated ARARs are listed in Table 6-1. Additional ARARs may be associated with other RAs. Action-specific ARARs should be evaluated on a site-specific basis considering the action(s) to be considered. An evaluation of federal and State air pollution control regulations should be considered for any alternative that could generate air pollutants, including dust and other fugitive emissions.

Location-Specific ARARs

Potential location-specific ARARs (Table 6-2) are associated with floodplains, wetlands, streams, protection of endangered species, and protection of historic or archeological areas. RAs should avoid or minimize adverse effects to such areas if possible. Any adverse effects from implementing an RA may need to be mitigated.

TABLE 6-1

SUMMARY OF POTENTIAL ACTION-SPECIFIC ARARs
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Remedial Action	Issue	Citation	Description
Capping (closure with waste in place)	Closure and post-closure requirements	COMAR 26.04.07	Contains requirements for closure and post-closure care of solid waste land disposal facilities.
		40 CFR 264 and COMAR 26.13.05	Contains requirements for closure and post-closure care of hazardous waste landfills.
Excavation and offsite disposal	Earth-moving activities	COMAR 26.17.01	Contains requirements for erosion and sediment control.
	Discharges to surface water	COMAR 26.08.04	Contains requirements for discharge of stormwater from construction activities.
	Hazardous waste	40 CFR 261 to 263 and 268 and COMAR 26.13.02 to 26.13.04	Contains requirements for identification of hazardous waste and standards applicable to generators and transporters of hazardous waste.
	Land disposal restrictions	40 CFR 268	Identifies waste analysis requirements and hazardous wastes that are restricted from land disposal.
In-situ groundwater treatment	Underground injection of chemicals	40 CFR 144 and COMAR 26.08.07	Contains provisions for control and prevention of pollutant injection into groundwater.
Groundwater extraction, treatment, and discharge	Extraction wells	COMAR 26.04.04	Contains design standards and procedures for construction of wells.
	Treatment of hazardous waste	40 CFR 264 and COMAR 26.13.05	Establishes minimum standards for acceptable management of hazardous waste. Contaminated groundwater could contain a listed hazardous waste or be classified as a characteristic hazardous waste.
	Control of volatile air emissions from air strippers	OSWER Directive 9344.0-28	Emission controls are required if actual or potential emission rates are exceeded in an ozone nonattainment area.
	Discharge to surface water (NPDES)	40 CFR 122 and COMAR 26.08.04	Contains requirements for discharge of treated groundwater to surface water.

CFR - Code of Federal Regulations
COMAR - Code of Maryland Regulations
NPDES - National Pollutant Discharge Elimination System

TABLE 6-2

SUMMARY OF POTENTIAL LOCATION-SPECIFIC ARARs
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

Activities/Issues	Citation	Description
Activities in wetlands	E.O. 11990 and 40 CFR 6 Appendix A	If no practicable alternative exists to a remedial activity that may affect a wetland, impacts must be mitigated.
	COMAR 26.23	Establishes requirements for activities in nontidal wetlands.
	COMAR 26.24	Establishes requirements for activities in tidal wetlands.
Activities in floodplains	E.O. 11988 and 40 CFR 6 Appendix A	If no practicable alternative exists to performing cleanup in a floodplain, potential harm must be mitigated and actions taken to preserve the beneficial values of the floodplain.
Construction on nontidal waters and floodplains	COMAR 26.17.04	Governs water obstructions or changes to a stream or body of water
Protection of threatened and endangered species and their critical habitats	16 USC 1531 et seq. and 50 CFR 402	The Endangered Species Act and associated regulations required federal agencies to act to avoid jeopardizing the continued existence of federally listed endangered or threatened species.
	COMAR 08.03.08	Provides for the consideration of the impacts on endangered, threatened, and rare species and their critical habitats.
Protection of historic areas	16 USC 470 et seq. and 36 CFR 65	The Archeological and Historical Preservation Act of 1974 establishes requirements relating to potential loss or destruction of significant scientific, historical, or archeological data as a result of a remedial action.

E.O. - Executive Order
COMAR - Code of Maryland Regulations
CFR - Code of Federal Regulations
USC - United States Code

7.0 PROJECT MANAGEMENT

This section discusses generic project management tasks such as Facility support, project personnel, and contingency plans. Project personnel will be identified in project-specific WPs. Responsibilities and authorities of management and support personnel are further detailed in the Master QAPP.

7.1 NAVY SUPPORT

The Navy Remedial Project Manager (RPM) will be provided from EFACHES and will provide overall management and coordination of the investigation project.

A Point of Contact (POC) will be identified by the Facility. The POC will coordinate activities at the Facility and be the liaison between the contractor and the Facility.

As necessary during site characterization activities, personnel from the Facility will sign disposal manifests for investigation-derived wastes, including any drill cuttings, well development fluids, or decontamination fluids suspected to be hazardous and requiring proper disposal according to applicable State and/or federal regulations. (Drums are to be provided by the contractor and/or its subcontractors.)

In addition, Facility personnel will aid in the following:

- Coordination of field activities within the Facility so that the ongoing mission of the Facility will not be adversely affected.

- Securing staging areas for decontamination operations and for storing equipment and supplies. More than one area may be required.

- Providing a supply (e.g., fire hydrant, stand pipe, etc.) of large quantities of potable water and electricity for equipment cleaning, etc.

- Arranging for a suitable area for setup of an operations field trailer near electric and telephone service (contractor will be responsible for arranging for utility connections).

7.2 PROJECT PERSONNEL

The contractor should identify a project manager (at a minimum) and a Field Operations Leader (FOL). Support staff including geology, chemistry, engineering, health and safety, database, and drafting personnel. Key personnel will be identified in the project-specific WP.

7.3 CONTINGENCY PLAN

In the event that problems are encountered during site investigation activities, the contractor project manager, the Navy RPM and the Facility POC will be notified immediately. The project manager will determine a course of action so as to minimize adverse impacts to the project schedule or budget. All contingency plans will be approved through the Navy RPM before enacted.

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Master Field Sampling Plan
for
Installation Restoration Program Environmental Investigations
at
Naval District Washington, Indian Head
Indian Head, Maryland

Engineering Field Activity Chesapeake
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888
Contract Task Order 0805

June 2004

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MASTER FIELD SAMPLING PLAN
FOR
INSTALLATION RESTORATION PROGRAM
ENVIRONMENTAL INVESTIGATIONS
AT
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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A EXAMPLE FORMS

1.0 INTRODUCTION

1.1 SCOPE AND OBJECTIVES

The purpose of this Master Field Sampling Plan (FSP) is to define the standardized sampling procedures to be used for environmental investigations performed within the Navy's Installation Restoration (IR) Program at the Naval District Washington, Indian Head[1] (NDW,IH, Facility) in Indian Head, Maryland. The plan specifies requirements for all field work and serves as a guide for use in the field by all members of the field investigation team. Investigations will comply with applicable State of Maryland and United States Environmental Protection Agency (USEPA) regulations. Either federal laws and regulations or State of Maryland laws and regulations, whichever are more stringent, will be Applicable or Relevant and Appropriate Requirements (ARARs) for actions taken at this National Priorities List (NPL) facility.

This Master FSP is intended to be used in conjunction with a project-specific work plan (WP) and the other master documents identified in the Master Plans.

This Master FSP consists of three sections. Section 1.0 presents this introduction and the overall project scope and objectives. Section 2.0 details the field operation tasks, including soil boring and well installation procedures, as well as decontamination and waste handling procedures. Section 3.0 details all aspects of the environmental sampling procedures. Standard operating procedures (SOPs) for these activities are provided in the Facility SOP document. Example forms are provided in Appendix A.

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[1] On 1 October 2003, the installation management functions at Indian Head transferred from Indian Head Division/Naval Surface Warfare Center to Naval District Washington. References to this Installation will now be Naval District Washington, Indian Head.

2.0 FIELD OPERATIONS

2.1 GENERAL FIELD OPERATIONS

This section discusses the general sampling operations, procedures, and proper documentation for the field operations to be performed at the Facility. All field operations must be in compliance with the control measures detailed in the Health and Safety Plan (HASP) Guidance Document and corresponding project-specific HASP. Details of environmental sampling operations are discussed in Section 3.0. Example forms related to field activities are provided in Appendix A.

2.1.1 Mobilization/Demobilization

Following approval of the project-specific FSP, mobilization activities will begin. At that time, all field team members will review the project-specific FSP as well as the project-specific WP, Quality Assurance Project Plan (QAPP), and HASP. In addition, a field team orientation meeting will be held to familiarize personnel with the scope of the field activities.

The Field Operations Leader (FOL) will be designated as the lead individual in coordinating all day-to-day site activities during the investigation. The FOL will be responsible for ensuring that all field team members are familiar with the applicable plans. Additionally, the FOL will be responsible for all sampling operations, quality assurance (QA)/quality control (QC), field documentation requirements, and field change orders. The FOL will also regularly report to the Project Manager regarding the status of field work and any problems that are anticipated or have occurred.

The FOL will coordinate the on-Facility mobilization activities upon arrival at the Facility and prior to the initiation of field work. These activities will include performing utility clearance for intrusive sampling locations in accordance with Facility SOP HS-1.0, determining requirements for unexploded ordnance (UXO) screening with Facility personnel, coordinating with Facility personnel, purchasing expendable equipment, marking sample locations, preparing sample bottles, and preparing the field trailer. After field activities are completed, the FOL will demobilize the equipment.

All site preparation will be coordinated through Facility personnel. When necessary, temporary barriers will be installed and traffic control provided at work locations as a safety precaution.

2.1.2 Site Restoration

All site restoration activities will be performed by the contractor and its subcontractors. Site restoration may include, but will not be limited to, regrading areas where drilling activities were performed, general

cleanup of investigation-related materials, and asphalt and concrete replacement where necessary. The site shall be returned to as close to pre-activity condition as feasible.

2.2 SUBSURFACE INVESTIGATIONS

Soil borings will be drilled to characterize subsurface lithology and soil contamination in accordance with Facility SOP GH-1.3. Drilling methods will be selected per guidance in American Society for Testing and Materials International (formerly ASTM) D6286-98, Guide for Selection of Drilling Methods for Environmental Site Characterization. Some of the soil borings may be converted into groundwater monitoring wells. Potential UXO issues will be evaluated on a site-by-site basis with guidance provided by the NDW,IH Environmental Department and Facility SOP HS-2.0.

2.2.1 Soil Borings

2.2.1.1 Hand Auger Method

Soil borings may be conducted using a hand auger method. A stainless steel auger head, constructed for sand or clay retention, and stainless steel rods (typically 3 feet in length) will be used. The auger is advanced by turning the "T" handle in a clockwise motion. Samples are extracted using a stainless steel or pre-cleaned disposable trowel. Further details are included in Facility SOP GH-1.3. Borings advanced with a hand auger will be backfilled with the soil cuttings.

2.2.1.2 Hollow-Stem Auger Method

Soil samples will typically be collected continuously from the ground surface to the top of the water table in accordance with Facility SOP GH-1.3. Boreholes will be advanced using nominal 4.25-inch inside diameter (ID) hollow-stem augers (HSA). The split-barrel samplers (i.e., “split-spoons”) will have a minimum ID of 2 inches and will be at least 2 feet long. Three-inch ID split-barrel samplers may be required to fulfill sample volume requirements for chemical analysis. The split-barrel sampler will be driven to the required depth by means of a drill rig-mounted hammer weighing 140 pounds falling a distance of 30 inches.

All samples obtained from the boreholes will be monitored with an organic vapor analyzer (OVA) or photoionization detector (PID) as specified in the project-specific HASP. Each split-barrel sampler will be screened with the OVA or PID immediately upon opening. These readings will be recorded on the boring logs. Additionally, some samples may be field screened for head-space analysis. Head-space analysis involves obtaining a small amount of soil from the split-barrel sampler and placing it into a sealed container. The container is warmed for 15 minutes, and then the OVA or PID is used to detect possible

volatile vapors in the sample. Chemical analyses samples will be obtained in accordance with the procedures outlined in Section 3.0. In addition to analytical samples, lithologic samples will be collected at all sampling intervals.

A lithologic description of each split-barrel sample and a complete log of each boring will be maintained by the geologist in accordance with Facility SOP GH-1.5. At a minimum, the boring log will contain the following information:

- Name of contractor
- Boring or well identification
- Name of drilling contractor
- 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
- Location of boring

In addition, depths of changes in lithology, sample moisture observations, depth to water, vapor readings, drilling methods, and total depth of each borehole will be included on each log, as well as any other pertinent observations. Drilling and well construction problems/deviations from project-specific FSP and IR Program Handbook will be documented in the field logbook. An example boring log form is provided in Appendix A.

After the borings are drilled to the desired depth, they will be grouted to the ground surface with a cement-bentonite slurry (approximately 94 pounds cement, not more than 4 pounds of bentonite powder, and not more than 6.5 gallons of potable water). The slurry will be placed within the boring using a tremie pipe.

Due to the remote location of some of the sites, an all-terrain vehicle (ATV) drilling rig may be required for the field work.

2.2.2 Test Pit Operations

Test pits are typically excavated in areas identified during geophysical surveys. Soil grab samples will be collected from each test pit based on visual observations, OVA or PID readings, or field analytical testing conducted by the site geologist. Samples will be collected directly from the backhoe bucket. Under no circumstances will personnel be permitted to enter the test pit. If drums or the unknown contents thereof are encountered during test pit excavations, the test pit excavation will cease, and the removed soils will be immediately replaced unless the project-specific WP or project-specific FSP contains procedures for addressing the situation. Test pits will be backfilled before completion of each day's work activities. A description of each test pit will be completed by the field geologist.

Test pit sampling and excavation will be performed in accordance with Facility SOP SA-1.3.

2.2.3 Direct Push Drilling

Direct-push drilling (DPD) equipment (e.g., Geoprobe® and Hydropunch®) may be utilized for subsurface investigations. DPD equipment must be operated by a driller licensed in the State of Maryland as per Code of Maryland Regulations (COMAR) 26.04.04.03 and 26.05.01. Geoprobe®-type equipment is commonly mounted in cargo vans, on the bed of a pickup truck, or on an ATV and includes a hydraulic-powered probe for driving and removal of hardened steel sample rods. These rigs are equipped with an additional air percussion option for penetrating dense material and an electric hammer for drilling through asphalt and concrete. A wide variety of sample rods can be utilized by the Geoprobe® for soil, soil gas, and groundwater sampling. Groundwater samples are typically obtained using peristaltic pumps, vacuum-lift pumps, or miniature bailers. Hydropunch® or similar systems use a drill rig to advance HSAs to a desired depth. The Hydropunch® is then hammered ahead of the augers and a discrete groundwater sample is collected using a bailer or a pump. Some DPD subcontractors may also provide field gas chromatographs (GCs) equipped with flame ionization detectors (FIDs), PID, and electron capture detectors (ECD) for real-time analysis of environmental samples. Facility SOP SA-2.5 describes the method for DPD sampling techniques.

Advantages of DPD include the ability to obtain a vertical profile of contaminant concentrations, almost complete elimination of drill cuttings production, sampling in tight-access locations, reduced overhead clearance requirements, and real-time laboratory analyses. Disadvantages include a maximum penetration depth limited to approximately 15 to 40 feet in dense soils and reduced capability of obtaining accurate water-level measurements.

2.3 MONITORING WELL CONSTRUCTION AND INSTALLATION

2.3.1 Monitoring Well Installation (Hollow-Stem Auger Method)

Soil borings advanced into the water table aquifer are typically converted to 2-inch ID polyvinyl chloride (PVC) monitoring wells. However, larger diameter monitoring wells may be installed as defined in the project-specific FSP. Monitoring wells must be installed by a driller licensed in the State of Maryland as per COMAR 26.04.04.03 and 26.05.01. All monitoring wells will be constructed of PVC flush-joint riser pipe and flush-joint factory slotted well screen. Each section of casing and screen will be National Sanitation Foundation (NSF)-approved. The monitoring well boring will be drilled using augers of sufficient diameter to allow proper placement of annulus materials. Additional monitoring well installation guidance using HSA methods is provided in Facility SOP GH-2.8. The diameter of the borehole will be recorded for each installation.

Unless otherwise specified, the top of the screened interval will be positioned approximately 2 feet above the stabilized water level. Typical screen lengths will be 10 feet and will have a screen slot size specified in the project-specific FSP. After the borings are drilled to the desired depth, the well will be installed through the HSAs.

A silica sand pack will be installed into the boring annulus around the well screen. The sand pack will be well-graded silica sand with the grain size specified in the project-specific FSP. The sand pack will be installed from the bottom of the hole to approximately 2 feet above the top of the well screen. The sand pack will be installed by pouring sand into the annular space between the riser pipe and HSAs. The HSAs act as a tremie pipe and are withdrawn from the boring as the sand is emplaced. The sand should always be kept within the HSAs during withdrawal in order to ensure an adequate sand pack. A weighted stainless steel or plastic tape measure will be used during the sand pack installation to ensure that no bridging occurs and to maintain no more than 1 foot of sand above the bottom of the HSAs. In shallower monitoring wells, it may be necessary to bring the sand pack up to only 1 foot above the top of the screen to allow enough room for a sufficient bentonite and grout seal.

A 100 percent sodium bentonite pellet seal, no less than 2 feet thick, will be installed above the sand pack and allowed to hydrate using potable water. The depths of all backfill materials will be constantly monitored during the well installation process by means of a weighted tape. Typically a 20:1 cement-to-bentonite grout seal will be placed, with a tremie pipe, to extend from the top of the bentonite seal to the land surface. However, in areas of shallow groundwater, a 100-percent bentonite grout will extend to the ground surface. Facility SOP GH-2.8 provides guidance for different types of well constructions such as confining layer monitoring wells, bedrock monitoring wells, and drive points.

An "at-grade" protective steel casing equipped with a sealing, locking cap will be installed around all wells in high-traffic areas. At-grade covers will be installed in accordance with State of Maryland requirements. For all other wells, a nominal 4-inch diameter protective steel casing equipped with a locking steel cap will be installed. All protective casings will be grouted a minimum of 3 feet into the ground. In addition, a concrete apron measuring 3 feet by 3 feet by 6 inches thick will be constructed equally portioned around the casing of each well. For stick-up casings in traffic areas, a minimum of three and typically four marker posts (3-inch nominal diameter, 5-foot-long steel pipe filled with concrete) will be embedded 2 feet into the ground and set in concrete, separate from the concrete apron around the well base. The marker posts will be positioned equidistant from one another. All locks supplied for the wells will be keyed alike. After installation, a notch of sufficient depth to be visible (e.g., 1/8 inch or less) will be cut into the top of the PVC well riser pipe to mark the location from which water depths will be measured. Then the top of the riser pipe (at the notch), the top of the protective casing, and the ground surface elevation at the well location will be surveyed to within 0.01-foot vertical accuracy. In addition, the well will be surveyed to a 0.1-foot horizontal accuracy.

A monitoring well construction diagram will be completed for each well installed. Example monitoring well construction forms are provided in Appendix A.

2.3.2 Monitoring Well Installation (Portable Solid-Stem Auger Method)

In areas with extreme access difficulties, a portable tripod drilling system or equivalent may be utilized to install monitoring wells. The methods potentially used for a portable system are described in Facility SOPs GH-1.3 and GH-2.8.

Following completion of the above task, the groundwater monitoring well will be completed as detailed in Section 2.3.1. If necessary as a deviation from Facility SOP GH-2.8, a factory-built, 2-inch ID, prepacked slotted screen (dual wall pipe with gravel pack between the inner and outer walls) may be used. Construction of the groundwater monitoring well will follow applicable procedures outlined in Facility SOP GH-2.8.

2.3.3 Other Drilling Methods for Monitoring Well Installation

Other drilling methods may be used for subsurface investigations, if necessary, depending on the project-specific needs. For example, deep, double-cased monitoring wells installed below a confining layer may require drilling methods other than HSA such as mud rotary, air rotary, or fluid rotary. The project-specific FSP will detail these needs and will reference Facility SOPs as applicable.

2.3.4 Monitoring Well Development

Following installation, each groundwater monitoring well will be developed in accordance with Facility SOP GH-2.8 to remove any mud pack, drill cuttings, or formation fines from the well screen. Based on field conditions (i.e. a well goes dry), the site geologist may modify these protocols. The groundwater monitoring wells will be developed no sooner than 24 hours nor longer than 7 calendar days after well installation, and this will be accomplished by surging, bailing, and/or pumping, as determined by the contractor's field geologist. If light or dense free product is suspected of being present in the monitoring well, a hydrocarbon interface probe will be used prior to well development to verify the presence (or absence) of those materials. Groundwater monitoring wells with free product will not be developed.

A minimum of five times the standing water volume in the well casing plus five times the water volume in the saturated gravel pack (assuming 30 percent porosity) will be removed provided the monitoring well can produce sufficient amounts of water. Turbidity will be measured during well development. An attempt will be made to develop the well to a turbidity not greater than 10 nephelometric turbidity units (NTUs). The wells will be developed until the discharge water is visibly clear, and temperature, pH and specific conductivity have stabilized to within 10 percent variance for three consecutive measurements, or as determined by the contractor's field geologist. Water quality measurements of pH, conductivity, and temperature and the volumes removed will be recorded for each well on a well development form. An example well development form is provided in Appendix A.

2.3.5 Monitoring Well Abandonment

Monitoring well abandonment will be performed by a driller licensed in the state of Maryland. The work will be performed in accordance with COMAR 26.04.04.11 and additional guidance provided in Facility SOP GH-2.9. A copy of COMAR 26.04.04.11 is provided in the Facility SOP document.

2.3.6 Evaluation of Existing Wells

Existing groundwater monitoring wells may be evaluated in accordance with Facility SOPs SA-1.1 and GH-1.2. If required, the well may be redeveloped in accordance with Section 2.3.4 of this Master FSP.

2.4 WATER-LEVEL MEASUREMENT

Synoptic water-level measurements will be taken from all newly installed monitoring wells within the study area as defined in the project-specific FSP. All measurements will be taken within a 24-hour period of consistent weather conditions to minimize atmospheric/precipitation effects on groundwater levels. The sequence of measuring water levels will be determined in the field by the field geologist.

Measurements will be taken using an electronic water-level meter capable of 0.01-foot resolution. The top of the well casing will be used as the reference point for determining depths to water in accordance with Facility SOP GH-1.2. The notch at the top of the PVC riser pipe will be used to ensure that measurements are taken consistently between measuring events. Water-level measurements will be recorded to the nearest 0.01 foot in the appropriate field logbook and on a groundwater-level measurement form. A groundwater-level measurement form is provided in Appendix A.

2.5 MEASUREMENT OF STREAM FLOW RATE

A stream's flow rate may be determined in accordance with Facility SOP GH-2.7.

2.6 FIELD MEASUREMENTS

Field measurements will be taken during field and sampling operations according to the Facility SOPs. Field measurements will include ambient air quality (Facility SOP SA-2.2) and water quality (Facility SOP SA-1.1) including pH, conductivity, temperature, dissolved oxygen (DO), oxidation-reduction potential, and turbidity. Measurements will be recorded either in the site logbook or on a sample log form. Instruments used in the field to record this data will be calibrated according to the procedures described below.

2.6.1 Equipment Calibration

One or more of the following monitoring instruments may be used during field activities:

- OVA FID
- PID
- Temperature probe
- Conductivity meter
- DO meter
- pH meter
- Turbidity meter
- Electronic water-level indicator
- Radiation survey meter

Field instruments will be calibrated according to the manufacturer's procedures, the Facility SOPs indicated above, and the following:

- The pH meters will be calibrated daily. At least two buffer solutions that bracket the expected sample pH will be used (e.g., 4.0 and 7.0) to calibrate pH meters.

- Conductivity meters will be calibrated prior to each day's use.

- The DO meter will be calibrated daily.

- Turbidity meters will be calibrated at least daily using a standard within the expected range of sample turbidities.

- Duplicate measurements of pH, specific conductivity, temperature, DO, oxidation-reduction potential, and turbidity will be taken at a frequency of 1 in 10 samples and used to estimate the precision of the field analytical measurements.

- PIDs or OVAs will be calibrated prior to each day's use.

Calibration will be documented on an equipment calibration log (provided in Appendix A). During calibration, an appropriate maintenance check will be performed on each piece of equipment. If damaged or defective parts are identified during the maintenance check, and it is determined that the damage could have an impact on the instrument's performance, the instrument will be removed from service until the defective parts are repaired or replaced.

2.7 GEOPHYSICAL INVESTIGATIONS

The following subsections describe the general procedures and requirements to be implemented during various geophysical investigations at the Facility. In some cases the equipment used for geophysical investigations will need to be inspected by Facility health and safety personnel for hazards of electromagnetic radiation due to ordnance (HERO) approval. All geophysical investigations shall be in accordance with Facility SOPs GH-3.1, GH-3.2, and GH-3.4.

2.7.1 Geophysical Reference Grid

A geophysical reference grid may be installed at the site such that data can be accurately collected and reported. The grid will be staked at a constant interval in units of feet using a transit, electronic distance measure (EDM), or tape measure. Stakes will consist of pin flags or other semi-permanent markings that will be labeled with the grid coordinates in units of feet.

The reference grid will be tied into an existing site of Facility grid system, if present, and also to any permanent site features such as monitoring wells or buildings. Pin flags or other semi-permanent markings will be left in place at the completion of the survey to also assist in the reuse of the grid for future investigations, if necessary. Data will be collected along parallel survey lines at station spacings specified in the project-specific FSP. A global positioning system (GPS)-type tracking system can be incorporated with the data logging of the geophysical investigation.

2.7.2 Electromagnetics

The following paragraphs describe equipment typically utilized for geophysical investigations.

2.7.2.1 High Resolution Geonics EM31 Terrain Conductivity Survey

A Geonics EM31 terrain conductivity meter (EM31) or equivalent device and digital data logger may be used to assist in the shallow (less than 15 feet deep) characterization of subsurface materials. The EM31 is a one-man-operated frequency domain electromagnetic (FDEM) device that utilizes the principle of electromagnetic (EM) induction to measure the apparent conductivity and magnetic susceptibility of surface and subsurface materials and their pore fluids. The instrument is equipped with a very low frequency (VLF) radio transmitter and receiver coil. These coils are separated by a distance of 12 feet and are located at the ends of a ridged, non-metallic pole.

Quadrature and in-phase component data will be simultaneously collected through the use of a digital data logger. Quadrature component data are a measure of the apparent electrical conductivity of the subsurface materials and their pore fluids. Quadrature component data are also commonly referred to as terrain conductivity or bulk conductivity data. A map of quadrature component data will assist in delineating areas of fill materials, contaminated soils, shallow contaminated groundwater, changes in soil types, changes in soil moisture content relative to undisturbed soils, and the presence of most buried ferrous and non-ferrous metals. Quadrature component data are presented in units of conductivity, millimhos per meter (mmhos/m) or milliSiemens per meter (mS/m).

The device should also record the in-phase component of the EM field. The in-phase component data are a measure of the presence of highly conductive material and are often referred to as the metal detection component. Buried metal within 15 feet of surface such as steel drums or metallic pipes can be mapped in this mode. In-phase data are presented in units of parts per thousand (ppt).

During investigations, data will be collected with the instrument at waist height, held parallel to ground surface, and with the coils vertically oriented. Data will be collected along parallel survey lines. Digital data should be downloaded daily through the use of a laptop computer and the manufacturer's software.

2.7.2.2 High-Resolution Geonics EM38 Terrain Conductivity Survey

A Geonics EM38 terrain conductivity meter (EM38) or equivalent device and digital data logger may be used to assist in the characterization of the shallow (less than 5 feet deep) subsurface materials. This procedure will be considered only where no UXO hazard is present. The EM38 is a one-man-operated FDEM device that utilizes the principle of EM induction to measure the apparent conductivity and magnetic susceptibility of surface and subsurface materials and their pore fluids. The instrument is equipped with a fixed-frequency, VLF radio transmitter and receiver coil. These coils are separated by a distance of approximately 3.3 feet and are located at the ends of the devices ridged, non-metallic frame.

Quadrature and in-phase data are collected separately through the use of a digital data logger. Quadrature data collected with this device are used to map subtle soil moisture content changes often associated with disturbed soils or fill materials, shallow soil stratigraphic changes, and the presence of shallow metallic objects and metallic pipes/utilities. The in-phase data are often used to further identify and confirm the presence of buried metallic objects, pipes, and utilities.

During investigations, data are collected with the instrument at ground surface, oriented parallel to the survey line, and with the coils vertically oriented. This will result in a depth of investigation of approximately 5 feet. Data are collected along parallel survey lines and at a station spacing of 1 to 2 feet through the use of a digital data logger. Digital data should be downloaded daily through the use of a laptop computer and the manufacturer's software.

2.7.2.3 Geonics EM34-3 Terrain Conductivity Survey

A Geonics EM34-3 terrain conductivity meter (EM34) or equivalent device and digital data logger may be used to assist in the characterization of the subsurface materials to depths of approximately 25 to 200 feet below ground surface. The EM34 is a two-man-operated FDEM device that utilizes the principle of EM induction to measure the apparent conductivity of surface and subsurface materials and their pore fluids. The instrument is equipped with a variable frequency radio transmitter and receiver coil that are separated by a flexible reference cable. The EM34 has variable coil separations of 32, 66, and 131 feet.

Data are often collected with the coil dipoles oriented horizontally, then vertically. Data are collected by adjusting the coil separation distance while maintaining the coils in the same geometric plane until an optimum instrument response is observed. Data collected when the coil dipoles are oriented vertically (vertical dipole mode) are extremely sensitive to errors as a result of coil alignment. Therefore, vertical dipole data collection can be difficult in areas of steep topography or dense brush. Data are recorded through the use of a digital data logger and by hand in the field notebook.

The depth of investigation of the EM34 is dependent on the coil separation and the orientation of the coil dipole. The depth of investigation increases as the coil separation increases. The approximate depth of investigation with the coil dipoles oriented horizontally is 0.75 times the coil separation. The depth of investigation with the coil dipole oriented vertically is 1.5 times the coil separation.

The EM34 is often used to map stratigraphic changes such as the presence of buried sand channels, clay lenses, or contaminated groundwater. Data are generally collected at two or three coil separations at each station location and in the horizontal and vertical dipole mode. However, the instrument is very sensitive to the presence of anthropogenic features and extremely electrically resistive soils when collecting data in the vertical dipole mode. Vertical dipole mode data collection is occasionally omitted in areas of potentially high cultural interference and where extremely resistive soils are present.

2.7.2.4 High Sensitivity EM61 Metal Detection Survey

A Geonics EM61 high-sensitivity metal detector (EM61) or equivalent device and digital data logger may be used to map the presence of buried metals, metallic pipes, and metallic utilities. These buried metals often may represent sources of contamination or may represent buried ordnance hazardous to future subsurface investigations. This device is a time domain electromagnetic (TDEM) instrument that utilizes the principles of EM induction to measure the presence of highly conductive ferrous and non-ferrous materials in the subsurface. The device is equipped with a portable 3.3-foot-square transmitter, a main receiver located coincident to the transmitter, and a focused receiver coil located 1.3 feet above the transmitter and main receiver coils. The transmitter and receiver coils are mounted onto a cart with plastic bicycle wheels and an electronic distance encoder. The power supply and electrical components are contained in a plastic backpack that is worn by the operator.

TDEM equipment operates by rapidly extinguishing a transmitted signal and measuring the induced secondary signal in the ground either at a specific point in time or as it decays with time. The EM61 transmitter coil generates a pulsed EM signal at a rate of 150 times per second. The two receiver coils measure the induced secondary EM field at a calibrated time in between the transmitted signal pulses. The secondary EM signal induced from the presence of natural earthen materials rapidly decays before the receiver coils measure the response. The secondary EM signal induced from the presence of metals has a much longer decay time such that it is still present when the receiver coils begin to collect data. This results in the EM61 being non-responsive to the presence of changing soil conditions that can sometimes obscure buried metallic targets. This device has a depth of investigation that is dependent on the surface area of metal that is present.

The EM61 utilizes a digital data logger to record the secondary EM signals received by the main and focused receiver coils. Data are recorded and presented in units of millivolts (mV). The data from the main and focused receiver coils are stored in channels 2 and 1 of the data logger, respectively. Channel 1 data are a measurement of the presence of surface and very near surface metals. Channel 2 data are a measure of surface and deep metals. The effects of near surface metals are minimized by subtracting channel 2's response from channel 1's response. This is referred to as the differential response and is very useful in mapping buried metals.

During investigations, data are collected along parallel survey lines and at a station spacing of approximately 1 foot. Data are collected using a digital data logger and downloaded daily onto a laptop computer using the manufacturer's software.

2.7.2.5 EM Data Reduction and Presentation

The downloaded data are typically preliminarily processed on site using the equipment manufacturer's software to help ensure that project objectives are achieved and that data coverage is sufficient. Digital data are edited and viewed in profile format to assist the onsite geophysicist in making preliminary data interpretations prior to demobilization. Final data presentation will consist of a profile format, or for larger data sets, map view contours may be constructed to visually depict anomalous areas.

2.7.3 Ground-Penetrating Radar

A Mala Geoscience Ramac/ground-penetrating radar (GPR) unit or similar device may be used to collect site data in areas where no UXO hazard is present. Use of this equipment must be approved on a project-specific basis by the Facility safety office. The Ramac/GPR instrument is a digital GPR device that will be equipped with a 200 megaHertz (MHz) transducer. GPR surveys will be conducted in general accordance with Facility SOP GH-3.4.

GPR techniques are based on the repetitive transmission of EM signals (pulses) via a transducer into the subsurface. The EM signal travels through the subsurface and is reflected at stratigraphic interfaces where contrast in the dielectric permittivity of the media are present. The reflected portion of the transmitted signal is received by the device's transducer. The two-way travel time and amplitude of the reflected signals versus the horizontal distance that the transducers traveled are digitally recorded.

The time it takes a signal to travel from the transducer, reflect off of a target, and return to the transducer is called the two-way reflection time. Two-way reflection times are recorded in units of nano-seconds and vary dependent on the electrical properties of the subsurface materials. As the subsurface materials permittivity increases, the two-way travel time increases and the velocity of the GPR signal decreases.

Areas of clayey soils, shales or saline groundwater have high permittivities, relatively long two-way reflection times, and slow velocities. GPR signals in these materials also attenuate rapidly, resulting in depths of investigation that may be limited to a few feet or less. Conversely, dry sandy soils have low permittivities that result in relatively short two-way reflection times and fast velocities. The depth of investigation is often much greater in dry sandy soils relative to clayey soils.

Two-way reflection travel times can be converted into units of depth where signal propagation velocities are known or can be estimated. Signal propagation velocities can be estimated by collecting data over targets of known depths, performing a common midpoint sounding, or estimating soil permittivities based on known or published values.

Data will be digitally recorded using a laptop computer and preliminarily processed while on site using the manufacturer's software. Observed anomalous responses will be annotated on site using pin flagging or other semi-permanent markings. The locations of anomalous responses will be recorded in the field logbook and plotted onto the base map upon return to the office. GPR data will be presented in profile format.

2.7.4 Pipe and Cable Survey

A Schonstedt MAC51B or similar device may be used to assist in the identification of buried metallic pipes and utilities. This instrument works by inductively or actively coupling an EM transmitter coil to a known pipe location and tracing the feature with the device's receiver coil. Data for this instrument are not recorded digitally, rather a qualitative audio output that is proportional to the magnetic gradient field intensity is observed. The subsurface anomalies identified with this instrument will be annotated on site with semi-permanent markings, and anomaly locations will be recorded in the field logbook for subsequent reporting.

2.7.5 Time Domain Electromagnetic Survey

TDEM soundings can be utilized to qualitatively assess stratigraphy, salt water intrusion, or the presence of conductive groundwater that may be associated with a contaminant plume. This method non-invasively maps the subsurface and is used to measure the lateral and vertical resistivity distributions (geo-electric section) of the subsurface to depths of 15 to more than 500 feet. Electrical resistivity (the inverse of conductivity) is dependent on the physical properties of the soils and/or rock. This includes the electrical conductivity of the groundwater and the soil and/or rock type. Clays and shales are naturally conductive (less resistive), whereas sands and limestones are poorly conductive (naturally resistive) to electricity.

TDEM surveys, if appropriate, would be conducted at the site using a Geonics PROTEM47D TDEM or equivalent device. The PROTEM47D system consists of a transmitter loop and a receiver coil. The transmitter is a square loop of single-turn insulated wire that is laid on the ground surface forming a square or rectangle. The depth of penetration is dependent on the size of the transmitter and the electrical resistivity of the subsurface. The larger the size of the transmitter loop, the greater the depth of penetration. Transmitter sizes commonly used are 20 by 20 or 40 by 40 meters.

The receiver is a small vertical magnetic dipole that is placed either in the center of the square transmitter loop or directly adjacent to it. A half-duty cycle current wave form is driven through the transmitter, where a steady current is quickly terminated. The time-varying primary EM field of the transmitter induces eddy currents in the subsurface. The receiver measures the electromotive force (emf) due to the secondary magnetic field of these eddy currents during transmitter off time.

Data are presented as a geo-electric section of the subsurface as a function of depth (feet or meters) and apparent resistivity (ohm-meters). Vertical resolution is defined by the resistivity contrast between the hydrostratigraphic units. The TDEM data should be collected between borehole locations and tied into the geologic and other geophysical logging results.

The digital TDEM data are downloaded from the instrument's data logger using the manufacturer's software. The raw data are then imported into software and plotted as time versus instrument response (in units of mV) curves. The response curves are then digitally forward-modeled based on existing geophysical logging and geologic information, generally producing a model-to-observed-data-fit error of less than 20 percent. Forward modeling allows the user to input the observed geo-electric conditions from nearby boreholes or monitoring wells and compare them to the observed TDEM data. The data are then inverse-modeled until a fit error of generally less than 5 percent is achieved. The final results are presented as geo-electric sections showing depth versus apparent resistivity. The geo-electric sections are often plotted as geo-electric profiles incorporating geologic well log information where available.

2.7.6 Magnetic Survey

Magnetic surveys are conducted using a portable gradiometer, such as a Geometrics model G-856AG, to define anomalous zones that may contain buried ferrous metals. The gradiometer uses two sensors to sample, stores readings from each in quick succession, and uses the difference between readings (i.e., the gradient) to more precisely locate shallow objects. Gradient information is useful for shallow search and survey applications because it can quickly define the depth and location of objects without the need for a base station. Gradiometer data help to resolve composite or complex anomalies into their individual constituents. The data will be recorded automatically in the field and will later be downloaded into a computer-based software, such as MAG-PAC, used to correct the magnetic data for diurnal drift. General

procedures, calibration, and data acquisition and interpretation are described in the manufacturer's manual and Facility SOP GH-3.2.

2.8 AQUIFER TESTING

2.8.1 Slug Tests

Slug tests can be performed to determine the hydraulic characteristics in the immediate vicinity of a well screen/open borehole. General procedures, data acquisition, and data analysis methods are described in Facility SOP GH-2.4. Although they typically require data logging equipment for rapidly recharging aquifers, they do not require pumping and are therefore applicable in low-yield aquifers or at locations where contaminated water disposal would be prohibitively expensive.

Prior to performing the slug test, the static water level must be recorded in addition to the well construction details. Both rising head and falling head tests can be performed either by inserting a solid slug into the well to raise water levels, then measuring the rate of decline in water level (falling head test), or by removing a slug of water and measuring the rate of rise in the water level back to equilibrium (rising head test). The change in water level should be induced as quickly as possible because the analysis assumes an instantaneous change in head. Falling head tests cannot be performed where the water level is within the screened interval. In addition, as slug tests are very sensitive to borehole skin effects, the well must be developed properly to obtain accurate data.

Slug test data should be collected using an electronic data logger with pressure transducer and/or electronic water-level indicator. To facilitate data graphing, the loggers will be programmed to record measurements on a logarithmic time scale. It is ideal to record water-level data to at least 90 percent recovery in the well before terminating the test. The resulting plot of time versus head ratio on semilog paper should approximate a straight line. The test should be rerun if data scatter is excessive. If excessive data scatter persist, use of a different method to induce the water-level change (e.g., vacuum pneumatic system) should be considered.

Raw data from the loggers or field records are used to calculate values of hydraulic conductivity in the immediate vicinity of the well screen or open borehole. The data will be analyzed using one or more of the following three methods:

- Hvorslev Method - rapid straight-line method for partially penetrating well screens
- Bouwer and Rice Method - rigorous straight-line method for complex well geometries
- Cooper et al. Method - type-curve method for low permeability aquifers

The above methods can be analyzed relatively simply by hand. However, the Bouwer and Rice method as well as the Cooper et al. method may also be analyzed using the AQTESOLV™ computer program (ARCADIS Geraghty & Miller, Inc.).

2.8.2 Pumping Tests

Pumping tests can be performed to determine more complex and aerially extensive hydraulic properties of the aquifer. General procedures, data acquisition, and data analysis methods are described in Facility SOP GH-2.3. Although they require data logging equipment and pumping, they are more applicable to high-yield aquifers or at locations where water disposal does not create severe management issues. In addition, a project-specific FSP should be developed prior to the initiation of the pumping test detailing all field activities needed to complete the test.

Prior to the pumping test, the static water level in all surrounding observation wells must be recorded. Several wells can be pumped at different times to determine both the lateral and vertical response of the aquifer to the pumping of the wells. For each individual test, the duration of pumping will be determined in the field based on the aquifer response to pumping, with a minimum duration of 4 hours and a maximum duration of 72 hours. It is ideal to stress the aquifer as much as possible near the pumping well without drawing the cone of depression below either the measuring device (in unconfined aquifers) or the confining layer (in confined aquifers). It is also important to maintain a consistent discharge rate from the pumping well.

Water levels will be periodically measured in the pumping well and in the observation wells throughout the duration of each pumping test (including water-level recovery after pumping is halted). To facilitate data graphing, the loggers for nearby observation wells will be programmed to record measurements on a logarithmic time scale. It is ideal to record water-level data to at least 90 percent recovery in the observation wells before terminating the test. The data gathered will be evaluated using techniques developed for pumping tests specific to the aquifer. Aquifer parameters determined during pumping tests include hydraulic conductivity, transmissivity, and storativity. Due to the limitless number of analytical techniques possible for each specific aquifer, the exact method will be determined upon completion of the test. Some analytical methods include:

- Cooper-Jacob Method - rapid straight-line method for simple aquifer geometries
- Theis Method - type-curve method for complex aquifer geometries
- Theis Recovery Method - method used for analyzing well recovery data
- Theim Method - method for analyzing pumping test that have reached equilibrium conditions

In addition, the AQTESOLV™ computer program (ARCADIS Geraghty & Miller, Inc.) can also be employed to assist in the technical analysis of pumping test data.

2.8.3 Specific Capacity Testing

Specific capacity tests are used to determine a well's potential yield and to estimate hydraulic conductivity. General procedures, data acquisition, and data analysis methods are described in Facility SOP GH-2.3. These tests involve pumping a well at a constant rate and measuring the drawdown when the water level stabilizes. Specific capacity tests are advantageous because they can be conducted while wells are being purged for sampling.

During specific capacity tests, water-level measurements are collected using an electronic water-level indicator or automatic data logging equipment. An electronic submersible or peristaltic pump is used to pump the well. Aquifer parameters will be calculated from the specific capacity test data using applicable computer software.

Drawdown data from the well is entered into the computer program along with required variables that characterize the aquifer (storage and well-loss coefficients), the pumping rate, and well dimensions. The program output will estimate specific capacity, transmissivity, and hydraulic conductivity.

2.9 SOIL GAS SURVEYING

Two types of soil gas surveys may be conducted; a contaminant-specific survey using a portable GC unit or a reconnaissance-type survey using an OVA. Grid patterns will be established within the areas to be covered by the soil gas survey using pin flags in unpaved areas and tape in paved areas. Where possible, the grid patterns will be tied into local permanent features such as building corners and roadway boundaries. Grid spacing will be determined on a project-specific basis.

In paved areas, a small pilot hole will be drilled through the asphalt using a power drill with a 1/2- to 1-inch-diameter drill bit. The soil gas boring will be completed by driving a 1/2-inch-diameter steel rod into the subsurface. The steel rod will be advanced to the desired depth, extracted, and a Teflon® tube will then be lowered into the boring. A surface seal of inert material will be used to seal the borehole annulus from the ambient atmosphere. The tube will then be attached to the analytical instrument. The tube will be purged of residual gas prior to sample collection at each sample location. The results will be recorded in the field on site maps and the survey modified based upon incoming data, with grid spacing adjusted accordingly. Additional guidance and information are provided in Facility SOP SA-2.4.

2.10 SURVEYING

The points to be surveyed will be specified in the project-specific FSP. At a minimum, all new groundwater monitoring wells and sampling locations will be surveyed. Existing survey monuments within the Facility will be utilized as reference points. Horizontal locations will be surveyed to Maryland State Plane Coordinate System, North Zone, North American Datum, 1983 (NAD83). All surveying will be conducted by a registered land surveyor licensed to practice in the State of Maryland.

Vertical elevations will be referenced to National Geodetic Vertical Datum, 1929 (NGVD29). For each groundwater well, the elevation will be determined at the measuring point where the uncapped well riser is notched at the top of the protective casing, and at the ground surface.

A GPS survey may also be utilized to locate sampling points and to map surface features. Alternately, a tape and compass may be used for non-permanent sampling locations.

The horizontal and vertical precision and accuracy for surveys conducted at a site will be described in the project-specific planning documents.

2.11 DECONTAMINATION

The equipment involved in field sampling activities will be decontaminated prior to and during drilling and sampling activities. This equipment includes drilling rigs, downhole tools, augers, and non-disposable soil and water sampling equipment.

2.11.1 Major Equipment

All downhole purging equipment and drilling equipment, including downhole drilling tools, will be cleaned with high-pressure hot water from a non-treated, Navy-approved source prior to beginning work, between boreholes, any time the drilling rig leaves the drill site prior to completing a boring, and at the conclusion of the drilling program. Well casing and screens will be supplied in certified-clean packaging.

These decontamination operations will consist of washing equipment using a high-pressure steam wash from a potable water supply. All decontamination activities will take place at an area determined during the FOL's coordination with NDW,IH Environmental Department personnel prior to commencement of field activities. Additional requirements for drilling equipment decontamination can be found in Facility SOP SA-7.1.

2.11.2 Sampling Equipment

All equipment used for collecting samples will be decontaminated both prior to beginning field sampling and between samples in accordance with Facility SOP SA-7.1. The following decontamination steps will be taken:

- Potable water rinse
- Detergent wash
- Potable water rinse
- Steam-distilled deionized water rinse
- Isopropyl alcohol
- Air dry
- Wrap in aluminum foil

Field analytical equipment such as turbidity, pH, conductivity and temperature instrument probes will be rinsed with steam-distilled deionized water.

2.12 HANDLING AND DISPOSAL OF INVESTIGATION-DERIVED WASTE

Investigation-derived waste (IDW) may consist of personnel protective equipment, decontamination fluids, monitoring well purge and development water, drill cuttings, and groundwater, surface water, soil and sediment that accumulate during sample collection. Unless described otherwise in the project-specific FSP to account for project-specific conditions, IDW for environmental investigations will be handled as follows:

1. Personnel protective equipment will be double bagged in plastic trash bags and disposed in an on-Facility dumpster.

2. All other IDW will be handled as follows:

    - Segregate solids and liquids and containerize them on site in United States Department of Transportation (USDOT)-approved drums.

    - Place all drums of IDW on pallets to protect them from sitting in standing water.

    - Label all drums of IDW with an indelible marker to include the following:

- Contents (IDW-soil cuttings, IDW-groundwater, etc.)
- Facility point of contact name
- Facility point of contact telephone extension
- Date

- Record in field logbooks and on drum labels, which samples or sampling locations (e.g., decontamination fluids) have contributed to the contents of each drum. The information must be recorded in the field log book prior to departing the site each day, and on the drum label of the day the drum is filled, or prior to departing the site at the conclusion of the field effort.

- If IDW is suspected of being hazardous waste prior to receiving TCLP analysis, then the requirements for hazardous waste storage in COMAR 26.13 must be followed, including secondary containment for liquid hazardous waste. Secondary containment can be created using a tarp or plastic sheeting under the drums.

- If IDW is determined to be hazardous waste based on the results of RCRA characterization, promptly notify the facility point of contact so the drums can be properly labeled and managed as hazardous waste. The IDW will be disposed in a permitted hazardous waste disposal facility.

- If the IDW is determined to be non-hazardous based on the results of RCRA characterization, the method of IDW disposal will be determined on a case by case basis.

2.13 ECOLOGICAL ASSESSMENT

Ecological sampling/investigations may be conducted at some sites to better characterize the ecology, to conduct a baseline ecological risk assessment (BERA), and/or to develop preliminary remediation goals. These sampling events/investigations may include flora and fauna surveys, timberstand mapping, wetlands delineation, surveys of threatened or endangered species, toxicity testing, and biota sampling. The specific type of sampling/investigations conducted at a site will depend on the media to be sampled, the type and size of the habitat to be sampled, the receptors present, and the chemicals of concern. The sampling methods may also vary depending on the equipment available to the sampling team. The large number of potential combinations of these variables results in a myriad of possible sampling techniques that may be employed to meet project-specific objectives. Therefore, when a site advances to the stage where ecological sampling is needed, a project-specific WP will be developed to detail how the samples will be collected. For that reason, this Master FSP does not describe methods for conducting ecological sampling.

2.13.1 Aquatic Habitat Characterization

The aquatic habitat characterization may be comprised of two parts: the macroinvertebrate inventory and the fish characterization.

2.13.1.1 Macroinvertebrate Inventory

Aquatic habitats typically include several types of organisms including plankton, macroinvertebrates, amphibians, and fish. Macroinvertebrates are generally the most effective choice for an inventory because they can be readily collected without specialized equipment, their general lack of mobility results in an increased chance of exposure to contaminants, and fish populations largely depend on macroinvertebrates for food.

Local and State officials will be contacted to determine if State-specific biotic indices have been established so that the relative "health" of impacted and unimpacted study areas might be evaluated.

Methods outlined in Rapid Bioassessment Protocols for Use in Stream and Rivers (USEPA, 1989), Protocol III, will be used to generate a number of matrices, such as taxa richness, species diversity, abundance, and percent contribution by dominant taxa. Following taxonomic identification of each macroinvertebrate sample, the data will be summarized and indices estimated using formulae cited in the Rapid Bioassessment Protocol. However, these matrices will not be compared to matrices generated for freshwater streams and rivers.

Samples will be shipped to a laboratory specializing in aquatic invertebrate taxonomy for identification of macroinvertebrate samples.

2.13.1.2 Fish Characterization

Fish characterization will be performed to characterize (in general terms) the fish species and to determine their utility in documenting potential bioaccumulation. Fish will be sampled by means of seine netting, electroshocking, gill netting, or other appropriate means. Fish samples will be submitted to a laboratory that specializes in such fish characterization analyses.

Additional studies (e.g., tissue analyses) may be necessary to determine if contaminants are adversely affecting aquatic communities and/or predators that feed on organisms comprising these communities.

2.13.2 Terrestrial Habitat Characterization

The terrestrial habitat characterization may be comprised of two parts: the vegetation inventory and the terrestrial wildlife inventory. These inventories are not intended to serve as surveys for threatened and endangered species.

2.13.2.1 Vegetation Inventory

Vegetation inventories will typically include trees (canopy), saplings, shrubs, herbaceous ground cover, woody vines, and bryophytes. The inventory will generate a list of vegetation for each investigation site. Each species will be listed by common and scientific name. The species will be classified according to wetland indicator status obtained from Region V listings (Reed, 1988) and by habitat type. Dominance of plant species will be judged subjectively. The absence of vegetation within the vicinity of an investigation site will also be documented.

The field data collected for the vegetation inventory will also be used to prepare detailed descriptions of each vegetative stratum in each habitat type. Although the inventory will provide detailed descriptive information for each habitat type, it is not designed to generate a comprehensive plant species list for investigation sites. Although most trees and shrubs can be identified any time of the year, many herbaceous plants are only seasonally present or can be identified only at specific times of the year when they are in flower or fruit.

Additionally, a canvas of each area will be conducted for stressed or dying vegetation. If any such vegetation is observed, its location will be noted on the habitat maps. Typical sources of stress (such as disease, insects, or physical injury) for the affected species will be investigated to assess whether they offer an explanation for the observed effects. Any area of absent or sparse vegetation that cannot be attributed to known causes will also be noted.

2.13.2.2 Terrestrial Wildlife Inventory

At a minimum, investigation site areas and areas potentially affected by each study site will be inspected for the presence of terrestrial mammals, birds, reptiles, amphibians, and other wildlife. Observations will include not only direct sightings but also sound (call) and sightings of signs such as tracks, nests, burrows, skins, and scat.

The terrestrial wildlife inventory will generate a list for each site. Each species will be listed by scientific and common name, followed by a column indicating those habitat types in which the species was observed. Any visually apparent stress experienced by the wildlife will be noted.

2.13.3 Wetland Delineation

Wetlands potentially affected by each site will be delineated. Wetlands are defined by the USEPA as areas that are saturated or inundated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, plant life adapted to saturated soil conditions (USACE, 1987 and FICWD, 1989). Wetlands perform a number of ecologically valuable functions, including but not limited to, providing habitat for a number of threatened or endangered plant and animal species, providing habitat for many lower food-chain organisms on which fish and wildlife depend, improving water quality, and stabilizing shoreline soils.

The wetland delineation will follow the three-parameter approach based on vegetation, soils, and hydrology developed in the Corps of Engineers Wetlands Delineation Manual (USACE, 1987) and supplementary guidance (USACE, 1992).

Specifically, wetland delineations will follow the procedures for routine determinations using an onsite inspection as outlined in Part IV, Section D, Subsection 2 of the Corps of Engineers Wetlands Delineation Manual. For small sites under 5 acres or for larger areas where the wetland/nonwetland boundaries are abrupt and distinct, the procedures developed for areas less than 5 acres in size (Steps 4 through 17) will be employed. Representative observation points for collecting vegetation, soil, and hydrology data will be established subjectively in each occurrence (stand) of each plant community on the site. For larger sites where the wetland/nonwetland boundaries are gradual or indistinct, the procedures developed for areas greater than 5 acres in size (Steps 18 through 22) will be employed. Representative observation points will be established on transects perpendicular to the hydrological gradient.

Each observation point will be flagged (or staked) and labeled in the field and mapped on the wetland delineation drawings generated in the report. If the delineation will be used to support permit applications or notifications under Section 404 of the Clean Water Act (CWA), the delineated wetland boundaries will also be staked in the field for subsequent land survey. Each habitat mapping unit meeting the technical criteria for a wetland will be identified on the habitat map. Each wetland will be classified on the map using the classification system developed by the U.S. Fish and Wildlife Service in Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al., 1979).

Vegetation, soil, and hydrology data will be collected at each data collection point and presented on a data collection form. Each data collection point will be examined for field indicators that will include hydrophytic vegetation, hydric soils, and wetland hydrology, respectively. Each dominant plant species identified at each data collection point will be assigned one of the wetland indicator statuses using data in the National List of Plant Species that Occur in Wetlands (Reed, 1988).

Soil pits will be hand augered at each data collection point to a minimum depth of 18 inches or to the depth necessary to adequately investigate the presence of field indicators of hydric soils and wetland hydrology. For each soil horizon encountered, the color will be determined using a Munsell soil color chart, and the texture will be estimated by feel (gloves worn to comply with the project-specific HASP will partially limit the accuracy of the texture estimates). If the water table or its capillary fringe is encountered, the depth below the ground surface will be recorded.

3.0 GENERAL SAMPLING OPERATIONS

3.1 GENERAL SAMPLING OPERATIONS

This section discusses the sampling methodology for all groundwater, surface water, soil, and sediment sampling activities to be performed at the NDW,IH. All sampling operations must be in compliance with the control measures detailed in the project-specific HASP.

3.1.1 Groundwater Sampling

The objective of this section is to provide guidance for the proper sampling equipment and techniques for groundwater sample collection. All groundwater sampling will be conducted in accordance with the requirements of the project-specific FSP and in accordance with the low-flow purging and sampling procedures provided in Facility SOP SA-1.1.

Prior to obtaining a groundwater sample, the water level in the monitoring well will be measured to within 0.01 foot from the marked location on the top of the well riser pipe. If volatile organic contamination is suspected, a head-space reading will be obtained in the well's riser pipe using an organic vapor monitor (i.e., PID or FID). Monitoring wells will typically be purged prior to sample collection. If, however, non-aqueous phase liquids (dense or light) are suspected and/or detected in the well, a project-specific decision will be made as to whether to collect samples of the free phase liquids and/or dissolved phase.

Purging will be accomplished by removing groundwater from the well using a low-flow peristaltic pump or a submersible, low-flow-rate pump with a new, clean length of polyethylene tubing. Temperature, pH, turbidity, and conductivity measurements will be taken at 5 to 10 minute intervals. Purging will continue until field measurements collected by in-line instrumentation have stabilized within 10 percent over at least two measurements. The volume removed will be determined by the time and measured pump rate or by direct measurement of the purged volume. In the event that the aquifer recharge does not allow sustained pumping or the water level does not return to 80 percent of original static water level after 2 hours, a field decision will be made to either purge the well intermittently, proceed with sampling, or sample the well under less than ideal conditions. When a peristaltic pump is used to purge, and the purging process is completed, the flow rate will be adjusted to the minimum rate to fill containers.

To minimize the potential for cross-contamination of samples that may result from inadequate decontamination of sampling equipment, well sampling will normally progress from the well expected to be least contaminated to that expected to be most contaminated. The samples will be collected and

containerized according to the volatility of the target analytes. At each sampled location, the collection order will be as follows:

(1) Volatile organic compounds (VOCs)
(2) Semivolatile organic compounds (SVOCs)
(3) Filtered and unfiltered metals and cyanides
(4) Nitrate/nitrite, pesticides/polychlorinated biphenyls (PCBs), and explosives

All non-dedicated well purge and sampling equipment will be thoroughly decontaminated between sampling sites as detailed in Section 2.10.

All pertinent field data will be recorded on a well sample form and in the field logbook. An example well sample form is provided in Appendix A.

3.1.2 Surface Water Sampling

Surface water samples will be collected as grab samples from surface water drainages, discharge ponds, and low wet areas in accordance with Facility SOP SA-1.2.

For all sampling events at each sample location and immediately prior to collecting each sample, the temperature, pH, DO, and conductivity of the water will be measured and recorded on a sample log in accordance with Section 2.5. An example sample log form is provided in Appendix A. During sampling, the sample bottle will be submerged just below the water surface and allowed to fill. After the sample bottle has been filled, preservatives will be added (if required) and the sample bottle will be capped. Samples to be analyzed for volatile constituents will be collected first and immediately sealed in a container so that no head space exists. Sampling will be conducted initially from the location farthest downstream and will proceed progressively upstream.

If there is an insufficient depth of water to use the direct fill method of sample collection, a stainless steel beaker will be used to fill the sample bottles. Non-dedicated sampling equipment will be decontaminated between samples as described in Section 2.10.2.

All pertinent field data will be recorded using a sample log form and in the field logbook. An example sample log form is provided in Appendix A.

3.1.3 Surface Soil Sampling

Surface soil samples will be collected from the ground surface to a depth not exceeding 6 inches, in accordance with Facility SOP SA-1.3. A stainless-steel trowel or hand auger will be used to collect the surface soil sample. All samples obtained will be monitored with an organic vapor monitor and then collected for lithologic and/or chemical analysis. Upon sample retrieval, the samples to be analyzed for volatile constituents will be taken first and immediately sealed. Sampling equipment will be decontaminated between samples as described in Section 2.10.2. All pertinent field data will be recorded using a sample log form and the field logbook. An example sample log form is provided in Appendix A.

3.1.4 Subsurface Soil Sampling

Subsurface soil samples may be collected from test pits and soil borings in accordance with Facility SOP SA-1.3. All samples obtained from the borehole will be monitored with an organic vapor monitor and then collected for lithologic and/or chemical analysis. Upon sample retrieval, the samples to be analyzed for volatile constituents will be taken first and immediately sealed. Sampling equipment will be decontaminated between samples as described in Section 2.10.2. All pertinent field data will be recorded using a sample log form and the field logbook. An example a sample log form is provided in Appendix A.

3.1.5 Sediment Sampling

Sediment samples will be collected as grab samples from both pond perimeters and interiors as well as from stream/drainage bottoms in accordance with Facility SOP SA-1.2. A stainless-steel Ekman or Ponar dredge (or similar device) will be used to collect sediment samples. The sediment samples will be collected from the top 4 to 6 inches in depositional or low-lying areas where fines comprise at least 50 percent of the sample. Upon sample retrieval, a sufficient volume will be obtained for volatile organics analysis and sealed with no head space. The remaining material will be homogenized and distributed to the remaining sample containers. Sample equipment will be decontaminated between samples as described in Section 2.10.2.

All pertinent field data will be recorded using a sample log form and the field logbook. An example sample log form is provided in Appendix A.

3.1.6 Head-Space Soil Sampling

If required, head-space soil analysis will be performed. Upon split-barrel sample retrieval, a small quantity of the soil will be removed from the sampler and immediately placed in a sealed container. The container will then be warmed for 15 minutes to volatilize the potential contaminants in the soil sample.

After 15 minutes, the tip of the OVA or PID will be pushed into or through the container or its lid and a direct reading obtained from the OVA or PID. All head-space readings will be noted on the appropriate boring log and/or sample form. Additional procedures are provided in Facility SOP SF-1.5

3.1.7 Air Sampling

During routine field activities, air monitoring can aid in the selection of sample locations and screening of samples for a rapid qualitative determination of volatile contamination. The purpose of this section is to provide a general guide for the determination of volatile airborne contamination. All air sampling will be performed in accordance with Facility SOP SA-2.2.

Continuous air monitoring is performed by drawing air samples from a fixed sampling point (e.g., screening of split-barrel samplers to select samples for laboratory analysis). Typical qualitative air monitoring equipment includes FID, PID, and calorimetric sorbent media (e.g., Draeger® tubes). It is important to choose the proper detector for the anticipated site contaminants and to account for air travel time required to move the contaminant from the source to the detector. It is sometimes advantageous to draw an air sample into a non-reactive sample bag (such as Mylar) for confirmatory, fixed-base analysis or for field analysis at a location away from potential site contaminants and temperature extremes.

Most air monitoring equipment is battery powered (requiring daily charging), lightweight, and water resistant. Some newer air monitors allow for chemical-specific calibration and have data logging capabilities. Advantages of qualitative air monitoring include immediate qualitative sample screening, the ability to obtain a general vertical profile of contaminant concentrations during drilling operations, and inexpensive screening of many samples in order to reduce expensive, fixed-base laboratory analyses. Disadvantages include a limited concentration range (both high and low), inability to detect some contaminants, sensitivity to site environmental conditions such as temperature and humidity, and limited battery life.

3.1.8 Drum Sampling

Drum sampling is only anticipated to be conducted for IDW waste generated during field investigative activities. Preliminary classification will be possible based on available data to minimize safety hazards associated with drum opening. Sampling procedures for drums and other containers from other sources are provided in Facility SOP SA-5.1.

3.1.9 Tank Sampling

Tank sampling may be conducted for IDW liquid waste stored in above-ground tanks or upon discovery of an underground storage tank in an investigation area. Additional tank sampling procedures are provided in Facility SOP SA-5.1.

3.1.10 Field Test Kits

Field test kits may be used for screening purposes, for determining gross contamination levels, or for natural attenuation parameters analysis. The field test kits will be used in accordance with manufacturer's specifications. USEPA-approved test kits will be used, when available. Additional field test kit information is provided in Facility SOP SA-1.6.

3.2 SAMPLE HANDLING

Sample handling includes the field-related considerations concerning the selection of sample containers, preservatives, allowable holding times, and analyses requested. Sample identification, packaging, and shipping are addressed in Facility SOP SA-6.1. Preservation requirements and procedures are summarized below. The project-specific QAPP discusses details concerning sample containers, volume requirements, preservatives, allowable holding times, and analyses planned.

3.2.1 Field Documentation

Sample documentation consists of the completion of chain-of-custody (COC) reports and matrix-specific sample logsheets. COC reports are detailed in Section 7.0 of the Master QAPP. Completion of sample logsheets are discussed along with the matrix-specific sampling procedures presented in Section 2.0.

In addition, various hardcover, bound, record books are maintained for each field activity. The site logbook (Facility SOP SA-6.3) serves as the overall record of field activities. Information included daily in the master site logbook includes weather conditions, identity and arrival and departure times of personnel, management issues, etc. Various other field notebooks are also maintained. For example, each geologist supervising drilling operations at a specific sampling location will maintain a field notebook.

The FOL is responsible for the maintenance and security of all field records. Eventually, all field records (COCs, sample log sheets, logbooks, and notebooks), are docketed and incorporated in the project central file.

Field Task Modification Records (FTMRs) are specific forms initiated when a change to or deviation from procedures provided for in the project planning documents occurs. The procedure for requesting and recording field changes follows:

- The FOL notifies the Project Manager (PM) of the need for the change.

- If necessary, the PM discusses the change with the pertinent individuals [e.g., the Navy Remedial Project Manager (RPM), contractor QA Manager (QAM)]. Verbal approval or denial of the proposed change is given at this time.

- The FOL then documents the change on an FTMR and forwards the form to the PM at the earliest convenient time (e.g., end of the workweek).

- The PM signs the form and distributes copies to the Navy RPM, contractor QAM, the PM, FOL, and project file.

- A copy of the completed FTMR is attached to the field copy of the affected document.

3.2.2 Sample Nomenclature

Each sample collected at the Facility will be assigned a unique tracking number. The sample designation includes the site number, sample or well location number, and an indication of the sample matrix (e.g., soil, groundwater, surface water, or sediment). The designations indicate, from left to right, site number, matrix/sample type, sample location number, and sample depth, as needed. The sample locations identified in the project-specific FSP incorporate the sample matrix/type, site, and sample location numbers. Additional sample nomenclature guidance is provided in Facility SOP CT-04.

3.2.3 Preservation

The existence of some chemical constituents in some environmental matrices is unstable. Therefore, these types of samples must be "stabilized" using preservatives and/or special handling procedures (such as maintaining the sample on ice at 4 degrees Celsius (°C) or using amber glass bottles to prevent photodegradation). These preservation techniques prevent (or forestall) degradation of the sample to ensure that the sample is representative of actual site conditions. Typically, sample containers are received in the field from the laboratory pre-preserved; however, if field preservation is required, Facility SOP SA-6.1 provides guidance for field preservation.

3.2.4 Documentation, Sample Packaging, and Shipping

Samples will be packaged and shipped in accordance with Facility SOP SA-6.1 and USDOT requirements provided in 40 Code of Federal Regulations (CFR) 100 through 185. Prior to inclusion in a project-specific FSP, the USDOT requirements and Facility SOP SA-6.1 should be reviewed to ensure that the current requirements are complied with.

The FOL will be responsible for completion of the following forms:

- Sample labels
- COC forms
- Appropriate labels applied to shipping coolers
- COC labels
- Express shipping airbills

3.3 SAMPLE CUSTODY

Custody of samples must be maintained and documented at all times. COC begins with the collection of the samples in the field. The Master QAPP and Facility SOP SA-6.3 further detail the COC procedures. An example of a COC record is provided in Appendix A.

3.4 QUALITY CONTROL SAMPLES

In addition to periodic calibration of field equipment and appropriate documentation, QC samples will be collected or generated during environmental sampling activities. QC samples include field blanks, rinsate duplicates, trip blanks, and background samples. Each type of field QC sample is defined in the Master QAPP.

REFERENCES

American Sopciety for Testing and Materials (ASTM) International. D6286-98 Standard Guide for Selection of Drilling Methods for Environmental Site Characterization. Philadelphia, Pennsylvania.

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FICWD (Federal Interagency Committee for Wetland Delineation), 1989. Federal Manual for Identifying and Delineating Jurisdictional Wetlands. U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and USDA Soil Conservation Service. Cooperative technical publication.

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USEPA (United States Environmental Protection Agency), 1989. Rapid Bioassessment Protocols for Use In Streams and Rivers. EPA/444/4-89-001.

APPENDIX A

EXAMPLE FORMS

LIST OF FORMS

Boring Log

Chain of Custody Form

Daily Activities Record

Equipment Calibration

Field Task Modification Request Form

Groundwater Level Measurement Sheet

Groundwater Sample Log Sheet

Hydraulic Conductivity Testing Data Sheet

Low Flow Purge Data Sheet

Monitoring Well Development Record

Monitoring Well Sheet, Bedrock, Open Hole Well

Monitoring Well Sheet, Bedrock, Well Installed in Bedrock – Flush Mount

Monitoring Well Sheet, Bedrock, Well Installed in Bedrock - Stick-Up

Monitoring Well Sheet, Confining Layer

Monitoring Well Sheet, Overburden – Flush Mount

Monitoring Well Sheet, Overburden – Stick-Up

Packer Test Report

Pumping Test Data Sheet

Soil and Sediment Sample Log Sheet

Surface Water Sample Log Sheet

Test Pit Log

BORING LOG

PROJECT NAME: _____ BORING No.: _____
PROJECT NUMBER: _____ DATE: _____
DRILLING COMPANY: _____ GEOLOGIST: _____
DRILLING RIG: _____ DRILLER: _____

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	MATERIAL DESCRIPTION: Color	MATERIAL DESCRIPTION: Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	PID/FID Reading (ppm): Sampler BZ	PID/FID Reading (ppm): Borehole**	PID/FID Reading (ppm): Driller BZ**

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated reponse read.

Drilling Area Background (ppm): [ ]

Remarks: _____

Converted to Well: Yes _____ No _____ Well I.D. #: _____

CHAIN OF CUSTODY | NUMBER | PAGE ____ OF _____

PROJECT NO:	FACILITY:	PROJECT MANAGER	PHONE NUMBER	LABORATORY NAME AND CONTACT:
SAMPLERS (SIGNATURE)		FIELD OPERATIONS LEADER	PHONE NUMBER	ADDRESS
		CARRIER/WAYBILL NUMBER		CITY, STATE

STANDARD TAT ☐
RUSH TAT ☐
☐ 24 hr. ☐ 48 hr. ☐ 72 hr. ☐ 7 day ☐ 14 day

CONTAINER TYPE PLASTIC (P) or GLASS (G)

PRESERVATIVE USED

TYPE OF ANALYSIS

DATE YEAR ____	TIME	SAMPLE ID	LOCATION ID	TOP DEPTH (FT)	BOTTOM DEPTH (FT)	MATRIX (GW, SO, SW, SD, QC, ETC.)	COLLECTION METHOD GRAP (G) COMP (C)	No. OF CONTAINERS									COMMENTS

1. RELINQUISHED BY	DATE	TIME	1. RECEIVED BY	DATE	TIME
2. RELINQUISHED BY	DATE	TIME	2. RECEIVED BY	DATE	TIME
3. RELINQUISHED BY	DATE	TIME	3. RECEIVED BY	DATE	TIME

COMMENTS

DISTRIBU[illegible]N: WHITE (ACCOMPANIES SAMPLE) YELLOW (F[illegible] COPY) PINK (FILE COPY)

DAILY ACTIVITIES RECORD

PROJECT NAME: _____ PROJECT NUMBER: _____

CLIENT: _____ LOCATION: _____

DATE: _____ ARRIVAL TIME: _____

Tt NUS PERSONNEL: _____ DEPARTURE TIME: _____

CONTRACTOR: _____ DRILLER: _____

ITEM	QUANTITY ESTIMATE	QUANTITY TODAY	PREVIOUS TOTAL QUANTITY	CUMULATIVE QUANTITY TO DATE

COMMENTS: _____

APPROVED BY:

_____ _____

Tt NUS REPRESENTATIVE DRILLER

DATE: _____

EQUIPMENT CALIBRATION LOG

PROJECT NAME : _____ INSTRUMENT NAME/MODEL: _____

SITE NAME: _____ MANUFACTURER: _____

PROJECT No.: _____ SERIAL NUMBER: _____

Date of Calibration	Instrument I.D. Number	Person Performing Calibration	Instrument Settings		Instrument Readings		Calibration Standard (Lot No.)	Remarks and Comments
			Pre-calibration	Post-calibration	Pre-calibration	Post-calibration		

FIELD TASK MODIFICATION REQUEST FORM

Project/Installation Name	CTO & Project Number	Task Mod. Number
Modification To (e.g. Work Plan)	Site/Sample Location	Date

Activity Description: _____

Reason for Change: _____

Recommended Disposition: _____

Field Operations Leader (Signature) _____ Date _____

Approved Disposition:

Project/Task Order Manager (Signature) _____ Date _____

Distribution:

Program/Project File –
Project/Task Order Manager –
Field Operations Leader –

Other: _____

GROUNDWATER LEVEL MEASUREMENT SHEET

Project Name: _____ **Project No.:** _____

Location: _____ **Personnel:** _____

Weather Conditions: _____ **Measuring Device:** _____

Tidally Influenced: Yes ___ No ___ **Remarks:** _____

Well or Piezometer Number	Date	Time	Elevation of Reference Point (feet)*	Total Well Depth (feet)*	Water Level Indicator Reading (feet)*	Thickness of Free Product (feet)*	Groundwater Elevation (feet)*	Comments

* All measurements to the nearest 0.01 foot

GROUNDWATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Domestic Well Data
[] Monitoring Well Data
[] Other Well Type: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____
Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date:	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time:	(Visual)	(S.U.)	(mS/cm)	(^{0}C)	(NTU)	(mg/l)	(%)	
Method:								

PURGE DATA:

Date:	Volume	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Method:								
Monitor Reading (ppm):								
Well Casing Diameter & Material								
Type:								
Total Well Depth (TD):								
Static Water Level (WL):								
One Casing Volume(gal/L):								
Start Purge (hrs):								
End Purge (hrs):								
Total Purge Time (min):								
Total Vol. Purged (gal/L):								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

HYDRAULIC CONDUCTIVITY TESTING DATA SHEET

PROJECT NAME: ..... WELL/BORING NO.: .....

PROJECT NO.: ..... GEOLOGIST: .....

WELL DIAMETER: ..... SCREEN LENGTH/DEPTH: ..... TEST NO.: .....

STATIC WATER LEVEL (Depth/Elevation): ..... DATE: .....

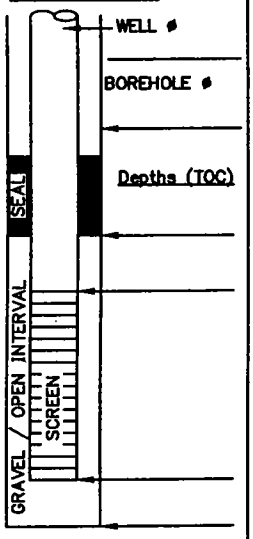
TEST TYPE (Rising/Falling/Constant Head): ..... CHECKED: .....

METHOD OF INDUCING WATER LEVEL CHANGE: ..... PAGE ..... OF .....

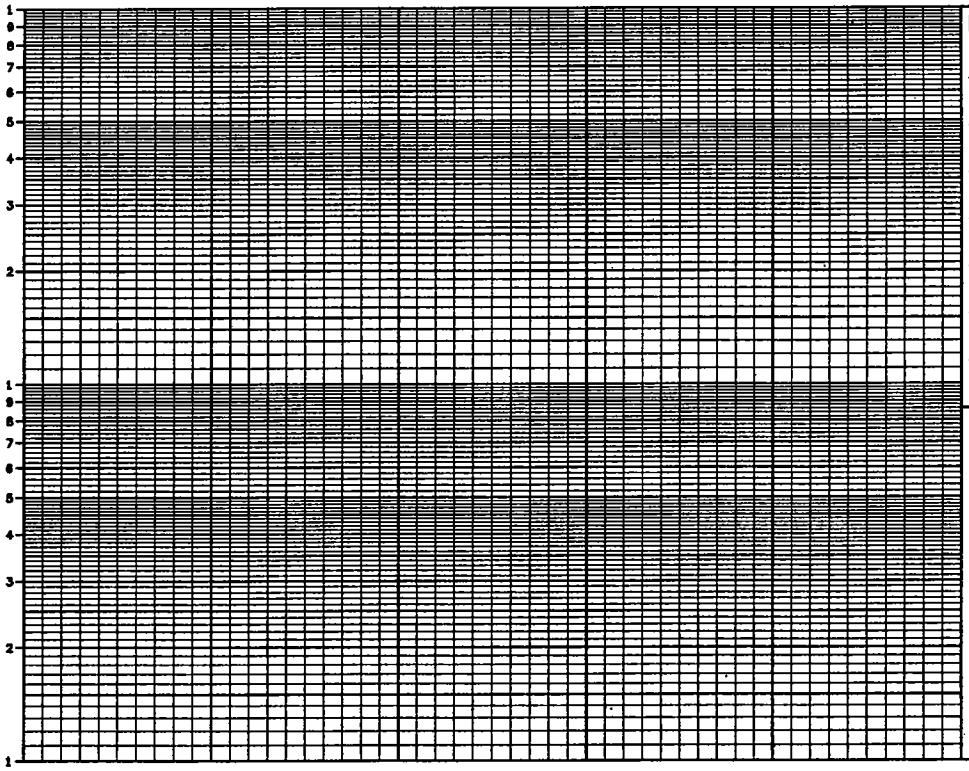
REFERENCE PT. FOR WL MEAS. (Top of Casing, Transducer, etc.): .....

ELAPSED TIME (min. or sec.)	MEASURED WATER LEVEL (feet)	DRAWDOWN OR HEAD (ΔH) (feet)	ELAPSED TIME (min. or sec.)	MEASURED WATER LEVEL (feet)	DRAWDOWN OR HEAD (ΔH) (feet)

WELL SCHEMATIC



▽ Indicate SWL Depth on Drawing



REMARKS:

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CALCS,SKETCH MAPS, ETC.:

ACAD:FORM_HYDCONTST.dwg 07/06/99 INL

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: _____ WELL ID.: _____

PROJECT NUMBER: _____ DATE: _____

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments

SIGNATURE(S): _____

PAGE___OF___

MONITORING WELL DEVELOPMENT RECORD

Page ___ of _____

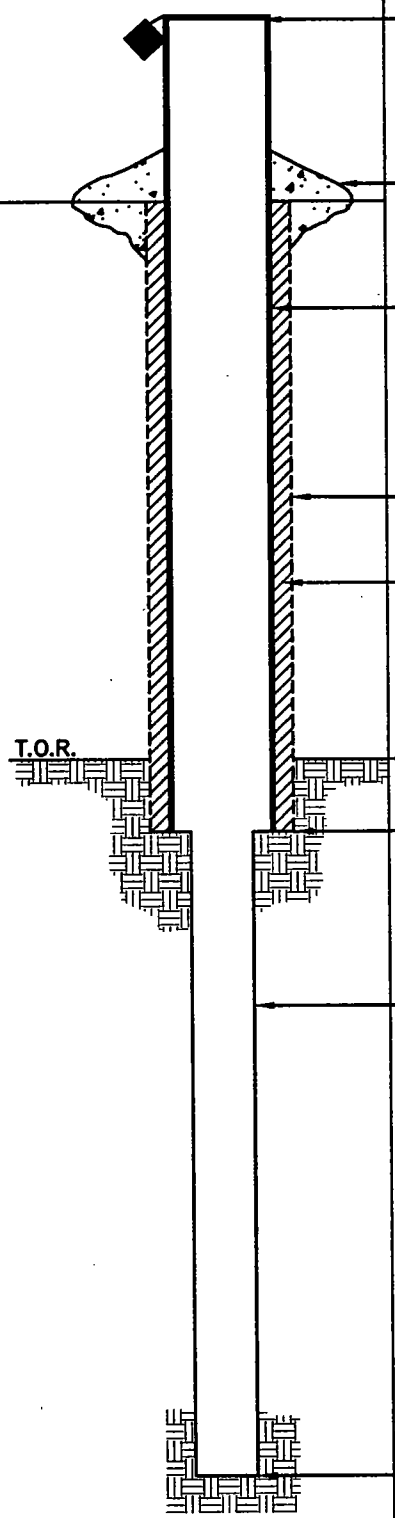
Well: _____ Depth to Bottom (ft.): _____ Responsible Personnel: _____
Site: _____ Static Water Level Before (ft.): _____ Drilling Co.: _____
Date Installed: _____ Static Water Level After (ft.): _____ Project Name: _____
Date Developed: _____ Screen Length (ft.): _____ Project Number: _____
Dev. Method: _____ Specific Capacity: _____
Pump Type: _____ Casing ID (in.): _____

Time	Estimated Sediment Thickness (Ft.)	Cumulative Water Volume (Gal.)	Water Level Readings (Ft. below TOC)	Temperature (Degrees C)	pH	Specific Conductance (Units _____)	Turbidity (NTU)	Remarks (odor, color, etc.)

WELL NO.: _____

BEDROCK
MONITORING WELL SHEET
OPEN HOLE WELL

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
DATE BEGUN _____	DATE COMPLETED _____	
FIELD GEOLOGIST _____		DEVELOPMENT METHOD _____
GROUND ELEVATION _____	DATUM _____	



ELEVATION/HEIGHT OF TOP OF SURFACE CASING: ____/____

TYPE OF SURFACE SEAL: _____

I.D. OF CASING: _____

TYPE OF CASING: _____

TEMP./PERM.: _____

DIAMETER OF HOLE: _____

TYPE OF CASING SEAL: _____

DEPTH TO TOP OF ROCK: _____

DEPTH TO BOTTOM CASING: _____

DIAMETER OF HOLE IN BEDROCK: _____

DESCRIBE IF CORE/REAMED WITH BIT:

DESCRIBE JOINTS IN BEDROCK AND DEPTH:

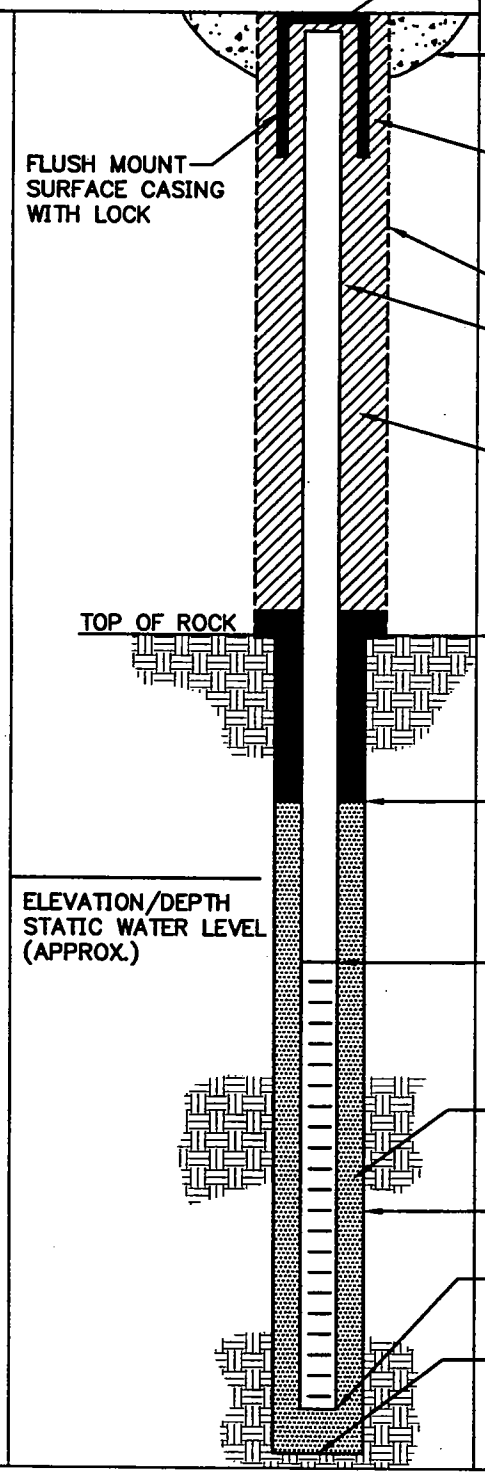
ELEVATION/DEPTH OF HOLE: ____/____

ACAD:FORM_MWOHW.dwg 07/20/99 INL

WELL NO.: _____

BEDROCK
MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
DATE BEGUN _____	DATE COMPLETED _____	
FIELD GEOLOGIST _____		DEVELOPMENT METHOD _____
GROUND ELEVATION _____	DATUM _____	



ELEVATION TOP OF RISER: _____

TYPE OF SURFACE SEAL: _____

TYPE OF PROTECTIVE CASING: _____

I.D. OF PROTECTIVE CASING: _____

DIAMETER OF HOLE: _____

TYPE OF RISER PIPE: _____

RISER PIPE I.D.: _____

TYPE OF BACKFILL/SEAL: _____

ELEVATION/DEPTH TOP OF BEDROCK: ____/____

ELEVATION/DEPTH TOP OF SAND: ____/____

ELEVATION/DEPTH TOP OF SCREEN: ____/____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

TYPE OF SAND PACK: _____

DIAMETER OF HOLE IN BEDROCK: _____

CORE/REAM: _____

ELEVATION / DEPTH BOTTOM OF SCREEN: ____/____

ELEVATION / DEPTH BOTTOM OF SAND: ____/____

ELEVATION/DEPTH BOTTOM OF HOLE: ____/____

BACKFILL MATERIAL BELOW SAND: _____

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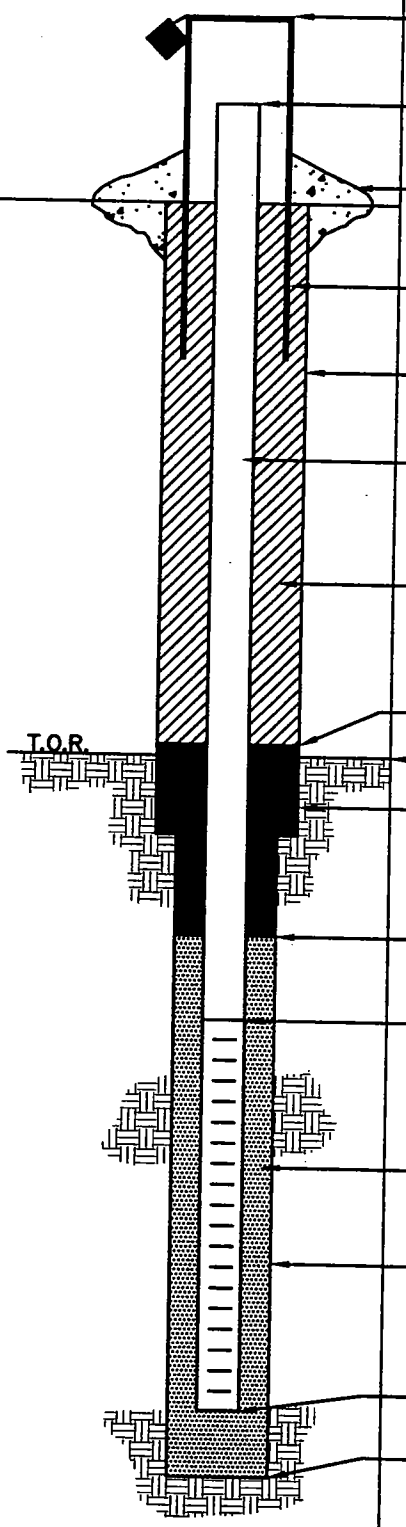
WELL NO.: _____

BEDROCK
MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK

PROJECT _____ LOCATION _____ DRILLER _____
PROJECT NO. _____ BORING _____ DRILLING METHOD _____
DATE BEGUN _____ DATE COMPLETED _____
FIELD GEOLOGIST _____ DEVELOPMENT METHOD _____
GROUND ELEVATION _____ DATUM _____



ELEVATION/HEIGHT OF TOP OF SURFACE CASING: ____/____

ELEVATION/HEIGHT TOP OF RISER: ____/____

TYPE OF SURFACE SEAL: _____

I.D. OF SURFACE CASING: _____

DIAMETER OF HOLE: _____

RISER PIPE I.D.: _____
TYPE OF RISER PIPE: _____

TYPE OF BACKFILL: _____

ELEVATION/DEPTH TOP OF SEAL: ____/____
ELEVATION/DEPTH TOP OF BEDROCK: _____
TYPE OF SEAL: _____

ELEVATION/DEPTH TOP OF SAND: ____/____

ELEVATION/DEPTH TOP OF SCREEN: ____/____
TYPE OF SCREEN: _____
SLOT SIZE x LENGTH: _____
I.D. SCREEN: _____

TYPE OF SAND PACK: _____

DIAMETER OF HOLE IN BEDROCK: _____
CORE/REAM: _____

ELEVATION/DEPTH BOTTOM SCREEN: ____/____
ELEVATION/DEPTH BOTTOM OF SAND: ____/____
ELEVATION/DEPTH BOTTOM OF HOLE: ____/____
BACKFILL MATERIAL BELOW SAND: _____

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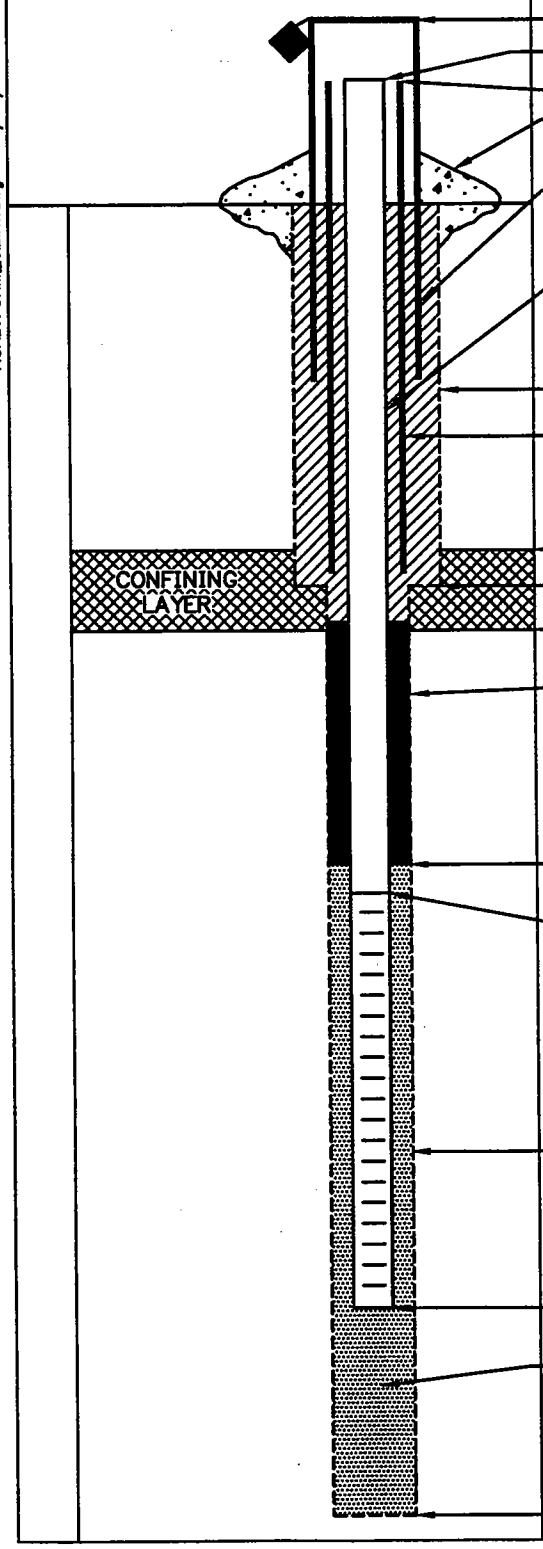
WELL NO.: _____

CONFINING LAYER
MONITORING WELL SHEET

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
DATE BEGUN _____	DATE COMPLETED _____	
FIELD GEOLOGIST _____		DEVELOPMENT METHOD _____
GROUND ELEVATION _____	DATUM _____	



ELEVATION/HEIGHT OF TOP OF SURFACE CASING: ____/____

ELEVATION/HEIGHT OF TOP OF RISER PIPE: ____/____

ELEVATION/HEIGHT OF 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 AND BACKFILL: _____

ELEVATION/DEPTH TOP CONFINING LAYER: ____/____

ELEVATION/DEPTH BOTTOM OF CASING: ____/____

ELEVATION/DEPTH BOTTOM 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: ____/____

BACKFILL MATERIAL BELOW SAND: _____

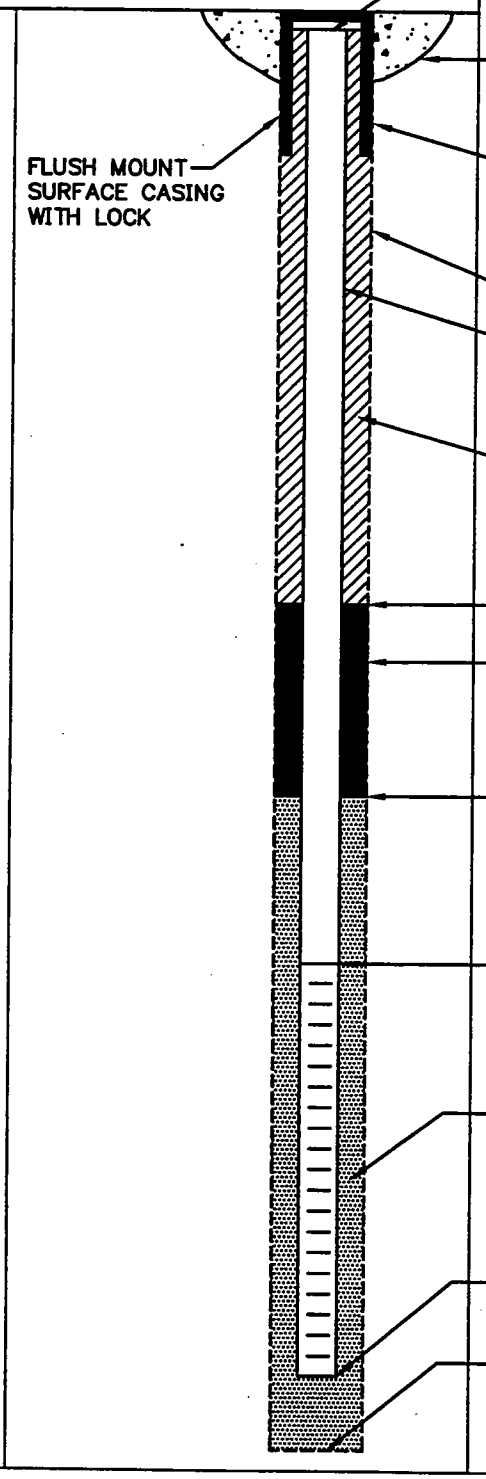
ELEVATION/DEPTH OF HOLE: ____/____

ACAD:FORM_CLMW.dwg 07/20/99 INL

WELL NO.: _____

OVERBURDEN
MONITORING WELL SHEET
FLUSH - MOUNT

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
DATE BEGUN _____	DATE COMPLETED _____	
FIELD GEOLOGIST _____		DEVELOPMENT METHOD _____
GROUND ELEVATION _____	DATUM _____	



ELEVATION TOP OF RISER: _____

TYPE OF SURFACE SEAL: _____

TYPE OF PROTECTIVE CASING: _____

I.D. OF PROTECTIVE CASING: _____

DIAMETER OF HOLE: _____

TYPE OF RISER PIPE: _____

RISER PIPE I.D.: _____

TYPE OF BACKFILL/SEAL: _____

ELEVATION/DEPTH TOP OF SEAL: ____/____

TYPE OF SEAL: _____

ELEVATION/DEPTH TOP OF SAND: ____/____

ELEVATION/DEPTH TOP OF SCREEN: ____/____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

TYPE OF SAND PACK: _____

DIAMETER OF HOLE IN BEDROCK: _____

ELEVATION / DEPTH BOTTOM OF SCREEN: ____/____

ELEVATION / DEPTH BOTTOM OF SAND: ____/____

ELEVATION/DEPTH BOTTOM OF HOLE: ____/____

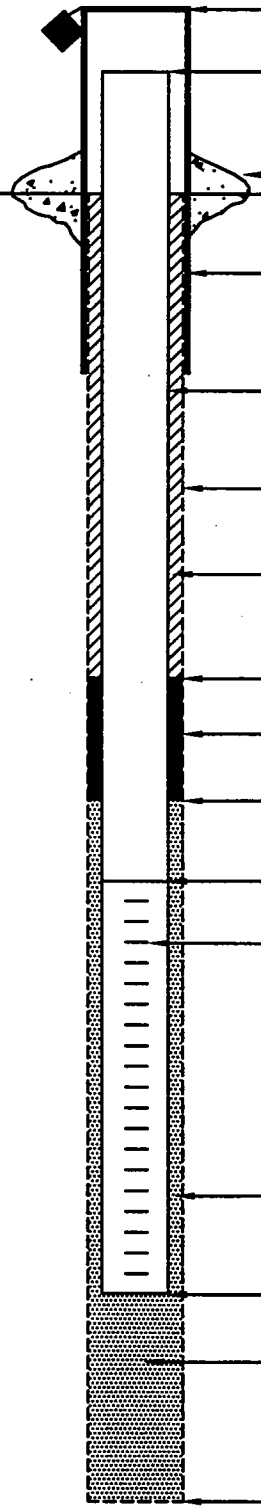
BACKFILL MATERIAL BELOW SAND: _____

ACAD:FORM_MWFM.dwg 07/28/99 INL

WELL NO.: _____

OVERBURDEN
MONITORING WELL SHEET
STICK-UP

PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
DATE BEGUN _____	DATE COMPLETED _____	
FIELD GEOLOGIST _____		DEVELOPMENT METHOD _____
GROUND ELEVATION _____	DATUM _____	



ELEVATION/HEIGHT OF TOP OF SURFACE CASING: ____/____

ELEVATION/HEIGHT OF TOP OF RISER PIPE: ____/____

TYPE OF SURFACE SEAL: _____

I.D. OF SURFACE CASING: _____
TYPE OF SURFACE CASING: _____

RISER PIPE I.D.: _____
TYPE OF RISER PIPE: _____

BOREHOLE DIAMETER: _____

TYPE OF BACKFILL: _____

ELEVATION/DEPTH TOP OF SEAL: ____/____

TYPE OF SEAL: _____

DEPTH TOP OF SAND PACK: _____

ELEVATION/DEPTH TOP OF SCREEN: ____/____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

I.D. OF SCREEN: _____

TYPE OF SAND PACK: _____

ELEVATION/DEPTH BOTTOM OF SCREEN: ____/____

ELEVATION/DEPTH BOTTOM OF SAND PACK: ____/____
BACKFILL MATERIAL BELOW SAND: _____

ELEVATION/DEPTH OF HOLE: ____/____

ACAD:FORM_MWSU.dwg 07/20/99 INL

PACKER TEST REPORT

PROJECT: _____ PROJECT NO.: _____ TEST NO.: _____ PAGE _____ OF _____

BORING NO.: _____ CASING DEPTH: _____ CONTRACTOR: _____ STATIC WATER LEVEL: _____

TEST INTERVAL: _____ BY: _____ CHECKED: _____ PACKER PRESSURE: _____

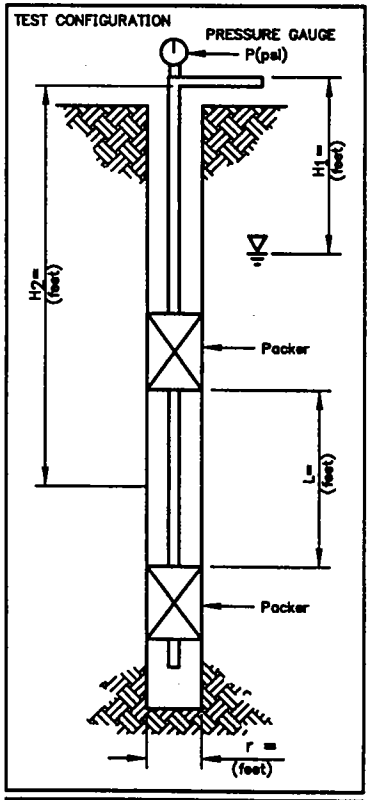
Flow Test					Calculated Results							
Pressure, p (psi)	Elapsed Time (min)	Flow Reading	ΔFlow ΔQ (ft^3)	ΔFlow ΔQ (gal)	Flow Rate Q (gal/min)	H_1 * (ft)	Hp(Ft)= 2.31(psi)	H_2 * (ft)	H = Hp + (H_1 or H_2)	Cp	K(ft/yr) = Cp*Q/H	K(cm/sec)= 9.67×10^{-7} K(ft/yr)

CP = (1/(2πL))LN(L/r) (70,315.5)
7.48 Gallons = $1Ft^3$
1psi = 2.31 ft head

* H_1 is used when the test length is below the water table.
H_2 is used when the test length is above the water table.

Remarks: _____

TEST CONFIGURATION



Length of Test Section in feet, L	Cp Drilling Bit Size			
	Ex (1.5")	Ax (1.875")	Bx (2.37")	Nx (3")
1	31,000	28,500	25,800	23,300
2	19,400	18,100	16,800	15,500
5	9,800	9,300	8,800	8,200
8	6,800	6,500	6,100	5,800
10	5,700	5,400	5,200	4,900
15	4,100	3,900	3,700	3,600
20	3,200	3,100	3,000	2,800

PUMPING TEST DATA SHEET

PROJECT NAME: _____	PUMPING WELL NUMBER: _____
PROJECT NUMBER: _____	MEASURED WELL NUMBER: _____
[ ] PUMPING TEST	[ ] STEP DRAW DOWN TEST
DATE(s):	MONITORING POINT:
MEASUREMENT METHOD:	DEPTH CORRECTION (ft):
TEST NUMBER:	PUMP SETTING (Ft. below monitoring point):
STATIC WATER LEVEL (ft):	DISTANCE FROM PUMPING WELL (ft):
PERSONNEL:	
REMARKS:	

MILITARY TIME	ELAPSED TIME SINCE PUMP START OR STOP (Min.)	WATER LEVEL (Ft.)	CORRECTION (Ft.)	DRAW DOWN OR RECOVERY (Ft.)	PUMPING RATE (GPM)	FLOW METER READING (Gals.)	REMARKS

NOTE: All measurements to nearest 0.01 foot measured from top of well riser pipe unless otherwise noted.

SOIL & SEDIMENT SAMPLE LOG SHEET

Project Site Name: _____
Project No.: _____

[] Surface Soil
[] Subsurface Soil
[] Sediment
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

GRAB SAMPLE DATA:

Date:	Depth Interval	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Time:			
Method:			
Monitor Reading (ppm):			

COMPOSITE SAMPLE DATA:

Date:	Time	Depth Interval	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Method:				
Monitor Readings (Range in ppm):				

SAMPLE COLLECTION INFORMATION:

Analysis	Container Requirements	Collected	Other

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

SURFACE WATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Stream
[] Spring
[] Pond
[] Lake
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA:

Date:	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Time:	(Visual)	(S.U.)	(mS/cm)	(^{0}C)	(NTU)	(mg/l)	(%)	
Depth:								
Method:								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

TEST PIT LOG

PROJECT NAME: _____ TEST PIT No.: _____
PROJECT NUMBER: _____ DATE: _____
LOCATION: _____ GEOLOGIST: _____

Depth (Ft.)	Lithology Change (Depth/Ft.)	MATERIAL DESCRIPTION	USCS	Remarks	PID/FID READING	
		Soil/Waste Characteristics (lithology, density, color, etc.)			Source (ppm)	BZ (ppm)

TEST PIT CROSS SECTION AND / OR PLAN VIEW

REMARKS: _____

PHOTO LOG: _____

Health and Safety Plan Guidance Document

for

Installation Restoration Program Environmental Investigations

at

Naval District Washington, Indian Head
Indian Head, Maryland

Engineering Field Activity Chesapeake
Naval Facilities Engineering Command
Northern Division Contract No. N62467-94-D-0888
Contract Task Order 0805

June 2004

020404/P

HEALTH AND SAFETY PLAN
FOR
INSTALLATION RESTORATION PROGRAM
ENVIRONMENTAL INVESTIGATIONS
AT
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
Engineering Field Activity Chesapeake
1314 Harwood Street, S.E.
Washington Navy Yard, D.C. 20374-5018

Submitted by:
Tetra Tech NUS, Inc.
600 Clark Avenue, Suite 3
King of Prussia, Pennsylvania 19406-1433

CONTRACT NUMBER N62467-94-D-0888
CONTRACT TASK ORDER 0805

JUNE 2004

PREPARED UNDER DIRECTION OF:

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ACRONYMS

CFR	Code of Federal Regulations
EAP	Emergency Action Plan
HASP	Health and safety plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
MSDS	Material Safety Data Sheets
NDW,IH	Naval District Washington, Indian Head
OSHA	Occupational Safety and Health Administration
PPE	Personal protective equipment
SOP	Standard operating procedure

PROJECT-SPECIFIC SAFETY AND HEALTH PLANNING

The foundation of an effective onsite health and safety program is the development, implementation, and maintenance of project-specific health and safety plans (HASPs). These documents are developed and implemented to satisfy regulatory and internal requirements and to ensure that appropriate steps are taken to protect personnel for each task and operation performed at Naval District Washington, Indian Head[1] (NDW,IH) in Indian Head, Maryland. This approach has been effectively used at project sites nationwide and satisfies requirements specified in Occupational Safety and Health Administration (OSHA) 1910.120 Hazardous Waste Operations and Emergency Response (HAZWOPER) standard.

The intent of this guidance document is to summarize the procedures that will be used to develop project-specific HASPs for environmental investigations at NDW,IH. The following information will provide the reader with an overview of this process.

1.0 INTRODUCTION

The introductory section of the project-specific HASP provides/identifies the following:

- Project information including
  - Project name and number
  - Date of preparation
  - Author(s)
  - Reviewer(s)

- A brief description of the intent and scope of the HASP.

- Applicable regulatory requirements as they pertain to the planned activities. Typically referenced are the primary regulatory drivers, which are 29 Code of Federal Regulations (CFR) 1910.120 and applicable sections of 29 CFR 1926 Safety and Health Regulations for the Construction Industry.

- The contractor-specific safety and health program. Safety and health programs provide field personnel with programmatic elements that support the project-specific HASP. Because of the relationship between the HASP and the safety and health programs, both the project-specific HASP

[1] On 1 October 2003, the installation management functions at Indian Head transferred from Indian Head Division/Naval Surface Warfare Center to Naval District Washington. References to this Installation will now be Naval District Washington, Indian Head.

and contractor-specific safety and health program documentation must be maintained at each field activity work site. The safety and health program elements include:

- Hazard analysis
- Standard operating procedures (SOPs)
- Topic-specific written safety and health programs [e.g., hazard communication, hearing conservation, respiratory protection, personal protective equipment (PPE), confined space operations]

- Names of key personnel tasked with the responsibility for implementation of the project-specific HASP. The roles for each of these individuals are typically described in this section. This mechanism also identifies the chain of command for dispute/question resolution.

- The process for addressing modifications to the project-specific HASP, when appropriate. Modification of these documents typically occurs.

  - If new information concerning chemical, physical, and/or natural hazards becomes available. For example, each time a sampling field event is completed, the resulting chemical analytical information should be reviewed to determine if project-specific HASP modifications are appropriate.

  - If the scope of work (or the nature of planned tasks) changes. This would warrant a task-specific hazard analysis as required by the OSHA HAZWOPER regulations.

2.0 EMERGENCY ACTION PLAN

A project Emergency Action Plan (EAP) will be developed and presented as the second section of each project-specific HASP and implemented prior to commencement of any onsite operations. The procedures implemented as part of the EAP will be designed to provide for initial-stage response measures until the incident is declared an emergency.[2] At the Facility, personnel will be directed to

[2] Emergency response or responding to emergencies means a response effort by employees from outside the immediate release area or by other designated responders (i.e., mutual-aid groups, local fire departments, etc.) to an occurrence that results, or is likely to result, in an uncontrolled release of a hazardous substance. Responses to an incidental release of hazardous substances where the substance can be absorbed, neutralized, or otherwise controlled at the time of release by employees in the immediate release area or by maintenance personnel are not considered to be emergency responses within the scope of this standard. Responses to releases of hazardous substances where there is no potential safety or health hazard (i.e., fire, explosion, or chemical exposure) are also not considered to be emergency responses.

evacuate the site in the event of an emergency. Therefore, the EAP will be prepared to meet the requirements in OSHA regulations 29 CFR 1910.38(a) and 29 CFR 1910.120[2] (as reflected below).

Emergency Action Plan for Initial-Stage Response and Site Evacuation

One of the first goals in the implementation of the EAP is coordination with available local emergency response resources. The EAP will provide the process for informing appropriate response organizations (e.g., on/off Facility medical, fire, security, etc.) in the event that their services become necessary. Minimum elements in this section of a HASP include the following:

- Emergency escape procedures and escape route assignments will be designated.
- Procedures will be specified for personnel who must remain on site to operate any critical operations before they evacuate (if appropriate).
- Procedures to account for all personnel following an evacuation.
- Procedures to activate Facility fire, rescue, hazardous materials, and medical units.
- Emergency reporting procedures.
- Names or job titles of persons or departments at the Facility who are to be contacted for additional information or explanations of duties under the EAP.
- Provisions for a site emergency alarm system.
- Training (and re-training) of site personnel in the contents of the EAP.
- Documentation requirements in support of response measures including
    - Chemical inventory/ Material Safety Data Sheets (MSDSs)
    - Medical data sheets

The EAP will also address:

- Emergency recognition and prevention of emergencies at the Facility.
- Safe distances and places of refuge located within the Facility.

- Decontamination procedures.
- Emergency route to Physicians Memorial Hospital or Southern Maryland Hospital.
- PPE and emergency equipment requirements. PPE and emergency equipment are selected as it may apply to initial response measures to the identified potential emergency conditions/situations.
- Contractor injury/illness reporting procedures

3.0 SITE BACKGROUND

Background information will be provided to familiarize field team members with the Facility's history, current mission, and physical features. A description of the Facility, the principal disposal methods for hazardous materials, available results of past monitoring (readings obtained using direct-reading instrumentation such as photoionization detectors, flame ionization detectors, radiation meters, etc.) and/or sampling data (groundwater, soil, air, etc.). Other information found in this section may include the following:

- Previous site-specific investigation information. This includes background, investigation results for each area/site, and information pertaining to previously identified site contaminants

- Site-specific location and unit boundaries.

- Operational status and possible restrictions associated with the current operation.

4.0 SCOPE OF WORK

A detailed description of the specific tasks to be conducted must be included in each project-specific HASP. If this is adequately addressed in a separate document (such as a project-specific Work Plan), it is acceptable for this section of the HASP to present an abbreviated scope of work description with a reference to that other document. OSHA regulatory requirements 1910.120(b)(4)(i) mandate that a HASP must address the potential safety and health hazards for each planned task and operation to be performed.

5.0 TASKS/HAZARDS/ASSOCIATED CONTROL MEASURES SUMMARIZATION

This section will identify the specific tasks to be performed as part of environmental investigations at the Facility. This will include information on the following:

- Anticipated site hazards and procedures for their evaluation
- Appropriate control measures
- Air monitoring requirements

The above information will be presented in a tabular format specifically customized for the conditions and anticipated or foreseeable hazards and specific control measures as they relate to the tasks and possibly site conditions found at the site.

Applicable safe work practices are typically included within this section.

6.0 HAZARD ASSESSMENT

This section provides information concerning chemical, physical, and natural hazards expected to be found at the planned work location. This information must be incorporated into the project-specific HASP and must be organized in a manner that will enable field team members to easily locate pertinent information. The HASP must provide information related to chemical contaminants that have been identified through analysis or suspected to be at the site based on historical data. Specifically, toxicological information, exposure limits, symptoms of exposure, physical properties, and air monitoring/sampling data are presented in this table.

Control measures as they apply to the identified hazards must also be provided within the Hazard Assessment section of the project-specific HASP as stated in OSHA 1910.120(b)(4)(ii)a through j.

7.0 AIR MONITORING

This section of a project-specific HASP identifies the equipment and procedures to be used for personal and area monitoring and sampling. Through the use of monitoring equipment, some potential health and safety hazards may be identified and quantified by onsite personnel. Monitoring the atmosphere in the work area will assist site personnel in the proper selection of engineering controls, safe work practices, and personal protective equipment. This section will also specify situations when air/hazard monitoring must be performed such as:

- When work begins on a different portion of the site.

- When contaminants not previously identified are encountered.

- When a different type of operation is initiated (e.g., drum opening as opposed to exploratory well drilling).

- When employees are handling leaking drums or containers or working in areas with obvious contamination (e.g., a spill or lagoon).

This HASP section addresses the types and frequencies of monitoring and sampling to be performed to evaluate potential hazards for the effective protection of field personnel. When possible and appropriate, specific instrument action levels will be developed and provided in this section. Section 7.0 also provides guidance for the calibration and maintenance of identified equipment.

8.0 TRAINING/MEDICAL SURVEILLANCE REQUIREMENTS

This section will identify employee training requirements necessary to ensure that personnel working at each site are qualified to safely perform their job duties and comply with regulatory requirements. Employees will be permitted to participate in (or supervise) field activities only when they have been adequately trained to the level required by their job function and responsibility. Although training requirements may vary, the following requirements are applicable to personnel performing work at the Facility:

- Initial training (40 hours in duration)
- Site supervision (for site managers and/or supervisors only; 8 hours in duration)
- Annual refresher training (8 hours in duration)
- Actual field experience (for new personnel only; 3 days in duration)
- Site-specific health and safety training (at the initiation of each field activity)
- Daily task-specific health and safety tailgate briefings (with task participants)

Documentation of the dates that each participant attended the training courses will be indicated in the project-specific HASP along with the requirements for maintaining documentation on site. Additional training requirements applicable to the specific project will also be addressed in this section of the HASP. Training required by OSHA for topics such as respiratory protection, powered industrial truck operation, asbestos-related work, confined-space entry, hot work operations, etc. will also be indicated, as appropriate.

Safety briefings procedures are identified and specified in the project-specific HASP for the following situations:

- On a routine or daily basis to delineate safety problems
- When new operations are conducted

- When site or environmental conditions change
- When safety practices are not being followed

Medical Surveillance

In this section, medical surveillance requirements will be identified to specify health monitoring requirements for project participants. Medical data sheets will be collected for all site personnel and will specify the date of the employee's most recent physical examination and other pertinent information such as any known allergies, medical conditions, and physical restrictions. Additionally, restrictions or work limitations may be specified in these employee data sheets as appropriate. In situations where unique contaminants and/or hazards exist, medical surveillance requirements beyond the standard contractor medical examination frequencies and protocols may be specified.

9.0 SITE CONTROL MEASURES

This section will identify appropriate site control procedures for projects conducted at the Facility. Information supplied in this section will include the following:

- Existing site perimeter and/or zone controls including specifications for delineating the needed zones
- Procedures and protective measures for entering/exiting those zones
- Requirements for use of the "buddy system"
- A map of the site
- MSDS procedures
- Communications procedures
- Site visitors access procedures
- Site security
- Use and application of safe work permits
- Provisions for sanitation and break areas, where applicable

10.0 SPILL CONTAINMENT PROGRAM

In this section, the procedures and equipment to be used in isolating and containing spills will be specified. This information includes training, spill prevention and containment, and spill equipment. A spill containment program for the specific site listing notification and response procedures will also be included in this section.

11.0 CONFINED-SPACE ENTRY

This section will define what a confined space is and the prohibitions for entry into such a space. It will also define the notification procedure that must be followed and the procedure for augmenting the project-specific HASP to include confined-space entry operations.

12.0 MATERIALS AND DOCUMENTATION

This section will list the materials that the onsite supervisor is required to keep onsite and how these documents are to be used. This section will also address documents that must be posted at the site.

13.0 GLOSSARY

This section will list important acronyms and site-specific terms relevant to the HASP contents.

CONCLUSION

The project-specific HASP is of vital importance to site personnel in order to maintain a healthful and safe working environment. For this reason, the contractor shall take great care in creating and implementing these documents and also recognize that the project-specific HASP is a dynamic document that must be periodically reviewed and updated when appropriate. The project-specific HASP must comply with the requirements outlined in OSHA 1910.120(b)(4) in order to address all aspects of a comprehensive site plan.

Facility Standard Operating Procedures

for

Installation Restoration Program Environmental Investigations

at

Naval District Washington, Indian Head
Indian Head, Maryland

Engineering Field Activity Chesapeake
Naval Facilities Engineering Command

Contract Number N62467-94-D-0888

Contract Task Order 0805

June 2004

020404/P

FACILITY STANDARD OPERATING PROCEDURES
FOR
INSTALLATION RESTORATION PROGRAM
ENVIRONMENTAL INVESTIGATIONS
AT
NAVAL DISTRICT WASHINGTON, INDIAN HEAD
INDIAN HEAD, MARYLAND

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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1.0 PURPOSE

The purpose of this document is to specify a consistent sample nomenclature system that will facilitate subsequent data management in a cost-effective manner. The sample nomenclature system has been devised such that the following objectives can be attained:

- Sorting of data by matrix.
- Sorting of data by depth.
- Maintenance of consistency (field, laboratory, and data base sample numbers).
- Accommodation of all project-specific requirements.
- Accommodation of laboratory sample number length constraints (maximum of 20 characters).

2.0 SCOPE

The methods described in this procedure shall be used consistently for all projects requiring electronic data.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Program Manager - It shall be the responsibility of the Program Manager (or designee) to inform contract-specific Project Managers of the existence and requirements of this Standard Operating Procedure.

Project Manager - It shall be the responsibility of the Project Manager to determine the applicability of this Standard Operating Procedure based on: (1) program-specific requirements, and (2) project size and objectives. It shall be the responsibility of the Project Manager (or designee) to ensure that the sample nomenclature is thoroughly specified in the relevant project planning document (e.g., sampling and analysis plan) and is consistent with this Standard Operating Procedure if relevant. It shall be the responsibility of the project manager to ensure that the Field Operations Leader is familiar with the sample nomenclature system.

Field Operations Leader - It shall be the responsibility of the Field Operations Leader to ensure that all field technicians or sampling personnel are thoroughly familiar with this Standard Operating Procedure and the project-specific sample nomenclature system. It shall be the responsibility of the Field Operations Leader to ensure that the sample nomenclature system is used during all project-specific sampling efforts.

5.0 PROCEDURES

5.1 Introduction

The sample identification (ID) system can consist of as few as 8 but not more than 20 distinct alpha-numeric characters. The sample ID will be provided to the laboratory on the sample labels and chain-of-custody forms. The basic sample ID provided to the lab has three segments and shall be as follows where "A" indicates "alpha," and "N" indicates "numeric":

A or N 3- or 4-Characters	AAA 2- or 3-Characters	A or N 3- to 6-Characters
Site Identifier	Sample Type	Sample Location

Additional segments may be added as needed. For example:

(1) Soil and Sediment Sample ID

A or N 3- or 4-Characters	AAA 2- or 3-Characters	A or N 3- to 6-Characters	NNNN 4-Characters
Site Identifier	Sample Type	Sample Location	Sample Depth

(2) Aqueous (groundwater or surface water) Sample ID

A or N 3- or 4-Characters	AAA 2- or 3-Characters	A or N 3- to 6-Characters	NN 2-Characters	-A
Site Identifier	Sample type	Sample Location	Round Number	Filtered Sample only

(3) Biota Sample ID

A or N 3- or 4-Characters	AAA 2- or 3-Characters	A or N 3- to 6-Characters	AA 2-Characters	NNN 3-Characters
Site Identifier	Sample Type	Sample Location	Species Identifier	Sample Group Number

5.2 Sample Identification Field Requirements

The various fields in the sample ID will include but are not limited to the following:

- Site Identifier
- Sample Type
- Sample Location
- Sample Depth
- Sampling Round Number
- Filtered
- Species Identifier
- Sample Group Number

The site identifier must be a three- or four-character field (numeric characters, alpha characters, or a mixture of alpha and numeric characters may be used). A site number is necessary since many facilities/sites have multiple individual sites, SWMUs, operable units, etc. Several examples are presented in Section 5.3 of this SOP.

The sample type must be a two- or three-character alpha field. Suggested codes are provided in Section 5.3 of this SOP.

The sample location must be at least a three-character field but may have up to six-characters (alpha, numeric, or a mixture). The six-characters may be useful in identifying a monitoring well to be sampled or describing a grid location.

The sample depth field is used to note the depth below ground surface (bgs) at which a soil or sediment sample is collected. The first two numbers of the four-number code specify the top interval, and the third and fourth specify the bottom interval in feet bgs of the sample. If the sample depth is equal to or greater than 100, then only the top interval would be represented and the sampling depth would be truncated to

three-characters. The depths will be noted in whole numbers only; further detail, if needed, will be recorded on the sample log sheet, boring log, logbook, etc.

A two-digit round number will be used to track the number of aqueous samples taken from a particular aqueous sample location. The first sample collected from a location will be assigned the round identifier 01, the second 02, etc. This applies to both existing and proposed monitoring wells and surface water locations.

Aqueous samples that are field filtered (dissolved analysis) will be identified with an "-F" in the last field segment. No entry in this segment signifies an unfiltered (total) sample.

The species identifier must be a two-character alpha field. Several suggested codes are provided in Section 5.3 of this SOP.

The three digit sample group number will be used to track the number of biota sample groups (a particular group size may be determined by sample technique, media type, the number of individual caught, weight issues, time, etc.) by species and location. The first sample group of a particular species collected from a given location will be assigned the sample group number 001 and the second sample group of the same species collected from the same location will be assigned the sample group number 002.

5.3 Example Sample Field Designations

Examples of each of the fields are as follows:

Site Identifier - Examples of site numbers/designations are as follows:

A01 - Area of Concern Number 1
125 - Solid Waste Management Unit Number 125
000 - Base or Facility Wide Sample (e.g., upgradient well)
BBG - Base Background

The examples cited are only suggestions. Each Project Manager (or designee) must designate appropriate (and consistent) site designations for their individual project.

Sample Type - Examples of sample types are as follows:

AH - Ash Sample
AS - Air Sample
BM - Building Material Sample
BSB - Biota Sample Full Body
BSF - Biota Sample Fillet
CP - Composite Sample
CS - Chip Sample
DS - Drum Sample
DU - Dust Sample
FP - Free Product
IDW - Investigation Derived Waste Sample
LT - Leachate Sample
MW - Monitoring Well Groundwater Sample
OF - Outfall Sample
RW - Residential Well Sample
SB - Soil Boring Sample
SD - Sediment Sample
SC - Scrape Sample

SG - Soil Gas Sample
SL - Sludge Sample
SP - Seep Sample
SS - Surface Soil Sample
ST - Storm Sewer Water Sample
SW - Surface Water Sample
TP - Test Pit Sample
TW - Temporary Well Sample
WC - Well Construction Material Sample
WP - Wipe Sample
WS - Waste/Solid Sample
WW - Wastewater Sample

Sample Location - Examples of the location field are as follows:

001 - Monitoring Well 1
N32E92 - Grid location 32 North and 92 East
D096 - Investigation derived waste drum number 96

Species Identifier - Examples of species identifier are as follows:

BC - Blue Crab
GB - Blue Gill
CO - Corn
SB - Soybean

5.4 Examples of Sample Nomenclature

The first round monitoring well groundwater sample collected from existing monitoring well 001 at SWMU 16 for a filtered sample would be designated as 016MW00101-F.

The second round monitoring well groundwater sample collected from existing monitoring well C20P2 at Site 23 for an unfiltered sample would be designated as 023MWC20P202.

The second surface water sample collected from point 01 at SWMU 130 for an unfiltered sample would be designated as 130SW00102.

A surface soil sample collected from grid location 32 North and 92 East at Site 32 at the 0- to 2-foot interval would be designated as 032SSN32E920002.

A subsurface soil sample from soil boring 03 at SWMU 32 at an interval of 4 to 5 feet bgs would be designated as 032SB0030405.

A sediment sample collected at SWMU 19 from 0 to 6 inches at location 14 would be designated as 019SD0140001. The sample data sheet would reflect the precise depth at which this sample was collected.

During biota sampling for full body analysis the first time a minnow trap was checked at grid location A25 of SWMU 1415 three small blue gills were captured, collected and designated with the sample ID of 1415BSBA25BG001. The second time blue gill were collected at the same location (grid location A25 at SWMU 1415) the sample ID designation given was 1415BSBA25BG002.

Note: No dash (-) or spacing is used between the segments with the exception of the filtered segment. The "F" used for a filtered aqueous sample is preceded by a dash "-F".

5.5 Field Quality Assurance/Quality Control (QA/QC) Sample Nomenclature

Field QA/QC will be designated using a different coding system. The QC code will consist of a three- to four-segment alpha-numeric code that identifies the sample QC type, the date the sample was collected, and the number of this type of QC sample collected on that date.

AA	NNNNNN	NN	-F
QC Type	Date	Sequence Number (per day)	Filtered (aqueous only, if needed)

The QC types are identified as:

TB = Trip Blank
RB = Rinsate Blank (Equipment Blank)
FD = Field Duplicate
AB = Ambient Conditions Blank
WB = Source Water Blank

The sampling time recorded on the Chain-of-Custody Form, labels, and tags for duplicate samples will be 0000 so that the samples are "blind" to the laboratory. Notes detailing the sample number, time, date, and type will be recorded on the routine sample log sheets and will document the location of the duplicate sample (sample log sheets are not provided to the laboratory). Documentation for all other QC types (TB, RB, AB, and WB) will be recorded on the QC Sample Log sheet (see SOP on Field Documentation).

5.6 Examples of Field QA/QC Sample Nomenclature

The first duplicate of the day for a filtered ground water sample collected on June 3, 2000 would be designated as FD06030001-F.

The third duplicate of the day taken of a subsurface soil sample collected on November 17, 2003 would be designated as FD11170303.

The first trip blank associated with samples collected on October 12, 2000 would be designated as TB10120001.

The only rinsate blank collected on November 17, 2001 would be designated as RB11170101.

6.0 DEVIATIONS

Any deviation from this SOP must be addressed in detail in the site specific planning documents.

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A SITE RECONNAISSANCE CHECKLIST 6

1.0 PURPOSE

The purpose of a site reconnaissance is to collect both general and technical information which will support the scoping, scheduling, implementing project activities, and writing reports for an environmental investigation. This procedure is not intended as a guide for Phase I investigations or for Environmental Baseline Survey activities.

2.0 SCOPE

This procedure is applicable to the performance of a site reconnaissance for initial site characterization. The steps necessary to develop and carry out a site reconnaissance are presented here. These steps include a list of equipment and items which may be needed, areas of special interest during field observations, and methods by which the field observation team can ensure that necessary and appropriate observations have been made.

3.0 GLOSSARY

Site reconnaissance. An onsite inspection program used to identify site-specific conditions that control scheduling, manpower, and affect costs. A site reconnaissance usually consists of visual observations and, often, the use of field monitoring instruments to identify potential health and safety threats and potential sampling locations for site evaluation during subsequent field investigations.

4.0 RESPONSIBILITIES

Field Operations Leader (FOL) is responsible for ensuring that the survey is carried out in sufficient detail. To accomplish this, the FOL must assign the proper personnel and equipment to characterize the site adequately, in accordance with the requirements defined in this procedure and best engineering practices. Other disciplines which may be applicable include (but are not limited to): Geology/Hydrogeology; Health and Safety; Ecological Specialists; and/or Engineering. In addition, the FOL is responsible for supervising equipment preparation, including necessary calibrations, and supervising field data collection and documentation in accordance with the methods described in all referenced standard operation procedures.

Project Manager is responsible for the following:

- Supervising the retrieval and examination of available, applicable information regarding the site.
- Obtaining appropriate program approvals and ensuring the preparation of a site Health and Safety plan for the site reconnaissance.
- Coordinating the field activities with facility personnel and other Navy and regulatory personnel, as applicable.

Field Personnel are primarily responsible for observing and documenting, either through written documentation or photographic evidence, the site reconnaissance. Field personnel will take direction from the FOL.

5.0 PROCEDURES

5.1 Equipment Items/Needed

Below is a list of items that may be useful when conducting a site reconnaissance. All, or a portion of these items may be required, depending upon the objective of the site reconnaissance.

- Health and Safety equipment and information as required by the Site Safety Officer.
- Maps (U.S.G.S. quadrangle, geologic maps, street and highway maps, and client facility maps).
- Geologic tools (compass, tape measure, hand level, digital camera, etc.).
- Physical monitoring equipment, if applicable (PID, Immunoassay Test Kits, etc.)
- Regional publications (U.S.G.S reports, water well surveys, U.S.D.A. soil conservation surveys, etc.).
- Site-specific publications by previous investigators (EPA aerial photographic analyses, remedial investigation reports, data on waste disposal practices, boring logs, etc.).
- Marking items (ink markers, surveyor's flagging, spray paint, pin flags, wooden stakes).
- Field notebooks.
- Local telephone book with yellow pages (for obtaining utilities, site trailer, living accommodations, etc.).

Sufficient time will be required in order to obtain some of the aforementioned material. In general, most publications can be obtained in time to be used in the site reconnaissance if ordered approximately 2 weeks before the actual site visit takes place.

5.2 Observations

A site reconnaissance usually requires one to two days, however, additional time may be needed depending upon the objective, site size, etc. The following observations, when applicable, should be documented either on a site map, field notebook, or photographed.

- General Site Access. It should be noted whether site roads provide access to all proposed work locations, or if it will be necessary to prepare access roads with either a backhoe, dozer, chain saws, etc., in order to get drill rigs, excavators, or other work vehicles to specific locations. If temporary driveways must be constructed from existing public roads, regulatory permits may be required. Military facilities may have specific security requirements which require detailed clearance procedures.
- Location of the Command Post or Site Trailer and Sanitary Facilities. The ideal location for the site trailer and sanitary facilities is a level area, within an uncontaminated zone, and centralized in order to provide easy access to work areas on the site. However, certain utility companies may require that the site trailer be placed within a specified radius (usually 100 feet), of the nearest utility pole. Contact the necessary utility companies and inquire about the requirements regarding service before conducting the site reconnaissance. Information that may be required by the utility companies is: type of electric service needed (inquire with trailer vendor for this information); and utility pole number of interest (pole numbers are usually stamped on a brass plate on the pole).

- Potable Water Sources. Local fire departments may allow access to fire hydrants. Private water delivery companies may also be available in the area.

- Sources of Possible Contamination. Drums, tanks, sludge areas, areas of stressed vegetation, fill areas, and leachate seeps may indicate where sources of contamination exist. Filler pipes protruding from the ground surface may indicate the presence of underground storage tanks. Areas where the original ground surface has been reworked may be contaminated fill areas that have since been buried and covered with natural material. Previous environmental investigations may also identify source areas.

- Location of Decon Areas and Storage/Disposal Areas for Equipment and Wastes Generated by Field Activities.

- Locations of Surface Water Bodies. The locations of surface water bodies, both man-made and natural, and their relation to topographic highs may give an indication of the groundwater flow direction in the area (groundwater flow typically follows topography with the topographic highs serving as groundwater recharge areas, and the surface waters at topographic lows serve as groundwater discharge areas). Visible signs of contamination, the existence of aquatic life, flow rates, and approximate levels should also be observed and noted. Check if the surface water bodies could potentially be impacted by field activities. If so, appropriate sedimentation and erosion controls will be required.

- Existing Wells. Existing monitoring wells, or domestic wells within the site and off site, should be noted on a map, and access checked to see if the wells can be used for data collection.

- Outcrops. Outcrops can be useful in providing hydrogeologic data (lithologic description, strike and dip information, fracture and joint system analysis, identification of moist zones, etc.) Outcrops may occur naturally or be a part of a man-made feature such as a road-cut.

- Lineaments. A lineament is a straight lengthy feature on the earth's surface which is expressed topographically as a line of depression. Stream beds, vegetation patterns or soil characteristics may be aligned or controlled by this feature. Lineaments are due in some cases to the presence of intense jointing or faults beneath the ground surface. Groundwater in the bedrock may follow lineaments. Lineaments should be noted on site maps and described in the field notebooks.

- Bench or Property Markers. Benchmarks or property markers should be marked with paint or surveyor's flagging if encountered during a site reconnaissance. Surveyors may need to use these markers as a reference point when surveying. Benchmarks are typically a brass plate secured in concrete in the ground with numbering on the top. Property markers can range from a stake driven into the ground to a rock protruding from the ground surface. Facility contacts may also be aware of local benchmarks used during the course of other environmental or public work projects.

- Metal Cultural Effects. Overhead power lines, railroad tracks, junk automobiles, fences, etc. will greatly affect certain geophysical surveys. These features should be noted while conducting a site reconnaissance.

6.0 RECORDS

The data collected during a site reconnaissance will be compiled into a trip report when returning from the field. This trip report can then be distributed to the project team. A site reconnaissance checklist is located in Attachment A which can be copied and used while conducting the site reconnaissance.

ATTACHMENT A

SITE RECONNAISSANCE CHECKLIST

SITE SKETCH

Include the following as appropriate:

- Site name
- Site location
- Site boundaries
- Entrance locations
- Access roads and security requirements
- Disposal locations
- Storage areas
- Office areas
- Well locations
- Treatment facility locations
- Surface drainage, outcrops, general topography descriptions
- Cultural interferences
- Fences
- Aboveground utilities

CHEMICAL STORAGE FACILITIES DESCRIPTION

- Storage tanks - numbers, volumes, condition, contents, etc.
- Drums - number, conditions, labeling, etc.
- Lagoons and surface pits - number, size, use of liner, contents, etc.

TREATMENT SYSTEMS

Note the presence of any treatment systems. These can be difficult to evaluate visually. One should appraise general appearance, maintenance and visual integrity; ask operators for any monitoring records; note presence of odors; and visually characterize any effluents or residues. Describe type of wastes and volumes treated.

- Incinerators
- Flocculation/filtration
- Chemical/physical treatment
- Biological treatment
- Volume reduction
- Waste recycling
- Compositing
- Other

ATTACHMENT A
SITE RECONNAISSANCE CHECKLIST
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DISPOSAL FACILITIES

Note the presence and use of any of the following operations. Include a description of the size, use of liners, soil type, and the presence of leachate. Provide a description of management practices. Interview site workers if possible. Describe waste types.

- Landfills
- Land forms
- Open dump
- Surface impoundment
- Underground injection
- Incineration

Also, records for disposal of concentrated/containerized waste should be reviewed.

HAZARDOUS SUBSTANCE CHARACTERISTICS

Ask facility contacts for manifests, inventories, or monitoring reports. Note markings on containers.

- Chemical identities
- Quantities
- Hazard characteristics (toxic, explosive, flammable, etc.)
- Container markings
- Monitoring data, other analytical data
- Physical state (liquid, solid, gas, sludge)

CHEMICAL PROCESS INFORMATION

- Manufacturing processes and chemicals
- Off-specification or by-product disposal processes
- Housekeeping practices
- Locations of plant operations

ATTACHMENT A
SITE RECONNAISSANCE CHECKLIST
PAGE THREE

HYDROGEOLOGIC ASSESSMENT

Look for situations that promote hazardous substance migration, i.e., porous soils, fractured bedrock formations, shallow water table and karst features.

- Soil type
- Surface water features
- Surface drainage pattern
- Outcrop studies
- Water wells (use, water depth, and construction details)
- Erosion potential
- Flooding potential
- Climatology

IDENTIFICATION OF SENSITIVE RECEPTORS

- Number and locations of private homes
- Public buildings including tenant usage
- Areas of dead or dying vegetation or animals
- Presence of sensitive ecosystems (wetlands, tidal marshes, etc.)
- Other public use areas (roads, parks, etc.)
- Natural areas

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B GROUNDWATER LEVEL MEASUREMENT SHEET 9

1.0 PURPOSE

The purpose of this procedure is to provide reference information regarding the proper methods for evaluating the physical condition and project utility of existing monitoring wells and determining water levels.

2.0 SCOPE

The procedures described herein are applicable to all existing monitoring wells and, for the most part, are independent of construction materials and methods.

3.0 GLOSSARY

Hydraulic Head - The height to which water will rise in a well.

Water Table - A surface in an unconfined aquifer where groundwater pressure is equal to atmospheric pressure (i.e., the pressure head is zero).

4.0 RESPONSIBILITIES

Site Geologist/Hydrogeologist - Has overall responsibility for the evaluation of existing wells, obtaining water level measurements and developing groundwater contour maps. The site geologist/hydrogeologist (in concurrence with the Project Manager) shall specify the reference point from which water levels are measured (usually a specific point on the upper edge of the inner well casing), the number and location of data points which shall be used for constructing a contour map, and how many complete sets of water levels are required to adequately define groundwater flow directions (e.g., if there are seasonal variations).

Field Personnel - Must have a basic familiarity with the equipment and procedures involved in obtaining water levels and must be aware of any project-specific requirements or objectives.

5.0 PROCEDURES

Accurate, valid and useful groundwater monitoring requires that four important conditions be met:

- Proper characterization of site hydrogeology.
- Proper design of the groundwater monitoring program, including adequate numbers of wells installed at appropriate locations and depths.
- Satisfactory methods of groundwater sampling and analysis to meet the project data quality objectives (DQOs).
- The assurance that specific monitoring well samples are representative of water quality conditions in the monitored interval.

To insure that these conditions are met, adequate descriptions of subsurface geology, well construction methods and well testing results must be available. The following steps will help to insure that the required data are available to permit an evaluation of the utility of existing monitoring wells for collecting additional samples.

5.1 Preliminary Evaluation

A necessary first step in evaluating existing monitoring well data is the study and review of the original work plan for monitoring well installation (if available). This helps to familiarize the site geologist/hydrogeologist with site-specific condition, and will promote an understanding of the original purpose of the monitoring wells.

The next step of the evaluation should involve a review of all available information concerning borehole drilling and well construction. This will allow interpretation of groundwater flow conditions and area geology, and will help to establish consistency between hydraulic properties of the well and physical features of the well or formation. The physical features which should be identified and detailed, if available, include:

- The well identification number, permit number and location by referenced coordinates, the distance from prominent site features, or the location of the well on a map.
- The installation dates, drilling methods, well development methods, past sampling dates, and drilling contractors.
- The depth to bedrock -- where rock cores were not taken, auger refusal, drive casing refusal or penetration test results (blow counts for split-barrel sampling) may be used to estimate bedrock interface.
- The soil profile and stratigraphy.
- The borehole depth and diameter.
- The elevation of the top of the protective casing, the top of the well riser, and the ground surface.
- The total depth of the well.
- The type of well materials, screen type, slot size, and length, and the elevation/depths of the screen, interval, and/or monitored interval.
- The elevation/depths of the tops and bottom of the filter pack and well seals and the type and size.

5.2 Field Inspection

During the onsite inspection of existing monitoring wells, features to be noted include:

- The condition of the protective casing, cap and lock.
- The condition of the cement seal surrounding the protective casing.
- The presence of depressions or standing water around the casing.
- The presence of and condition of dedicated sampling equipment.
- The presence of a survey mark (e.g., a notch) on the inner well casing.

If the protective casing, cap and lock have been damaged or the cement collar appears deteriorated, or if there are any depressions around the well casing capable of holding water, surface water may have infiltrated into the well. This may invalidate previous sampling results unless the time when leakage started can be precisely determined.

The routine physical inspection must be followed by a more detailed investigation to identify other potential routes of contamination or sampling equipment malfunction. Any of these occurrences may invalidate

previously-collected water quality data. If the monitoring well is to be used in the future, considerations shown in the steps described above should be rectified to rehabilitate the well.

After disconnecting any wires, cables or electrical sources, remove the lock and open the cap. Check for the presence of organic vapors with a photoionization detector (PID) or flame-ionization detector (FID) to determine the appropriate worker safety level. The following information should be noted:

- Cap function.
- Physical characteristics and composition of the inner casing or riser, including inner diameter and annular space.
- Presence of grout between the riser and outer protective casing and the existence of drain holes in the protective casing.
- Presence of a riser cap, method of attachment to casing, and venting of the riser.
- Presence of dedicated sampling equipment; if possible, remove such equipment and inspect size, materials of construction and condition.

The final step of the field inspection is to confirm previous hydraulic or physical property data and to obtain data not previously available. This includes the determination of static water levels, total well depth and well obstruction. This may be accomplished using a weighted tape measure which can also be used to check for sediment (the weight will advance slowly if sediment is present, and the presence of sediment on the weight upon removal should be noted). If sediment is present and/or the well has not been sampled in 12 or more months, it should be redeveloped before sampling.

Lastly, as a final step, the location, condition and expected water quality of the wells should be reviewed in light of their usefulness for the intended purpose of the investigation.

See Attachment A, Monitoring Well Inspection Sheet.

5.3 Water Level (Hydraulic Head) Measurements

5.3.1 General

Groundwater level measurements can be made in monitoring wells, private or public water wells, piezometers, open boreholes, or test pits (after stabilization). Groundwater measurements should generally not be made in boreholes with drilling rods or auger flights present. If groundwater sampling activities are to occur, groundwater level measurements shall take place prior to well purging or sampling.

All groundwater level measurements shall be made to the nearest 0.01 foot, and recorded in the site geologist/hydrogeologist's field notebook or on the Groundwater Level Measurement Sheet (Attachment B), along with the date and time of the reading. The total depth of the well shall be measured and recorded, if not already known. Weather changes that occur over the period of time during which water levels are being taken, such as precipitation and barometric pressure changes, should be noted.

In measuring groundwater levels, there shall be a clearly-established reference point of known elevation, which is normally identified by a mark (e.g., a notch) on the upper edge of the inner well casing. To be useful, the reference point should be tied in with an established USGS benchmark or other properly surveyed elevation datum. An arbitrary datum could be used for an isolated group of wells, if necessary.

Cascading water within a borehole or steel well casings can cause false readings with some types of sounding devices (chalked line, electrical). Oil layers may also cause problems in determining the true water level in a well. Special devices (interface probes) are available for measuring the thickness of oil layers and true depth to groundwater, if required.

Water level readings shall be taken regularly, as required by the site geologist/hydrogeologist. Monitoring wells or open-cased boreholes that are subject to tidal fluctuations should be read in conjunction with a tidal chart (or preferably in conjunction with readings of a tide staff or tide level recorder installed in the adjacent water body); the frequency of such readings shall be established by the site hydrogeologist. All water level measurements at a site used to develop a groundwater contour map shall be made in the shortest practical time to minimize affects due to weather changes.

5.3.2 Water Level Measuring Techniques

There are several methods for determining standing or changing water levels in boreholes and monitoring wells. Certain methods have particular advantages and disadvantages depending upon well conditions. A general description of these methods is presented, along with a listing of various advantages and disadvantages of each technique. An effective technique shall be selected for the particular site conditions by the site geologist/hydrogeologist.

In most instances, preparation of accurate potentiometric surface maps requires that static water level measurements be obtained to a precision of 0.01 feet. To obtain such measurements in individual accessible wells, electrical water level indicator methods have been found to be best, and thus should be utilized whenever possible when precision is required (e.g., synoptic water level measurements for defining potentiometric surfaces). Other, less precise methods, such as the popper or bell sound, or bailer line methods, should be avoided when precision is required, but may be suitable when used to establish approximate water depths for purging and sampling purposes. When a large number of (or continuous) readings are required, time-consuming individual readings are not usually feasible. In such cases, it is best to use a pressure transducer.

5.3.3 Methods

Water levels can be measured by several different techniques, but the same steps shall be followed in each case. The proper sequence is as follows:

1. Check operation of recording equipment above ground. Prior to opening the well, don personal protective equipment, as required. Never remove an air-tight lock (such as a J-plug) with your face over the well. Pressure changes within the well may explosively force the cap off once loosened.

2. Record all information specified below in the geologist/hydrogeologist's field notebook or on the Groundwater Level Measurement Sheet (Attachment B):

   - Well number.
   - Water level (to the nearest 0.01 foot). Water levels shall be taken from the surveyed reference mark (e.g., notch) on the top edge of the inner well casing. If the J-plug was on the well very tightly, it may take several minutes for the water level to stabilize.
   - Time and day of the measurement.
   - Thickness of free product if present.

Water level measuring devices with permanently marked intervals shall be used. The devices shall be free of kinks or folds which will affect the ability of the equipment to hang straight in the well pipe.

5.3.4 Water Level Measuring Devices

Electric Water Level Indicators

These are the most commonly used devices and consist of a spool of small-diameter cable and a weighted probe attached to the end. When the probe comes in contact with the water, an electrical circuit is closed and a meter, light, and/or buzzer attached to the spool will signal the contact.

There are a number of commercial electric sounders available, none of which is entirely reliable under all conditions likely to occur in a contaminated monitoring well. In conditions where there is oil on the water, groundwater with high specific conductance, water cascading into the well, steel well casing, or a turbulent water surface in the well, measuring with an electric sounder may be difficult.

For accurate readings, the probe shall be lowered slowly into the well adjacent to the survey mark on the inner well casing. The electric tape is read (to the nearest 0.01 ft.) at the measuring point and recorded where contact with the water surface was indicated.

Popper or Bell Sounder

A bell- or cup-shaped weight that is hollow on the bottom is attached to a measuring tape and lowered into the well. A "plopping" or "popping" sound is made when the weight strikes the surface of the water. An accurate reading can be determined by lifting and lowering the weight in short strokes, and reading the tape when the weight strikes the water. This method is not sufficiently accurate to obtain water levels to 0.01 feet, and thus is more appropriate for obtaining only approximate water levels quickly.

Pressure Transducer

Pressure transducers can be lowered into a well or borehole to measure the pressure of water and therefore the water elevation above the transducer. The transducer is wired into a recorder at the surface to record changes in water level with time. The recorder digitizes the information and can provide a printout or transfer the information to a computer for evaluation (using a well drawdown/recovery model). The pressure transducer should be initially calibrated with another water level measurement technique to ensure accuracy. This technique is very useful for hydraulic conductivity testing in highly permeable material where repeated, accurate water level measurements are required in a very short period of time. A sensitive transducer element is required to measure water levels to 0.01 foot accuracy.

Borehole Geophysics

Approximate water levels can be determined during geophysical logging of the borehole (although this is not the primary purpose for geophysical logging and such logging is not cost effective if used only for this purpose). Several logging techniques will indicate water level. Commonly-used logs which will indicate saturated/unsaturated conditions include the spontaneous potential (SP) log and the neutron log.

5.3.5 Data Recording

Water level measurements, time, data, and weather conditions shall be recorded in the geologist/hydrogeologist's field notebook or on the Groundwater Level Measurement Sheet. All water level measurements shall be measured from a known reference point. The reference point is generally a marked point on the upper edge of the inner well casing that has been surveyed for an elevation. The exact reference point shall be marked with permanent ink on the casing since the top of the casing may not be entirely level. It is important to note changes in weather conditions because changes in the barometric pressure may affect the water level within the well.

5.3.6 Specific Quality Control Procedures for Water Level Measuring Devices

All groundwater level measurement devices must be cleaned before and after each use to prevent cross contamination of wells. See Section 5.4 regarding decontamination of water level measuring equipment. Some devices used to measure groundwater levels may need to be calibrated. These devices shall be calibrated to 0.01 foot accuracy and any adjustments/corrections shall be recorded in the field logbook/notebook. After the corrections/adjustments are made to the measuring device and entered in the field logbook/notebook, the corrected readings shall be entered onto the Groundwater Level Measurement Sheet (Attachment B). Elevations will be entered on the sheet when they become available.

5.4 Equipment Decontamination

All portions of a device which projects down the well casing must be decontaminated prior to advancing to the next well. Manufacturer's instructions for equipment decontamination should be followed. Variations from the manufacturer's requirements may be implemented based on the project objectives, but they must be defined prior to conducting any field activities. Consult the project planning documents and SA-7.1 Decontamination of Field Equipment.

5.5 Health and Safety Considerations

Groundwater contaminated by volatile organic compounds may release toxic vapors into the air space inside the well pipe. The release of this air when the well is initially opened is a health/safety hazard which must be considered. Initial monitoring of the well headspace and breathing zone concentrations using a PID or FID shall be performed to determine required levels of protection. Under certain conditions, air-tight well caps may explosively fly off the well when the pressure is relieved. Never stand directly over a well when uncapping it.

6.0 RECORDS

A record of all field procedures, tests and observations must be recorded in the site logbook or designated field notebook. Entries in the log/notebook should include the individuals participating in the field effort, and the date and time. The use of annotated sketches may help to supplement the evaluation.

ATTACHMENT A
MONITORING WELL INSPECTION SHEET

Monitoring Well Inspection Sheet

Project Name: _____ Date: _____

Location: _____ Time: _____

Tidally Influenced: Y / N Personnel: _____

Field Measurements				
Well ID	PID Reading PPM	Depth to Water *	Total Depth *	Flush Mt./ Stick-up

Well Construction Details (Taken from construction logs)		
Total Depth *	Ground Elev.	Top/Btm Screen *

Check List:

Riser Pipe Material:
Riser Notched for Surveyors:
Well ID Tag In-place:
Well security:
Photo taken:

Condition of Well:

Protective Case:
Riser:
Well Pad:
Other:

Presence/Evidence of:

Standing Water Around Well:
Existing Sampling Equipment:
Sediment build-up in Well Btm:

Comments:

** = Measurements are from the top of the inner case to the nearest 0.01'*

ATTACHMENT B
GROUNDWATER LEVEL MEASUREMENT SHEET

Tetra Tech NUS, Inc.

GROUNDWATER LEVEL MEASUREMENT SHEET

Project Name: _____ **Project No.:** _____
Location: _____ **Personnel:** _____
Weather Conditions: _____ **Measuring Device:** _____
Tidally Influenced: Yes ___ No ___ **Remarks:** _____

Well or Piezometer Number	Date	Time	Elevation of Reference Point (feet)*	Water Level Indicator Reading (feet)*	Thickness of Free Product (feet)*	Comments

* All measurements to the nearest 0.01 foot, from surveyed mark (unless noted)

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A DRILLING EQUIPMENT SIZES 19

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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 to collecting surface and subsurface soil samples, and obtaining rock core samples for lithologic and hydrogeologic evaluation, excavation/foundation design, remedial alternative design and related civil engineering purposes.

3.0 GLOSSARY

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 alternative to conventional coring, this technique 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, the Project Manager is responsible for evaluating the drilling requirements for the site and specifying drilling techniques that will be successful given the study objectives and the known or suspected geologic conditions at the site. The Project Manager also determines the disposal methods for 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.

Field Operations Leader (FOL) - The FOL is responsible for the overall supervision and scheduling of drilling activities, and is strongly supported by the project geologist.

Project Geologist - The project geologist is responsible for ensuring 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 SOPs SA-6.3 and GH-1.5). 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 and/or Sampling and Analysis Plan.

Drilling Subcontractor - Operates under the supervision of the FOL. 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 FOL within 24 hours of determination, and must provide advance written notification of any changes in field procedures, describing and justifying such changes. No such changes shall be made unless requested and authorized in writing by the FOL (with the concurrence of the Project Manager). Depending on the subcontract, the Project Manager may need to obtain written authorization from appropriate administrative personnel before approving any changes.

The drilling subcontractor is responsible for following decontamination procedures specified in the project plan documents. Upon completion of the work, the driller is 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 between samples and borings using appropriate decontamination procedures as outlined in SOP SA-7.1. 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 site geologist as they proceed (see SOPs SA-6.3 and GH-1.5). 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, although the site 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, the waste conditions at the site, and reviewing the purpose of drilling 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 Hollow-Stem Auger Drilling

This method of drilling consists of rotating 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 requires 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) 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 may be the prime objective of the borehole construction). With this in mind, the preferred order of choice of drilling method after hollow-stem augering (HSA) is:

- Drill-through casing drive
- Jet drilling
- Hand auger

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 guidelines established in SOP SA-1.3 shall also be followed. 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.

The hollow-stem auger may be used without the plug when boring for geotechnical examination or for well installation. However, 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 drilling configuration 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 SOP GH-2.8 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).

At the option of the Field Operations Leader (in communication with the Project Manager), 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 penetrate only the water table aquifer, since loose soil backfill in the boring may still provide a preferred pathway for surface liquids to reach the water table. Backfilling requirements may also be driven by state or local regulations.

5.2.2 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 SOP 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 within which wash water is used and in which the casing is driven must be clearly 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).

5.2.3 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 this method has also been used to install 3- to 4-inch-diameter casings to a depth of 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.
- 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.

5.2.4 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 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 project plan documents. 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). These techniques are slow but effective where larger pieces of equipment do not have access, and where very shallow holes are desired (less than 15 feet). Surficial soils must be composed of relatively soft and non-cemented formations to allow penetration by the auger.

5.2.5 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 of 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 project plans. 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.

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.

5.2.6 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.

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 dismounted tripod. The skid is pushed, dragged, or winched (using the cathead drum) between boring locations.

- Small truck-mounted drilling equipment using 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 vehicles 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 include:

  - 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.

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.

5.2.7 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 commonly manufactured in sizes ranging from 2 inches to 3-1/2 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 project plan documents.

5.2.8 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:

Drilling Method	Average Daily Progress (linear feet)
Hollow-stem augers	75'
Solid-stem augers	50'
Mud-Rotary Drilling	100' (cuttings samples)
Rotosonic Drilling	100'-160' (continuous core)
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 5.2.10, except that larger casing is used) or by using a driven-casing method (see Section 5.2.6 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 ensure 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 of 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.

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 clean out 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 as to 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 site geologist measure the "stickup" of the drill string. This is accomplished by 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 measuring 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 of 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 SOP GH-2.8. 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 Project Manager. The specific slurry composition and the concentration of suspected contaminants 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 by the judgment of the site geologist and noted in the site logbook, and only after approval by the Project 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 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.

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.

Surface protocols for various soil sampling techniques are discussed in SOP SA-1.3. Continuous-core soil sampling and rock coring are discussed below. 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.

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. Rotosonic drilling methods also provide a continuous soil sample.

5.7 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. Rock coring can, however, proceed for thousands of feet continuously, depending on the size of the drill rig, and 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. Down hole 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 Figure 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).

FIGURE 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	0.735
EWT	1 1/2	29/32	1.470	0.905
EX, EXL, EWG, EWM	1 1/2	13/16	1.470	0.845
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 ___|___/	1 7/8	1	1.875	1.000
BX Wire line ___|___/	2 3/8	1 7/16	2.345	1.437
NX Wire line ___|___/	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.

FIGURE 1
STANDARD SIZES OF CORE BARRELS AND CASING
PAGE TWO

Size Designations			Casing Coupling					Approximate Core Diameter	
Casing; Casing coupling; Casing bits; Core barrel bits	Rod; rod couplings	Casing O.D., Inches	O.D., Inches	I.D., Inches	Casing bit O.D., Inches	Core barrel bit O.D., Inches*	Drill rod O.D., Inches	Normal, Inches	Thinwall, Inches
RX	RW	1.437	1.437	1.188	1.485	1.160	1.094	---	0.735
EX	E	1.812	1.812	1.500	1.875	1.470	1.313	0.845	0.905
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	Flush Joint	No Coupling	1.485	1.160	1.094	---	0.735
EW	EW	1.812			1.875	1.470	1.375	0.845	0.905
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 __|__\	---	---	---	---	1.875	1.750	1.000	---
---	BX __|__\	---	---	---	---	2.345	2.250	1.437	---
---	NX __|__\	---	---	---	---	2.965	2.813	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.

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

5.7.1 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-barrel sampler shall be considered an indication that soil sampling methods may not be applicable and that coring may be necessary to obtain samples.

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, leveling 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); sample soils per SOP SA-1.3. 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 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.

5.7.2 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 SOP GH-1.5. 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 designating 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 Project 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 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. 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.

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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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.

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.

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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 on site, 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 hydrochloric acid (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 (Figure 1) or in a field notebook if more space is needed. Details on filling out the boring log are discussed in Section 5.5.

FIGURE 1
BORING LOG (EXAMPLE)

BORING LOG

Page ___ of ___

PROJECT NAME: _____ BORING NUMBER: _____
PROJECT NUMBER: _____ DATE: _____
DRILLING COMPANY: _____ GEOLOGIST: _____
DRILLING RIG: _____ DRILLER: _____

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	MATERIAL DESCRIPTION: Color	MATERIAL DESCRIPTION: Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	PID/FID Reading (ppm): Sampler BZ	PID/FID Reading (ppm): Borehole**	PID/FID Reading (ppm): Driller BZ**

* When rock coring, enter rock brokeness.
** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated response read.

Remarks: _____

Drilling Area Background (ppm): [ ]

Converted to Well: Yes _____ No _____ Well I.D. #: _____

FIGURE 1 (CONTINUED)

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			
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)			
					Identification Procedures on Fraction Smaller than No. 40 Sieve Size			
						DRY STRENGTH (Crushing Characteristics)	DILATANCY (Reaction to Shaking)	TOUGHNESS (Consistency Near Plastic Limit)
GRAVELS (50%(+)>1/4"Ø	CLEAN GRAVELS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	GW	Well graded gravels, gravel-sand mixtures, little or no fines	SILTS AND CLAYS Liquid Limit <50	None to Slight	Quick to Slow	None
		Predominantly one size or a range of sizes with some intermediate sizes missing	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Medium to High	None to Very Slow	Medium
	GRAVELS W/FINES (High % Fines)	Non-plastic fines (for identification procedures, see ML)	GM	Silty gravels, poorly graded gravel-sand-silt mixtures		Slight to Medium	Slow	Slight
		Plastic fines (for identification procedures, see CL)	GC	Clayey gravels, poorly graded gravel-sand-clay mixtures	SILTS AND CLAYS Liquid Limit >50	Slight to Medium	Slow to None	Slight to Medium
SANDS 50%(+)<1/4"Ø	CLEAN SANDS (Low % Fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	SW	Well graded sand, gravelly sands, little or no fines		High to Very High	None	High
		Predominantly one size or a range of sizes with some intermediate sizes missing	SP	Poorly graded sands, gravelly sands, little or no fines		Medium to High	None to Very Slow	Slight to Medium
	SANDS W/FINES (High % Fines)	Non-plastic fines (for identification procedures, see MCL)	SM	Silty sands, poorly graded sand-silt mixtures.	HIGHLY ORGANIC SOILS	Readily identified by color, odor, spongy feel and frequently by fibrous texture.		
		Plastic fines (for identification procedures see CL)	SC	Clayey sands, poorly graded sand-clay mixtures				

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 sieve sizes on this chart are U.S. Standard

DENSITY OF GRANULAR SOILS

DESIGNATION	STANDARD PENETRATION RESISTANCE-BLOWS/FOOT
Very Loose	0-4
Loose	5-10
Medium Loose	11-30
Dense	31-50
Very Dense	Over 50

CONSISTENCY OF COHESIVE SOILS

CONSISTENCY	UNC COMPRESSIVE STRENGTH (TONS/SQ. FT.)	STANDARD PENETRATION RESISTANCE-BLOWS/FOOT	
Very Soft	Less than 0.25	0 to 2	Easily penetra
Soft	0.25 to 0.50	2 to 4	Easily penetra
Medium Stiff	0.50 to 1.0	4 to 8	Can be penetr
Stiff	1.0 to 2.0	8 to 15	Readily indent
Very Stiff	2.0 to 4.0	15 to 30	Readily indent
Hard	More than 4.0	Over 30	Indented with

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 (one blow); crumbly edges	Broken	(Br.)	2"-1'
Medium Hard	Can be scratched	Breaks (one blow); sharp edges	Blocky	(Bl.)	1'-3'
Hard	Cannot be scratched	Breaks conchoidally (several blows); sharp edges	Massive	(M.)	3'-10'

LEGEND

SOIL SAMPLES - TYPES	ROCK SAMPLES - TYPES		WATER LEVELS
5-2" Split-Barrel Sample	X-NX (Conventional Core (~ 2-1/8" O.D.)	12/18	▽ 12.6' Initial Level w/Date & Depth
ST-3" O.D. Undisturbed Sample	Q-NQ (Wireline) Core (~ 1-7/8" O.D.)		
O - Other Samples, Specify in Remarks	Z - Other Core Sizes, Specify in Remarks	12/18	▽ 12.6' Stabilized Level w/Date & Depth

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 Figure 1 (Continued).
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 inchΦ-1/2 inchΦ)" 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).

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-1.3. 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, or SC (see Figure 1).

The consistency of cohesive soils is determined by performing field tests and identifying the consistency as shown in Figure 2.

Cohesive soils are given the USCS classifications ML, MH, CL, CH, OL, or OH (see Figure 1).

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 shown in Figure 2.

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
Adjective form of the soil type (e.g., "sandy")	31 - 50 percent

FIGURE 2

CONSISTENCY FOR COHESIVE SOILS

Consistency	Standard Penetration Resistance (Blows per Foot)	Unconfined Compressive Strength (Tons/Sq. 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 with difficulty by thumbnail

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.

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 Figure 3.

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

FIGURE 3

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)

5.3 Classification of Rocks

Rocks are grouped into three main divisions: sedimentary, igneous and metamorphic. 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.
- 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. 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 types 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. Figure 4 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.

FIGURE 4

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

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 (see Figure 3) will also be used for rock classification.

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 works "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.

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 inches 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."

- 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.

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 Figure 5.

The field geologist/engineer shall use this example as a guide in completing each boring 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 either on the back of the boring log or on a separate sheet, 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 at 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 on 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.

FIGURE 5
COMPLETED BORING LOG (EXAMPLE)

BORING LOG

Page 1 of 1

PROJECT NAME: NSB - SITE
PROJECT NUMBER: 9594
DRILLING COMPANY: SOILTEST CO.
DRILLING RIG: CME - 55
BORING NUMBER: SB/MW 1
DATE: 3/8/96
GEOLOGIST: SJ CONTI
DRILLER: R. ROCK

Sample No. and Type or RQD	Depth (Ft.) or Run No.	Blows / 6" or RQD (%)	Sample Recovery / Sample Length	Lithology Change (Depth/Ft.) or Screened Interval	MATERIAL DESCRIPTION: Soil Density/ Consistency or Rock Hardness	Color	Material Classification	USCS *	Remarks	PID/FID Reading (ppm): Sample	Sampler BZ	Borehole**	Driller BZ**
S-1	0.0	7/6	1.5/2.0		M DENSE	BRN	SILTY SAND - SOME	SM	MOIST SL. ORG.	5	0	0	0
@ 0800	2.0	9/10				TO BLK	ROCK FR. - TR BRICKS		ODOR				
							(FILL)		FILL TO 4'±				
	4.0			4.0									
S-2 @		5/7	2.0/2.0		M DENSE	BRN	SILTY SAND - TR FINE	SM	MOIST - W ODOR	10	0	–	–
0810	6.0	9/8					GRAVEL		NAT. MATL. TOOK SAMPLE				
	•			7'± ▽					SB01-0406 FOR ANALYSIS				
	8.0			8.0									
S-3 @		6/8	1.9/2.0		DENSE	TAN BRN	FINE TO COARSE SAND	SW	WET	0	0	0	0
0820	10.0	17/16					TR. F. GRAVEL		HIT WATER ≈ 7'±				
	12.0			12.0									
S-4 @		7/6	1.6/2.0		STIFF	GRAY	SILTY CLAY	CL	MOIST → WET	0	.5	–	–
0830	14.0	5/8											
	15.0			15.0					AUGER REF @ 15'				
				11 HSA 16	M HARD	BRN	SILTSTONE	VBR	WEATHERED				
									LO ∡ JNTS @ 15.5				
0/5	①		4.0/5.0						WATER STAINS @ 16.5, 17.1, 17.5	0	0	0	0
				19'					LOSING SOME				
	20.0				HARD	GRAY	SANDSTONE - SOME	BR	DRILL H2O @ 17'±				
							SILTSTONE		SET TEMP 6" CAS TO 15.5				
4.0/5.0	②		5.0/5.0						SET 2"Φ PVC SCREEN 16-25	0	0	0	0
									SAND 14-25				
	25.0			25					PELLETS 12-14				

* When rock coring, enter rock brokeness.

** Include monitor reading in 6 foot intervals @ borehole. Increase reading frequency if elevated response read.

• 1-20Z
1-80Z

Drilling Area Background (ppm): 0

Remarks: CME-55 R16, 4¼" ID HSA - 9" OD ±
2" SPLIT SPOONS - 140 LB HAMMER - 30" DROP
NX CORE IN BEDROCK RUN ① = 25 min. RUN ② = 15 min

Converted to Well: Yes ✓ No _____ Well I.D. #: MW-1

- Enter color of the material in the appropriate column.

- Describe material using the USCS. Limit this column for sample description only. The predominant 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/Or: 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 the terms angular, subangular, subrounded, or 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 Photoionization Detector (PID) or Flame Ionization Detector (FID) reading if applicable.

  - Indicate any change in lithology by drawing a line through the lithology change column and indicate the depth. This will help when cross-sections are subsequently 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).

  - Vertical lines shall be drawn (as shown in Figure 5) in columns 6 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.

- 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 Figure 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.

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.

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1.0 PURPOSE

The objective of this procedure is to provide general reference information and technical guidance on the performance and evaluation of pumping tests.

2.0 SCOPE

This procedure gives overall technical guidance for the performance and evaluation of pumping tests. The methodologies presented should be modified to meet the requirements/constraints of specific projects.

Pumping test data analysis is subject to much interpretation. Therefore, evaluation of the test results should be performed by an experienced hydrogeologist familiar with pumping test analytical techniques and interpretation. Due to the complexity of some of the evaluation methods and the wide variety of corrections which may be required to be factored into the data obtained, this guideline presents only a general overview of the pumping test evaluation process. The references provided in Section 6.0 should be consulted for detailed discussions regarding pumping test evaluation techniques.

3.0 GLOSSARY

Cone of Depression - The area around a discharging well where the hydraulic head in the aquifer has been lowered by pumping. Also called cone of influence.

Confined Aquifer - An aquifer that is completely saturated and is overlain and underlain by strata of lower permeability. The potentiometric surface of a confined aquifer is higher than the base of the upper confining layer at any given point.

Discharge (Q) - Volume of water removed per unit time.

Drawdown (S) - Difference between the initial static water level and the water level position at a given time during pumping.

Hydraulic Conductivity (K) - A quantitative measure of the ability of porous material to transmit water. Volume of water that will flow through a unit cross sectional area of porous material per unit time under a head gradient. Hydraulic conductivity is dependent upon properties of the medium and fluid.

Pumping Test - A test made by pumping a well for a period of time and observing the resulting change in hydraulic head in the aquifer. A pumping test may be used to determine the hydraulic characteristics of the aquifer and the capacity of the pumped well.

Specific Capacity (SC) - Rate of yield per unit drawdown. Often expressed as gallons per minute per foot of drawdown. The pumping time prior to measurement of drawdown should be stated, e.g., SC = 5 gal/ft after 12 hrs pumping.

Specific Storage - The amount of water released from or taken into storage per unit volume of aquifer per unit change in head.

Specific yield - The ratio of the volume of water a rock or soil will yield by gravity drainage to the total volume of the rock or soil.

Storage Coefficient (S) - Volume of water an aquifer releases from or takes into storage per unit volume of aquifer per unit change in head. The product of specific storage times saturated thickness. Also called storativity.

Transmissivity (T) - A quantitative measure of the ability of an aquifer to transmit water. The product of the hydraulic conductivity times saturated thickness.

4.0 RESPONSIBILITIES

Project Hydrogeologist - The Project Hydrogeologist, in conjunction with the Project Manager, has the responsibility of determining the need to perform a pumping test or tests for investigative purposes. Factors that should be taken into account when considering whether a pumping test should be performed or not include:

- Project objectives and the data required to meet these objectives.
- The amount and accuracy of hydrogeologic data currently available.
- Cost and schedule constraints.
- Physical site limitations (discharge of contaminated/uncontaminated water, aquifer water yielding capability, access, etc.)

Pumping tests (especially long-term tests) can be time-consuming, labor intensive, and costly. On the other hand, pumping tests generally yield the most accurate data regarding aquifer characteristics that can be obtained, when designed, performed, and evaluated properly. Specific uses for pumping tests include:

- Determination of aquifer hydraulic characteristics.
- Determination of the extent of influence of a pumped well.
- Design of groundwater withdrawal systems (for groundwater treatment or water supply).
- Determination of the interconnection between water bearing formations.
- Identification of aquifer boundaries (recharge/discharge boundaries).

Once the need to perform a pumping test has been established, the Project Hydrogeologist is responsible for the design and oversight of the pumping test, including identifying the wells to be used, designing and locating the pumping and observation wells as needed, specifying methodologies to be used, and determining the length of time of the test. The Project Hydrogeologist should ensure that all field personnel involved are familiar with the planned test and the field operations related to the performance of the test. During the startup of the pumping test, the Project Hydrogeologist may need to be onsite to ensure that proper field procedures are used. Data generated during the performance of the pumping test should be concurrently reviewed by the Project Hydrogeologist to identify any modifications to the planned procedure that may be required during the performance of the test. Data reduction/evaluation should be performed under the supervision of the Project Hydrogeologist.

Field Personnel - All field personnel should be familiar with the overall methodology of performing pumping tests, as well as being familiar with the specific requirements of each individual test that they will participate in. The field personnel should be familiar with the types and uses of the various field equipment required for the performance of a pumping test (surface or submersible pumps, generators, water level measuring devices, flow measuring devices, support equipment). It is the responsibility of the field personnel to alert the Project Hydrogeologist to any unexpected conditions that may be encountered that would require modifications to the planned procedure. The field personnel are responsible for performing the test as described in the approved project plans and any approved modifications. Once the pumping test has been completed, field personnel are to assist the Project Hydrogeologist in the process of data reduction/evaluation.

5.0 PROCEDURES

5.1 Planning for a Pumping Test

The need for and design of a pumping test is determined largely by the project goals and geologic/hydrogeologic conditions within the study area. The pumping test should be designed so the results obtained will be representative of the area under study.

As much information as possible should be collected and evaluated before running a pumping test. This includes data regarding physical and hydraulic characteristics of the aquifer, groundwater flow direction, hydraulic gradients, velocity, regional water level trend, the existence of other pumping wells in the vicinity of the test area, and the expected quality/quantity of the discharge water.

The placement and design of the pumping well is critical to the success of the pumping test. Placement of the well is dependent on pumping test objectives and local geologic conditions. In general, the pumping well should fully penetrate the aquifer to be pumped, and be screened across the entire saturated interval of the aquifer. Due to project constraints and physical practicality, this is often not the case, and corrections must be factored into the data analysis for partially penetrating wells.

If an existing well is to be used for a test, the well should closely conform to the requirements for aquifer testing. Boring logs, construction data, and performance characteristics of other wells in the area should be examined to develop a preliminary estimate of the aquifer characteristics. Transmissivities can be estimated from the boring logs and preliminary testing.

Any number of observation wells may be used. The number chosen depends on maintaining a balance between cost and need to obtain the maximum amount of accurate and reliable data. If three or four observation wells are to be installed in the pumped aquifer, all but one well should be installed along a radial line from the pumping well, with the remaining well placed along a line normal to the line of observation wells and passing through the pumping well, to detect any radial anisotropy within the aquifer. If two observation wells are to be installed, they should be placed in a straight line away from the pumping well. In a fracture controlled bedrock flow system; fracture orientations should be considered when deciding where to place observation wells. In general, observation wells for an unconfined aquifer test should be placed closer to the pumping well than for a confined aquifer test.

When a pumping well does not fully penetrate an unconfined aquifer (any well with an 85 percent or more open or screened hole in the saturated thickness may be considered as fully penetrating), the observation wells should be located at a minimum distance equal to 1-1/2 to 2 times the aquifer thickness from a partially penetrating pumping well if partial penetration corrections are to be avoided. This minimizes the effect of flow field distortions resulting from pumping a partially penetrating well.

If the confined aquifer is not thick, the pumping well should be screened for the entire thickness of the aquifer. The nearest observation well should be located at least 25 feet from the pumping well and should penetrate and be screened in the middle portion of the aquifer.

Observation wells screened within the aquifer being pumped will provide information regarding aquifer characteristics. Wells screened in an overlying or underlying aquifer will provide information regarding the degree of interconnection between aquifers. If an observation well is screened in an overlying aquifer, it should be placed close to the pumping well so the response of the overlying aquifer is monitored at a point where the difference in head between aquifers is relatively large.

The pumping and observation well configurations and locations described above are not requirements, but are suggested setups to maximize the accuracy of the data generated. In many instances, less than ideal conditions regarding screened intervals/depths and observation well numbers/locations will be

encountered due to project constraints. Valid pumping tests can still be performed if the wells used do not conform to the ideal setup.

Single well pumping tests can be performed when project constraints do not allow for the installation of observation wells. The data obtained from these tests is less accurate than for tests performed using observation wells, and specific yield/specific storage cannot be determined. Drawdown measurements in a pumped well are generally greater than the actual drawdown in the adjacent aquifer due to well inefficiency, so this factor must be considered when interpreting results.

5.2 Preparation for a Test

For a few days before starting a long-term pumping test, water levels in the pumping well and observation wells should be measured at about the same time each day to determine whether there is a measurable trend in groundwater levels. If such a trend is apparent, a graph of the change in water level versus time should be prepared and used to correct the water levels obtained during the test.

Pumping wells should undergo a preliminary pumping prior to the actual test to ensure that the well will function at it's maximum efficiency. This will enable fines to be flushed from the formation and a steady flow rate to be established. The preliminary pumping should determine the maximum drawdown in the well at a given pumping rate and establish the pumping rate for the later test. The aquifer should then be given adequate time to fully recover before the pumping test is begun.

Step-drawdown tests can be performed prior to the actual pumping test, to determine the optimum pumping rate for the test. A step-drawdown test consists of pumping a well at several successively higher rates, for a given time period (1/2-2 hours for each rate), and measuring the rate of drawdown for each pumping rate. If possible, the well should be allowed to recover between tests. The resulting data generated can be used to predict drawdown versus time over an extended period for various pumping rates.

Barometric changes may affect water levels in wells, particularly those screened in confined aquifers. An increase in barometric pressure may cause a decrease in the water level. The response of wells to changes in barometric pressure should be determined in order to correct the measurement of water levels during a long-term pumping test.

A record should be maintained of the pumping times and discharge rates of other pumping wells in the vicinity, if their radius of may influence potentially intersect the cone of depression of the pumping test well.

In areas of severe winter climate, where the frostline may extend to depths of several feet, pumping tests should be avoided during the winter in areas where the water table is near ground surface. Under some circumstances, the frozen soil acts as a confining bed, combining with leaky aquifer and delayed yield characteristics to make the results of the test unreliable.

5.3 Conducting a Test

Immediately before the pump is started, the water levels should be measured in the pumping well and all observation wells to determine the static water levels upon which drawdowns will be based. These data and the time of measurement should be recorded on a pumping test data sheet (see Attachment A for an example).

It may be useful to collect water samples from the pumping well (at least) before and after pumping. This data can give an indication of changes in groundwater quality due to pumpage.

Critical data that must be collected for each pumping test include the time that pumping started and ended, water level measurements during the test, periodic measurements of the pumping rate, and the distances between the pumping well and the observation wells.

Pump selection depends on the expected pumping rate and the physical constraints of the test (e.g., depth to water, expected total drawdown, pumping well diameter). Pump size is related to the required discharge capacity and the well diameter. Submersible pumps or air-lift set-ups are required when the drawdown of the water level is expected to exceed 25 feet below ground surface. Suction pumps can be used if total drawdown plus well headspace is not expected to exceed 25 feet.

Once pumping is initiated, the flow rate should immediately be measured and adjusted as necessary to achieve a constant discharge at the desired rate. The discharge rate should be checked, adjusted, and recorded frequently during the performance of the test, especially during the early stages of the test. The initial pumping rate should not be the maximum rate that the pump is capable of, as progressive drawdown may decrease the pump's efficiency, and as a result reduces the discharge rate. If the pump is initially operating at less than full capacity, the decrease in efficiency can be countered by increasing the pump speed or, if the discharge rate is controlled through a valve (as is more typical), opening the valve further. Pumping rates can be monitored using a flowmeter or, for low volume pumping tests, a stopwatch and calibrated bucket can be used to measure discharge rates.

The tone or rhythm of a pump or generator motor engine provides a check of performance. If there is sudden change in tone, the discharge should be checked immediately and proper adjustments made to the gate valve or to the engine speed if necessary.

At least 10 observations of drawdown within each log cycle of time should be measured in the pumping well and observation wells. Continuous water level recording for the observation wells nearest to the pumping well can be extremely useful. A suggested schedule for measurements is as follows:

- 0 to 10 minutes: 0.0, 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 6.5, 8, and 10 minutes. It is important in the early part of the test to record with maximum accuracy the time at which readings are taken.
- 10 to 100 minutes: 10, 15, 20, 25, 30, 40, 50, 60, 80, and 100 minutes.
- to 2-hour intervals: To the end of the first day.
- 500- to 1,000-minute intervals: After the first day.

In addition, water level measurements should be collected periodically (every 4-8 hrs) from one or more background wells located outside the cone of depression.

Initially, there should be enough personnel available to measure flow rates/adjust pump rates continuously and to station a person at each nearby well used in the pumping test, unless continuous water level recorders or pressure transducers and data loggers are used. After the first two hours of the pumping test, two people are usually sufficient to continue the test.

The total pumping time for a test depends on the type of aquifer and degree of accuracy desired, and can range from less than 2 hours to several days. Economizing on the period of pumping is not recommended. More reliable results are obtained if pumping continues until the cone of depression reaches a stabilized condition, however, this is not always practical or necessary. The cone of depression will continue to expand at a progressively slower rate until recharge of the aquifer equals the pumping rate and a steady state condition is established. The time required to achieve steady state flow conditions may vary from less than an hour to beyond the practical limits of a pumping test. Under average conditions, it is good practice to run a large scale pumping test in a confined aquifer for at least 24 hours and in an unconfined aquifer, for a minimum of 72 hours. A longer period of pumping may reveal the presence of boundary conditions not previously known. Single well pumping tests or small scale tests may be run for shorter time periods. Preliminary field plotting of drawdown data should be conducted during the test to evaluate how the test is progressing and how much longer it should continue.

Water pumped from an unconfined aquifer during a pumping test should be disposed of in such a way so that the aquifer is not recharged by discharge water infiltration during the test, as recharge may offset drawdown effects. Also, if contaminated water is pumped during the test, the water may have to be stored, treated, or disposed of in an acceptable manner.

The method of disposal of discharge water from the pumping well should be planned. The discharge water could be routed to a storm sewer or surface water body if uncontaminated, or temporarily stored in tanks, drums or in a lined pit if collection is required. Contaminated water can also be treated and discharged in an appropriate manner, with client/regulatory approval. If necessary, contaminated discharge water should be transported and deposited into a designated secure area.

5.4 Recovery Test

When pumping is stopped after completing the drawdown portion of the pumping test, the cumulative drawdown and time at which pumping was discontinued are recorded. The rate of recovery of the water levels in the wells should then be measured.

The same procedure and time pattern are followed as at the beginning of a pumping test; that is, the depth-to-water is periodically measured during the recovery test in the pumping well and observation wells, with readings obtained more frequently during the early phase of recovery. Recovery data should follow the same general trend as drawdown data, and is considered in many cases to be more accurate and useful for pumping test analysis than drawdown data.

The recovery data should be recorded until the aquifer fully recovers, or as long as possible within project constraints.

5.5 Data Analysis

A constant rate pumping test can be run to determine transmissivity and hydraulic conductivity. If the effects of pumping the well can be measured in one or more observation wells at known distances from the pumping well, the specific yield or storage coefficient can also be determined. A good check of the transmissivity value can be made using recovery data from the pumped well and of transmissivity and storage coefficient from recovery rate measurements in observation wells.

Example data collection forms for a pumping test are illustrated in Attachments A and B. The forms can be used to record data for the pumping well or an observation well. It should be noted that there are some differences in the types of data recorded for pumping versus observation wells.

The effects of all extraneous factors such as barometric pressure, tidal influence, injection interference, or other pumpage in the nearby area, can be adjusted for and corrected from the measured data by using applicable correlation techniques.

After correction of the raw data to eliminate or reduce the amount of extraneous interference, graphs are prepared showing resulting drawdowns versus time and/or distance; these are plotted on semi-log or log-log paper. The graphs are used to determine aquifer characteristics by matching type curves or by straight line slope analysis procedures. Analytical methods not requiring the use of a graph have also been developed. Selection of the most appropriate evaluation technique is dependent on the test setup and results. In addition to manual methods of analysis, there are numerous computer programs available for data analysis. Selection and application of the proper analysis method(s) requires the judgement and guidance of an experienced hydrogeologist.

5.6 Records

The Pumping Test Data Sheet exhibited on Attachment A should be used to record data from pumping wells, and the Pumping Test Data Sheet exhibited on Attachment B should be used to record data from observation wells. A written log of the field setup and performance of the pumping test must also be kept in a bound site logbook or notebook. Descriptions of procedures used, daily activities, and any other pertinent observations made prior to, during, and following the test should also be recorded.

6.0 REFERENCES

Driscoll, Fletcher G., 1975. Groundwater and Wells. Johnson Division, UOP, Inc.

Fetter, C. W. Jr., 1980. Applied Hydrogeology. C. E. Merrill Publishing Co., Columbus, Ohio.

Freeze, R. A. and J. A. Cherry. 1979. Groundwater. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

Kruseman, G. P. and N. A. DeRidder, 1979. Analysis and Evaluation of Pumping Test Data. International Institute for Land Reclamation and Improvement, P.O. Box 45, 6700 AA Wageningen, Netherlands.

Lohman, S. W., 1979. Ground-Water Hydraulics - Geological Survey Professional Paper 708. United States Department of the Interior, U.S. Government Printing Office, Washington, D.C.

United States Department of the Interior, 1981. Groundwater Manual. United States Government Printing Office, Denver, Colorado.

ATTACHMENT A
EXAMPLE PUMPING TEST DATA SHEET, PUMPING WELL

PUMPING TEST DATA SHEET
PUMPING WELL

Page ___ of ___

PROJECT NAME: _____
PROJECT NUMBER: _____
PUMPING TEST: [ ]
TEST NUMBER: _____
METHOD OF MEASUREMENT: _____
DEPTH CORRECTION: _____

PUMPING WELL NUMBER: _____
DATE(s): _____
STEP DRAW DOWN TEST [ ]
MONITORING POINT: _____
ELEVATION OF MONITORING POINT: _____ MSL
PUMP SETTING (Ft. below monitoring point): _____

PUMPING TEST PERFORMED BY: _____
REMARKS: _____

TIME (Hour:Min.)	(t) ELAPSED TIME SINCE PUMP START OR STOP (Min.)	WATER LEVEL (Ft.)	(s) DRAW DOWN OR RECOVERY (Ft.)	FLOW METER READING (Gals.)	(Q) PUMPING RATE (GPM)	REMARKS

SIGNATURES: _____

ATTACHMENT B
EXAMPLE PUMPING TEST DATA SHEET, OBSERVATION WELL

PUMPING TEST DATA SHEET
OBSERVATION WELL

Page ___ of ___

PROJECT NAME: _____
PROJECT NUMBER: _____
TEST NUMBER: _____
METHOD OF MEASUREMENT: _____
DEPTH CORRECTION: _____

OBSERVATION WELL NUMBER: _____
DATE(s): _____
MONITORING POINT: _____
ELEVATION OF MONITORING POINT: _____ MSL

CORRESPONDING PUMPING WELL NUMBER: _____
DISTANCE FROM PUMPING WELL (Ft.) (r): _____
REFERENCE POINT MEASUREMENTS BY: _____
REMARKS: _____

TIME (Hour:Min.)	(t) ELAPSED TIME SINCE PUMP START OR STOP (Min.)	WATER LEVEL (Ft.)	(s) DRAW DOWN OR RECOVERY (Ft.)	REMARKS

SIGNATURES: _____

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ATTACHMENTS

A HYDRAULIC CONDUCTIVITY TESTING DATA SHEET 7

1.0 PURPOSE

This guideline is intended to describe procedures for performing in-situ hydraulic conductivity testing (slug testing) in boreholes and monitoring wells, and provide a short description of commonly used evaluation techniques for the data generated. Slug tests are used to provide data regarding the hydraulic properties of the formation tested. A variation of the slug test, called a constant-head test, is also briefly described.

2.0 SCOPE

Slug tests are short-term tests designed to provide approximate hydraulic conductivity values for the portion of a formation immediately surrounding the screened/open interval of a well or boring. These tests are much less accurate than pumping tests, as a much more localized area is involved. Therefore, a number of slug tests are typically performed and averaged to determine a representative hydraulic conductivity value for the formation tested. Performance of slug tests may be preferable to pumping tests in situations where handling of large volumes of contaminated water is a concern or when time/budget constraints preclude the more expensive and time-consuming setup and performance of a pumping test.

Constant-head tests also are used to determine hydraulic conductivity values and are similar to slug tests with regard to the quality of data obtained and time/cost considerations. A disadvantage of constant-head tests is that a significant volume of water may be added to high-permeability formations, potentially affecting short-term water quality.

3.0 GLOSSARY

Hydraulic Conductivity (K) - A quantitative measure of the ability of a porous material to transmit water, defined as the volume of water that will flow through a unit cross-sectional area of porous material per unit time under a head gradient of 1. Hydraulic conductivity is dependent upon properties of the medium and fluid. Common units of expression include centimeters per second (cm/sec), feet per day (ft/day), and gallons per day per foot^2 (gpd/ft^2).

Transmissivity (T) - A quantitative measure of the ability of an aquifer to transmit water. The product of the hydraulic conductivity times the saturated thickness.

Slug Test - A rising head or falling head test used to measure hydraulic conductivity. A slug test consists of instantaneously changing the water level within a well and measuring the rate of recovery of the water level to equilibrium conditions. Slug tests are performed by either withdrawing a slug of water (rising head test) or adding a slug of water (falling head test), then measuring recovery over time. A solid slug of known volume can be used to displace a volume of water, thereby simulating the addition or removal of water.

4.0 RESPONSIBILITIES

Project Hydrogeologist - The project hydrogeologist, in conjunction with the Project Manager, shall evaluate the type(s) and extent of hydraulic testing required for a given project during the planning process, and design the field program accordingly. The project hydrogeologist also shall ensure that field personnel have the necessary training and guidance to properly perform the tests, and shall oversee data reduction activities, including selecting the appropriate evaluation techniques and checking calculations for accuracy.

Field Geologist - The field geologist is responsible for performing the planned field tests as specified in the project planning documents, (or approved modifications thereto). The field geologist also generally assists in the data evaluation process. The field geologist shall be knowledgeable in the testing methodologies used and is responsible for obtaining the necessary support equipment required to perform

the field tests. All applicable data regarding testing procedures, equipment used, well construction, and geologic/hydrogeologic conditions shall be recorded by the field geologist. The field geologist shall be familiar enough with testing procedures/requirements to be able to recommend changes in methodology, should unanticipated field conditions be encountered.

5.0 PROCEDURES

5.1 In-situ Hydraulic Conductivity Testing in Wells

Slug tests are commonly performed in completed wells. Prior to testing, the well shall be thoroughly developed and allowed to stabilize, in order to obtain accurate results. Once the water level within the well has stabilized at its static level, it shall be quickly raised or lowered and the rate of recovery measured.

One of the basic assumptions of slug testing is that the initial change in water level is instantaneous; therefore, an effort shall be made to minimize the time involved in raising or lowering the water level initially. Various methods can be used to induce instantaneous (or nearly instantaneous) changes in water level within the well. A rise in water levels can be induced by pouring water into the well. A solid slug of known volume, quickly lowered below the water level within the well, will displace an equivalent volume of water and raise the water level within the well. The slug can be left in place until the water level restabilizes at the static water level, then suddenly removed to create a drop in water level within the well. An advantage of using a solid cylinder of known volume (slug) to change the water level is that no water is removed or added to the monitoring well. This eliminates the need to dispose of contaminated water and/or add water to the system. A bailer or pump can be used to withdraw water from the well. If a pump is used, pumping shall not continue for more than several seconds so that a cone of depression is not created which would adversely impact testing results. The pump hose shall also be removed from the well during the recovery period, as data analysis techniques involve volume of recovery versus time, and leaving the hose within the well would distort the calculated testing results by altering the apparent volume of recovery. Falling head slug tests should only be performed in wells with fully submerged screens, while rising head slug tests can be performed in wells with either partially or fully submerged screens/open intervals.

Other methods that can be used to change water levels within a well include creating a vacuum or a high pressure environment within the well. The vacuum method will raise water levels within the well, while the pressure method will depress the water level in the well. These methods are particularly useful in highly permeable formations where other methods are ineffective in creating measurable changes in water levels. Both of these methods are limited to wells which have completely submerged screens.

Rate of recovery measurements shall be obtained from time zero (maximum change in water level) until water level recovery exceeds 90 percent of the initial change in water level. In low permeability formations, the test may be cut-off short of 90 percent recovery due to time constraints. Time intervals between water level readings will vary according to the rate of recovery of the well. For a moderately fast recovering well, water level readings at 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.75, 1.0, 1.25, 1.5, 2.0, 2.5, 3.0, 4.0, . . . minutes may be required. With practice, readings at down to 0.05-minute (3 seconds) time intervals can be obtained with reasonable accuracy, using a pressure transducer and hand held readout. For wells which recover very fast, a pressure transducer and data logger may be required to obtain representative data. Time intervals between measurements can be extended for slow recovering wells. A typical schedule for measurements for a slow recovering well would be 0, 0.25, 0.5, 0.75, 1.0, 1.5, 2.0, 3.0, 4.0, 6.0, 8.0, 10.0, 15.0, 20.0, 30.0, . . . minutes from the beginning the test. Measurements shall be taken from the top of the well casing.

Water level measurements can be obtained using an electric water level indicator, popper, or pressure transducer. Steel tape coated with chalk or water sensitive paste although very accurate, is a slower

method of obtaining water levels and is generally not recommended for use due to the frequency at which water level measurements need to be obtained during the performance of a slug test.

Time/recovery should be field-plotted on semilog graph paper to determine the data quality. The data set should plot along a sloped, straight line. If excessive data scatter is observed, the test should be rerun until acceptable results are obtained.

The following data shall be recorded when performing slug tests in wells or borings:

- Well/boring ID number
- Total depth of well/boring
- Screened/open interval depth and length
- Gravel pack interval depth and length
- Well stickup above ground surface
- Gravel pack radius
- Static water level
- Aquifer thickness
- Depth to confining layer
- Time/recovery data

A variation of the slug test, called a constant-head test, is a test in which water is added to the well at a measured rate sufficient to maintain the water level in the well at a constant height above the static water level. Once a stable elevated water level has been achieved, discharge (pumping) rate measurements are recorded in place of time/recovery data for approximately 10 to 20 minutes. The hydraulic conductivity is then calculated from this information. The constant-head test is generally not recommended for monitoring wells as large volumes of water may be introduced into the screened formation, potentially impacting later sampling events.

5.2 In-situ Hydraulic Conductivity Testing in Borings

Slug tests can be performed in borings while the boring is being advanced. This permits testing of formations at different depths throughout the drilling process. Boreholes to be tested shall be drilled using casing, so that discrete depths may be investigated. Various tests and testing methods are described below. The most appropriate test and testing method to be used in a situation varies and shall be selected after a careful evaluation of drilling, geologic, and general site conditions.

Rising head or falling head slug tests can be performed in saturated and unsaturated formations during drilling. There are two ways that the tests can be performed. One way entails setting the casing flush with the bottom of the boring when the desired testing depth has been reached. The hole is then cleaned out to remove loose materials, the drill bit and rods are carefully withdrawn from the boring, and a few feet of sand (of higher permeability than the surrounding formation) is added to the bottom of the boring. After the water level in the boring has stabilized (for saturated formations), the static water level is measured and recorded. The water level is then raised (falling head test) or lowered (rising head test) and the change in water level is measured at time intervals determined by the field hydrogeologist. Only falling head tests can be performed for depth intervals within the unsaturated (vadose) zone. As described for wells, time intervals for water level measurements will vary according to the formation's hydraulic conductivity. The faster the rate of recovery expected, the shorter the time intervals between measurements shall be. The rate of change of water level will be used to calculate hydraulic conductivity. The test is to be conducted until the water level again stabilizes, or for a minimum of 20 minutes. In low permeability formations, it is not always practical to run the test until the water level stabilizes, as it may take a long time to do so. The top of the casing shall be used as the reference point for all water level measurements.

The second method for conducting a slug test during drilling consists of placing a temporary well with a short screen into the cleaned-out boring, pulling the drilling casing back to expose the screen, allowing the formation to collapse around the screen (or placing a sand/gravel pack around the screen), and performing the appropriate hydraulic conductivity test in the well, as described for the first method. Again, the test shall be conducted until the water level stabilizes or for a minimum of 20 minutes. This method allows for testing a larger section of the formation and results in more reliable hydraulic conductivity estimates.

Constant-head tests may also be performed in borings. As described for monitoring wells, once a stable elevated level has been achieved, the discharge rate into the boring is measured for a period of time, usually 10 to 20 minutes, and the hydraulic conductivity is calculated from this. This method is the most accurate method depicted in this section, and shall be given preference over others if the materials are available to perform the test and the addition of water to the boring does not adversely impact project objectives. Once the test is over, additional information can be gathered by measuring the rate of the drop in water level in the boring (for saturated formations). A limitation of the constant-head test is that foreign water is introduced into the formation which must be removed from the well area by natural or artificial means, before a representative groundwater sample can be obtained.

Detailed descriptions regarding the performance of borehole hydraulic conductivity tests and subsequent data analysis techniques are provided in Ground Water Manual (1981).

5.3 Data Analysis

There are a number of data analysis methods available to reduce and evaluate slug testing data. The determination of which method is most appropriate shall be made based on the testing conditions (including physical setup of the well/boring tested, hydrogeologic conditions, and testing methodology) and the limitations of each test analysis method. Well construction details, aquifer type (confined or unconfined), and screened/open interval (fully or partially penetrating the aquifer) shall be taken into account in selecting an analysis method. Cooper, et al. (1967), and Papadapulos, et al. (1973) have developed test interpretation procedures for fully penetrating wells in confined aquifers. Hvorslev (1951) developed a relatively simple analytical procedure for point piezometers in an infinite isotropic medium. In Cedergren (1967), Hvorslev presents a number of analytical procedures which cover a wide variety of hydrogeologic conditions, testing procedures, and well/boring/piezometer configurations. Bouwer and Rice (1976) developed an analytical technique applicable to both unconfined and confined conditions, which factors in partial/full penetration and discusses well screen gravel pack considerations. The Ground Water Manual (1981) presents a number of testing and test analysis procedures for wells and borings open above or below the water table, and for both falling head and constant-head tests. The methods described above do not represent a complete listing of test analysis methods available, but are some of the more commonly used and accepted methods. Other methods can be used, at the discretion of the project hydrogeologist and in concurrence with the Project Manager and client.

One consideration to be noted during data analysis is the determination of the screened/open interval of a tested well. If a well with a fully submerged screen is installed in a relatively low permeability formation, and a gravel pack which is significantly more permeable is installed around the screen, the length of the gravel pack (if longer than the screened interval) should be used as the screened/open length, rather than the screen length itself. In situations where the formation permeability is judged to be comparable to the gravel pack permeability (within about an order of magnitude) this adjustment is not required.

All data analysis applications and calculations shall be reviewed by technical personnel thoroughly familiar with testing and test analysis procedures. Upon approval of the calculations and results, the calculation sheets shall be initialed and dated by the reviewer. Distribution copies shall be supplied to appropriate project personnel and the original copy stored in the project central file.

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7.0 RECORDS

Field data shall be recorded on the data sheet included as Attachment A (or equivalent). 1 Any notes regarding testing procedures, problems encountered, and general observations not included on the data sheet shall be noted in the bound site logbook or field notebook. The boring log and well construction diagrams for each well/boring tested shall be used as references during testing and data analysis activities. Original data sheets shall be placed in the project file, along with the logbook/notebook.

1 If an automated data recorder is used, the data may be displayed using the printer output from the unit. Such printouts should be annoted to include the relevant data form, or attached to the form shown as Attachment A.

ATTACHMENT A
EXAMPLE HYDRAULIC CONDUCTIVITY TESTING DATA SHEET

HYDRAULIC CONDUCTIVITY TESTING DATA SHEET

PROJECT NAME: ..... WELL/BORING NO.: .....

PROJECT NO.: ..... GEOLOGIST: .....

WELL DIAMETER: ..... SCREEN LENGTH/DEPTH: ..... TEST NO.: .....

STATIC WATER LEVEL (Depth/Elevation): ..... DATE: .....

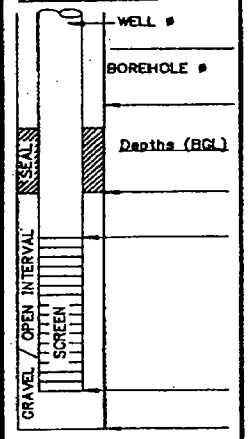
TEST TYPE (Rising/Falling/Constant Head): ..... CHECKED: .....

METHOD OF INDUCING WATER LEVEL CHANGE: ..... PAGE ..... OF .....

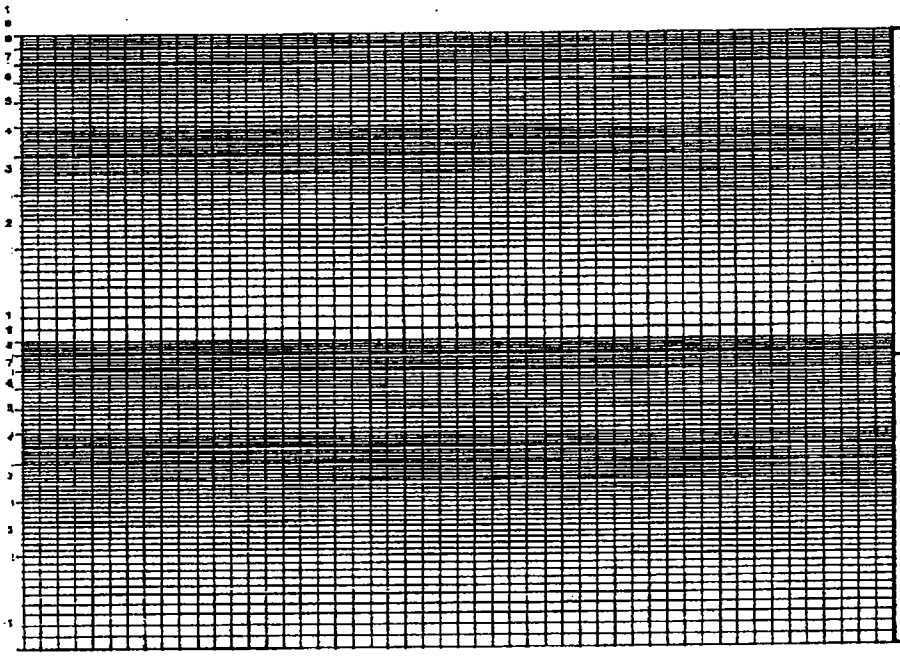
REFERENCE PT. FOR WL MEAS. (Top of Casing, Transducer, etc.): .....

ELAPSED TIME (min. or sec.)	MEASURED WATER LEVEL (feet)	DRAWDOWN OR HEAD (ΔH) (feet)	ELAPSED TIME (min. or sec.)	MEASURED WATER LEVEL (feet)	DRAWDOWN OR HEAD (ΔH) (feet)

WELL SCHEMATIC



Indicate SWL Depth on Drawing



REMARKS:

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CALCS,SKETCH MAPS, ETC.:

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A STREAM CHANNEL CROSS-SECTION DIAGRAM AND FORMULA **8**

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide general guidance on field methods and equipment used to measure flow in open channels.

2.0 SCOPE

This SOP describes several methods for determining cross-sectional area and flow. Since the physical characteristics that a stream exhibits could vary widely, several methods and techniques are presented which can be used in the field.

3.0 GLOSSARY

Open Channel Flow - open channel flow is flow in any channel in which the liquid flows with a free surface.

Flow (or volumetric flow rate) - the volume of water which passes through a cross-sectional plane in some unit of time. (Syn. - DISCHARGE)

Flume - an artificial channel used for constricting the flow of wastewater or water, in order to promote laminar flow and provide a flow channel of known configuration for the purpose of measuring flow.

Stage - the height of a water surface above an arbitrarily established datum plane.

Weir - an obstruction or dam-type structure containing a notch through which the flow of water can be measured. Weirs are classified according to the shape of the notch, e.g., rectangular, trapezoidal, triangular.

4.0 RESPONSIBILITIES

Project Manager. In consultation with the project hydrologist, responsible for determining the optimum location for performing flow determinations within an open channel, including the selection of the appropriate methodology, technique and field procedure for conducting the field test.

Field Operations Leader (FOL). FOL is responsible for direct supervision of the installation and execution of the field tests used to determine flow in an open channel. FOL is responsible for inspection of the equipment, to ensure its adequacy for performance of the test.

5.0 PROCEDURES

5.1 General

The discussion below addresses the various methods and techniques used to measure stream cross-section areas and stream velocities with respect to the velocity-area open channel technique of stream flow measurement. These techniques should be applied whenever stream gaging information is not available. When possible, stream gaging station information shall be utilized since, not only can real-time flow information be obtained, but historical flow information can be readily obtained from the authority responsible for the station.

The most common method of open channel flow determination is the velocity-area method. In this method, a flow or discharge measurement is computed as the summation of the products of partial areas of the flow cross-section and their respective average velocities. This is represented by the formula:

$$Q = \Sigma(av)$$

where: Q = total discharge,
a = individual partial cross-sectional area,
v = corresponding mean velocity normal to the partial area.

See Attachment A for more detail.

5.2 Cross Sectional Area Determination

5.2.1 Width Determination

Width determination for shallow streams and brooks can usually be accomplished by a simple tape measurement. However, when streams or rivers are wide (greater than 100 feet), deep (greater than 5 feet), or exhibit a high flow velocity, width determination can be a problem. As a general rule, width determinations under these conditions need only be accurate to the nearest foot per 100-foot stream width. Tape measurement of streams or rivers is usually accurate enough for streams up to 500 feet in width; however, for large streams, alternatives may be required. Bridges are convenient avenues across which measurements can be made. An equally acceptable method of determining width is by transit and stadia survey techniques.

5.2.2 Depth Determinations

Most often depth measurements are taken directly with a measuring rod or sounding weight. The mass of the weight suspended at the end of the tape must be sufficient to keep the tape essentially vertical. For high velocity streams or excessively deep channels, a sonic sounder may be appropriate, since some can be adapted to produce a continuous strip chart profile of the channel depth.

5.2.3 Stormwater Containment Capacity

In some cases it may be useful to measure the cross sectional area of a stream or drainage ditch channel up to the top of the stream channel (including both the submerged portion of the channel and the portion above the water surface). Knowledge of the volume capacity of the stream channel at various points can be used to determine the capability of the channel to contain increased water flows from storm events of various magnitudes, and predict when and where overflows may occur.

5.3 Velocity/Flow Determinations

As a general procedure, the actual measurement of depth, width and velocity would normally occur concurrently. In any case, in many parts of the country and along many sections of streams, the actual measurement of the above parameters are not required because this information has already been determined at gaging stations.

5.3.1 Stream Gaging Stations

A network of stream gaging stations has been in place for several decades. The authorities responsible for their placement are the US Army COE, USGS, and other federal or state agencies. In general, they have been placed in sensitive watersheds and along major tributaries and rivers throughout the United States.

Stream flow conditions, daily and historical, can be found on line at http://waterdata.usgs.gov/nwis/rt. These stations measure both the stage and discharge for over 7,000 locations in the United States.

5.3.2 Alternative Velocity/Flow Determination Methods

In general, the methods specified below refer to open channel stream flow where continuous long-term measurements are not required. Zero flow or non-channel flow conditions (overland flow) are not discussed within this text and require special procedures for flow determination. The main parameters to be collected for open channel flow determinations are cross-sectional area and stream velocity.

5.3.2.1 Current Meters

Current meters provide a rather quick and relatively accurate method of determining flow under existing site conditions. They are generally not used for long-term determinations. There are many types of current meters. Some are mechanical, others are electrical; some have vertical shafts, and others have horizontal shafts. The type preferred for open channel stream measurement are those which have a vertical shaft. The basic concept behind a current meter is that a rotating element at the end of the vertical shaft (or, in some cases, stationary electrodes) is submerged beneath the stream's surface where the flow of water rotates the element (or passes between the electrodes). The speed of rotation of the element (or flow between the electrodes) is measured directly by the current meter, which is then correlated to stream flow velocity through the meter's own electronic circuitry or by graphs or charts which accompany the instrument. Speed is normally measured in meters/sec or feet/sec.

Current meters can generally measure flow down to 0.03 meters/sec (0.1 ft/sec). Current meters which use electrodes are good for measuring streams that have weedy growths emanating from the stream bottom which would affect the rotating element. The depth to which current meters can be used is only limited by the ability to hold the element rigid at depth. Once a current meter measurement is taken, the measurement is averaged with other measurements taken along a vertical transect of the stream at that point to determine the mean velocity along that vertical transect. In a wide stream, several vertical transects are constructed. The mean stream velocity is calculated as the average of the individual average vertical velocities of each transect, with each average velocity weighted by the cross-sectional area of the stream that it represents. Some of the methods by which a current meter can be used are as follows:

- Six-Tenths Method. This method is best utilized when flow information must be gained quickly and/or the depth of the stream is less than 0.8 meters (2.6 feet) but greater than 0.1 meters (0.3 feet). In general, current meters cannot be used when depth of streams are less than 0.1 meters (0.3 feet). In this method, one measurement is taken at a depth 0.6 of the total depth below the surface along each of the vertical transects mentioned above. To gain a little more accuracy, each measurement within each transect may be taken three times and the result averaged to determine the mean velocity along that transect. This method reduces the effects of aberrant measurements.

- Two-Point Method. This method can only be used for streams exhibiting a depth greater than 0.8 meters (2.6 feet). This restriction is due to the effects that the surface of the stream and stream bed would have on the rotating element. In this method, measurements are taken at 0.2 and 0.8 of the total depth below the surface. The two measurements are then averaged to obtain the mean velocity along the vertical transect. Then all the transects are averaged to determine the stream flow.

- Three-Point Method. This method is also restricted to those streams exhibit a depth greater than 0.8 meters (2.6 feet). In this method, velocities are determined with a current meter at 0.2, 0.6, and 0.8 of the total depth below the surface. The 0.2 and 0.8 readings are averaged. The result is then averaged with the 0.6 reading. This method is very effective in those streams in which the vertical velocities are not normally distributed.

- Vertical-Velocity Method. This method is primarily used for deep channels. In this method, readings are taken at 0.1 depth increments starting at 0.1 and ending at 0.9. These values are then averaged together to determine the mean velocity of the vertical. Due to the numerous readings required, this method is not often used.

5.3.2.2 Deflection or Drag-body Methods

This method utilizes the relationship that drag is proportional to the square of the velocity. This method tends to be insensitive to very low velocities and is also affected by aquatic growth or debris which can affect the drag coefficient of the body utilized. This method is, however, relatively inexpensive and, under certain conditions, will yield as accurate a result as any device.

5.3.2.3 Floats

Floats use the principle that velocity of the stream can be determined by measuring the velocity of a float carried on the surface of the stream. If the stream is wide enough to require several velocity measurements, several floats should be used, with the resulting velocity multiplied by the fraction of the cross-sectional area of each represented measurement. The sum of the products equates to the flow or total discharge of the stream. There are many types of floats and each has its own coefficient to obtain mean velocity from a surface velocity measurement.

5.3.2.4 Pressure Methods

Pressure methods use a device called an impact tube to measure stream velocity. The impact tube comes in several different varieties, e.g., the Pilot tube, Barcy tube, Prandtl tube, or Brabbe tube. Impact tubes work under the principle that velocity is proportional to the square root of the dynamic pressure head, which is either measured directly or as a difference between the total and static pressure head in these impact tubes.

5.3.2.5 Bucket and Stopwatch

One of the simpler and reliable methods for measuring small flows (up to 80 ± GPM) where the entire flow can be captured in a container is the bucket and stopwatch method. A calibrated container (e.g., 5 gallon bucket) is inserted under the flow discharge, and a stopwatch is used to measure the time required to fill to a known volume.

Example: 8 seconds are required to fill a 5 gallon container

$Q = vol/t$
$Q = 5/8$
$Q = 0.625$ GPS
or 37.5 GPM (0.625 x 60)

Where: Q = flow rate in GPS
vol = volume in gallons
t = time in seconds

5.3.2.6 Tracer Methods

Several types of tracers, including salt, dye, or radioisotopes, can be used in this method. The major drawback to this type of velocity measurement is that pools and eddies tend to trap the tracer. Therefore, a uniform cross-sectional portion of the stream channel must be used. The tracer must be introduced as

a slug into the stream channel. This may be at one point or simultaneously at many points across the stream. The tracer concentration is measured at one or more points at known distances downstream of the injection point. At each of the downstream points, concentration/time curves are created by continuous measurement. The most precise determination of average velocity is made by using the centroid of the concentration/time curve to measure the travel time; however, the measurement of time at the concentration peaks is nearly as accurate.

5.3.2.7 Weirs and Flumes

A considerably more sophisticated method of determining stream flow is through the installation of artificial pre-calibrated control structures such as weirs and flumes. A weir is a dam-like structure behind which the water is ponded. The top of the weir contains a calibrated notch through which the ponded water eventually flows. Stream flow is determined by measuring the height of flow through the weir, which is a function of potential energy behind the overfall. A flume is basically a constricted flow structure which provides a uniform cross-section for measurement of flow. Flow is determined within the supercritical section within the throat of the constriction.

5.4 Estimating Discharge of Small Streams

5.4.1 Using Stream Channel Cross-sectioning

Establish a transect across the stream, along a straight reach where the stream is relatively narrow and velocity across the stream is relatively uniform. Orient the transect perpendicular to the flow. Use the diagram and formula shown in Attachment A to determine the stream's discharge rate in gallons per minute.

5.4.2 Using Culverts

One of the easiest ways to determine the discharge rate of a small stream is to locate a culvert where the stream was diverted beneath a road or railroad tracks. Simply measure (e.g., graduated bucket and stopwatch) the culvert's discharge over a given period of time and convert to gallons per minute (gpm) if applicable. However, be sure that all of the stream's discharge is diverted through the measured culvert.

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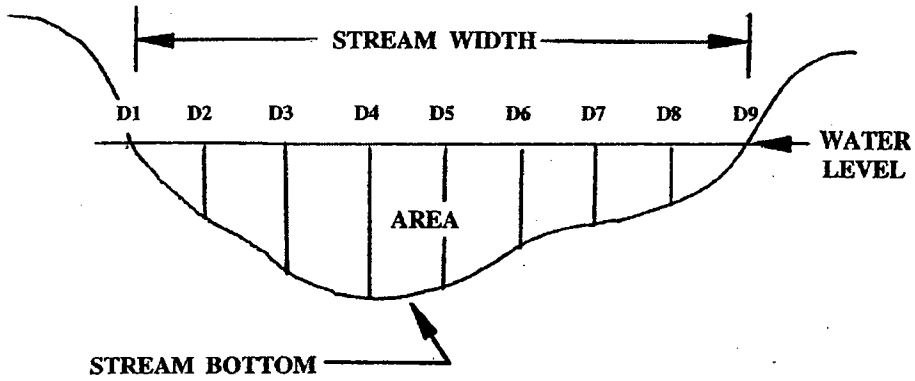
ATTACHMENT A
STREAM CHANNEL CROSS-SECTION DIAGRAM AND FORMULA



(1) Cross-sectional Area (A) = Average Depth (D) X Width (W) = _____ ft. sq.

Average Depth Example (D):
D1 + D2 + D3 + D4 + D5 + D6 + D7 + D8 + D9 = _____ / 9 = _____ feet

Note: For smaller streams use 5 or 7 depth measurement points. The two end points however will always be equal to zero (i.e., D1 and D9 in the above example are equal to zero).

(2) Mean Velocity (V) = time in seconds for float to travel 10 feet, divided by 10 equals feet per second

Note: An orange can be used as a float for streams > 6-inches in depth and a grape can be used as a float for streams under 6-inches in depth.

(3) Discharge (Q) = Cross-sectional Area (A) X Mean Velocity (V) = _____cu. ft./sec.

(4) To convert the discharge rate to gallons per minute multiply cubic feet per second by the constant 448.83.

(5) Gallons per Minute (GPM) = Discharge (Q) X 448.83

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1.0 PURPOSE

This procedure provides general guidance and information pertaining to proper monitoring well design, installation, and development.

2.0 SCOPE

This procedure is applicable to the construction of monitoring wells. The methods described herein may be modified by project-specific requirements for monitoring well construction. In addition, many regulatory agencies have specific regulations pertaining to monitoring well construction and permitting. These requirements must be determined during the project planning phases of the investigation, and any required permits must be obtained before field work begins. Innovative monitoring well installation techniques, which typically are not used, will be discussed only generally in this procedure.

3.0 GLOSSARY

Monitoring Well - A well which is screened, cased, and sealed which is capable of providing a groundwater level and groundwater sample representative of the zone being monitored. Some monitoring wells may be constructed as open boreholes.

Piezometer - A pipe or tube inserted into the water bearing zone, typically open to water flow at the bottom and to the atmosphere at the top, and used to measure water level elevations. Piezometers may range in size from 1/2-inch-diameter plastic tubes to well points or monitoring wells.

Potentiometric Surface - The surface representative of the level to which water will rise in a well cased to the screened aquifer.

Well Point (Drive Point) - A screened or perforated tube (Typically 1-1/4 or 2 inches in diameter) with a solid, conical, hardened point at one end, which is attached to a riser pipe and driven into the ground with a sledge hammer, drop weight, or mechanical vibrator. Well points may be used for groundwater injection and recovery, as piezometers (i.e., to measure water levels) or to provide groundwater samples for water quality data.

4.0 RESPONSIBILITIES

Driller - The driller provides adequate and operable equipment, sufficient quantities of materials, and an experienced and efficient labor force capable of performing all phases of proper monitoring well installation and construction. The driller may also be responsible for obtaining, in advance, any required permits for monitoring well installation and construction.

Field Geologist - The field geologist supervises and documents well installation and construction performed by the driller, and insures that well construction is adequate to provide representative groundwater data from the monitored interval. Geotechnical engineers, field technicians, or other suitable trained personnel may also serve in this capacity.

5.0 PROCEDURES

5.1 Equipment/Items Needed

Below is a list of items that may be needed when installing a monitoring well or piezometer:

- Health and safety equipment (hard hats, safety glasses, etc.) as required by the Site Safety Officer.
- Well drilling and installation equipment with associated materials (typically supplied by the driller).
- Hydrogeologic equipment (weighted engineer's tape, water level indicator, retractable engineers rule, electronic calculator, clipboard, mirror and flashlight - for observing downhole activities, paint and ink marker for marking monitoring wells, sample jars, well installation forms, and a field notebook).
- Drive point installation tools (sledge hammer, drop hammer, or mechanical vibrator; tripod, pipe wrenches, drive points, riser pipe, and end caps).

5.2 Well Design

The objectives and intended use for each monitoring well must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, require different types of construction. During all phases of the well design, attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials used. The objectives for installing the monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for trace contaminants.
- Determining aquifer characteristics (e.g., hydraulic conductivity).

Siting of monitoring wells shall be performed after a preliminary estimation of the groundwater flow direction. In most cases, groundwater flow directions and potential well locations can be determined by an experienced hydrogeologist through the review of geologic data and the site terrain. In addition, data from production wells or other monitoring wells in the area may be used to determine the groundwater flow direction. If these methods cannot be used, piezometers, which are relatively inexpensive to install, may have to be installed in a preliminary investigative phase to determine groundwater flow direction.

5.2.1 Well Depth, Diameter, and Monitored Interval

The well depth, diameter, and monitored interval must be tailored to the specific monitoring needs of each investigation. Specification of these items generally depends on the purpose of the monitoring system and the characteristics of the hydrogeologic system being monitored. Wells of different depth, diameter, and monitored interval can be employed in the same groundwater monitoring system. For instance, varying the monitored interval in several wells, at the same location (cluster wells) can help to determine the vertical gradient and the depths at which contaminants are present. Conversely, a fully penetrating well is usually not used to quantify or vertically locate a contaminant plume, since groundwater samples collected in wells that are screened over the full thickness of the water-bearing zone will be representative of average conditions across the entire monitored interval. However, fully penetrating wells can be used to establish the existence of contamination in the water-bearing zone. The well diameter desired depends upon the hydraulic characteristics of the water-bearing zone, sampling requirements, drilling method and cost.

The decision concerning the monitored interval and well depth is based on the following (and possibly other) information:

- The vertical location of the contaminant source in relation to the water-bearing zone.
- The depth, thickness and uniformity of the water-bearing zone.
- The anticipated depth, thickness, and characteristics (e.g., density relative to water) of the contaminant plume.
- Fluctuation in groundwater levels (due to pumping, tidal influences, or natural recharge/discharge events).
- The presence and location of contaminants encountered during drilling.
- Whether the purpose of the installation is for determining existence or non-existence of contamination or if a particular stratigraphic zone is being investigated.
- The analysis of borehole geophysical logs.

In most situations where groundwater flow lines are horizontal, depending on the purpose of the well and the site conditions, monitored intervals are 20 feet or less. Shorter screen lengths (5 feet or less) are usually required where flow lines are not horizontal, (i.e., if the wells are to be used for accurate measurement of the potentiometric head at a specific point).

Many factors influence the diameter of a monitoring well. The diameter of the monitoring well depends on the application. In determining well diameter, the following needs must be considered:

- Adequate water volume for sampling.
- Drilling methodology.
- Type of sampling device to be used.
- Costs.

Standard monitoring well diameters are 2, 4, 6, or 8 inches. Drive points are typically 1-1/4 or 2 inches in diameter. For monitoring programs which require screened monitoring wells, either a 2-inch or 4-inch-diameter well is preferred. Typically, well diameters greater than 4 inches are used in monitoring programs in which open-hole bedrock monitoring wells are used. With smaller diameter wells, the volume of stagnant water in the well is minimized, and well construction costs are reduced; however, the sampling devices that can be used are limited.

In specifying well diameter, sampling requirements must be considered (up to a total of 4 gallons of water may be required for a single sample to account for full organic and inorganic analyses, and split samples), particularly if the monitored formation is known to be a low-yielding formation. The unit volume of water contained within a monitoring well is dependent on the well diameter as follows:

Casing Inside Diameter (Inch)	Standing Water Length to Obtain 1 Gallon Water (Feet)
2	6.13
4	1.53
6	0.68

If a well recharges quickly after purging, then well diameter may not be an important factor regarding sample volume requirements.

Pumping tests for determining aquifer characteristics may require larger diameter wells (for installation of high capacity pumps); however, in small-diameter wells in-situ permeability tests can be performed during drilling or after well installation is completed.

5.2.2 Riser Pipe and Screen Materials

Well materials are specified by diameter, type of material, and thickness of pipe. Well screens require an additional specification of slot size. Thickness of pipe is referred to as "Schedule" for polyvinyl chloride (PVC) casing and is usually Schedule 40 (thinner wall) or 80 (thicker wall). Steel pipe thickness is often referred to as "Strength". Standard Strength is usually adequate for monitoring well purposes. With larger diameter pipe, the wall thickness must be greater to maintain adequate strength. The required thickness is also dependent on the method of installation; risers for drive points require greater strength than wells installed inside drilled borings.

The selection of well screen and riser materials depends on the method of drilling, the type of subsurface materials the well penetrates, the type of contamination expected, and natural water quality and depth. Cost and the level of accuracy required are also important. The materials generally available are Teflon, stainless steel, PVC galvanized steel, and carbon steel. Each has advantages and limitations (see Attachment A of this guideline for an extensive presentation on this topic). The two most commonly used materials are PVC and stainless steel. Properties of these two materials are compared in Attachment B. Stainless steel is a good choice where trace metals or organic sampling is required; however, costs are high. Teflon materials are extremely expensive, but are relatively inert and provide the least opportunity for water contamination due to well materials. PVC has many advantages, including low cost, excellent availability, light weight, ease of manipulation, and widespread acceptance. The crushing strength of PVC may limit the depth of installation, but the use of Schedule 80 materials may overcome some of the problems associated with depth. However, the smaller inside diameter of Schedule 80 pipe may be an important factor when considering the size of bailers or pumps required for sampling or testing. Due to this problem, the minimum well pipe size recommended for Schedule 80 wells is 4-inch I.D.

Screens and risers may have to be decontaminated before use because oil-based preservatives and oil used during thread cutting and screen manufacturing may contaminate samples. Metal pipe may corrode and release metal ions or chemically react with organic constituents, but this is considered a minor issue. Galvanized steel is not recommended where samples may be collected for metals analyses, as zinc and cadmium levels in groundwater samples may become elevated from leaching of the zinc coating.

Threaded, flush-joint casing is most often preferred for monitoring well applications. PVC, Teflon, and steel can all be obtained with threaded joints. Welded-joint steel casing is also acceptable. Glued PVC may release organic contaminants into the well, and therefore, should not be used if the well is to be sampled for organic constituents.

When the water-bearing zone is in consolidated bedrock, such as limestone or fractured granite, a well screen is often not necessary (the well is simply an open hole in bedrock). Unconsolidated materials, such as sands, clay, and silts require a screen. A screen slot size of 0.010 or 0.020 inch is generally used when a screen is necessary, and the annular borehole space around the screened interval is artificially packed with an appropriately sized sand, selected based on formation grain size. The slot size controls the quantity of water entering the well and prevents entry of natural materials or sand pack. The screen shall pass no more than 10 percent of the pack material, or in-situ aquifer material. The site geologist shall specify the combination of screen slot size and sand pack which will be compatible with the water-bearing zone, to maximize groundwater inflow and minimize head losses and movement of fines into the wells. For example, as a standard procedure, a Morie No. 1 or No. 10 to No. 20 U.S. Standard Sieve size filter pack is typically appropriate for a 0.020-inch slot screen; however, a No. 20 to No. 40 U.S. Standard Sieve size filter pack is typically appropriate for a 0.010-inch slot screen.

5.2.3 Annular Materials

Materials placed in the annular space between the borehole and riser pipe and screen include a sand pack when necessary, a bentonite seal, and cement-bentonite grout. The sand pack is usually a medium- to coarse-grained poorly graded, silica sand and should relate to the grain size of the aquifer sediments. The quantity of sand placed in the annular space is dependent upon the length of the screened interval, but should always extend at least 1 foot above the top of the screen. At least 1 to 3 feet of bentonite pellets or equivalent shall be placed above the sand pack. Cement-bentonite grout (or equivalent) is then placed to extent from the top of the bentonite pellets to the ground surface.

On occasion, and with the concurrence of the involved regulatory agencies, monitoring wells may be packed naturally (i.e., no artificial sand pack installed). In this case, the natural formation material is allowed to collapse around the well screen after the well is installed. This method has been used where the formation material itself is a relatively uniform grain size, or when artificial sand packing is not possible due to borehole collapse.

Bentonite expands by absorbing water and provides a seal between the screened interval and the overlying portion of the annular space and formation. Cement-bentonite grout is placed on top of the bentonite pellets, extending to the surface. The grout effectively seals the remaining borehole annulus and eliminates the possibility for surface infiltration reaching the screened interval. Grouting also replaces material removed during drilling and prevents hole collapse and subsidence around the well. A tremie pipe should be used to introduce grout from the bottom upward, to prevent bridging, and to provide a better seal. In shallow boreholes that don't collapse, it may be more practical to pour the grout from the surface without a tremie pipe.

Grout is a general term which has several different connotations. For all practical purposes within the monitoring well installation industry, grout refers to the solidified material which is installed and occupies the annular space above the bentonite pellet seal. Grout, most of the time, is made up of one or two assemblages of material, (e.g., cement and/or bentonite). A cement-bentonite grout, which is the most common type of grout used in monitoring well completions, normally is a mixture of cement, bentonite, and water at a ratio of one 90-pound bag of Portland Type I cement, plus 3 to 5 pounds of granular or flake-type bentonite, and 6-7 gallons of water. A neat cement consists of one ninety-pound bag of Portland Type I cement and 6-7 gallons of water. A bentonite slurry (bentonite and water mixed to a thick but pumpable mixture) is sometimes used instead of grout for deep well installations where placement of bentonite pellets is difficult. Bentonite chips are also occasionally used for annular backfill in place of grout.

In certain cases, the borehole may be drilled to a depth greater than the anticipated well installation depth. For these cases, the well shall be backfilled to the desired depth with bentonite pellets/chips or sand. A short (1- to 2-foot) section of capped riser pipe sump is sometimes installed immediately below the screen, as a silt reservoir, when significant post-development silting is anticipated. This will ensure that the entire screen surface remains unobstructed.

5.2.4 Protective Casing

When the well is completed and grouted to the surface, a protective steel casing is typically placed over the top of the well. This casing generally has a hinged cap and can be locked to prevent vandalism. The protective casing has a larger diameter than the well and is set into the wet cement grout over the well upon completion. In addition, one hole is drilled just above the cement collar through the protective casing which acts as a weep hole for the flow of water which may enter the annulus during well development, purging, or sampling.

A protective casing which is level with the ground surface (flush-mounted) is used in roadway or parking lot applications where the top of a monitoring well must be below the pavement. The top of the riser pipe is placed 4 to 5 inches below the pavement, and a locking protective casing is cemented in place to 3 inches below the pavement. A large diameter, manhole-type protective collar is set into the wet cement around the well with the top set level with or slightly above the pavement. An appropriately-sized id is placed over the protective sleeve. The cement should be slightly mounded to direct pooled water away from the well head.

5.3 Monitoring Well Installation

Pertinent data regarding monitoring well installation shall be recorded on log sheets as depicted and discussed in SOP SA-6.3. Attachments to this referenced SOP illustrate terms and physical construction of various types of monitoring wells.

5.3.1 Monitoring Wells in Unconsolidated Sediments

After the borehole is drilled to the desired depth, well installation can begin. The procedure for well installation will partially be dictated by the stability of the formation in which the well is being placed. If the borehole collapses immediately after the drilling tools are withdrawn, then a temporary casing must be installed and well installation will proceed through the center of the temporary casing, and continue as the temporary casing is withdrawn from the borehole. In the case of hollow-stem auger drilling, the augers will act to stabilize the borehole during well installation.

Before the screen and riser pipe are lowered into the borehole, all pipe and screen sections should be measured with an engineer's rule to ensure proper placement. When measuring sections, the threads on one end of the pipe or screen must be excluded while measuring, since the pipe and screen sections are screwed flush together.

After the screen and riser pipe are lowered through the temporary casing, the sand pack can be installed. A weighted tape measure must be used during the installation procedure to carefully monitor installation progress. The sand is slowly poured into the annulus between the riser pipe and temporary casing, as the casing is withdrawn. Sand should always be kept within the temporary casing during withdrawal in order to ensure an adequate sand pack. However, if too much sand is within the temporary casing (greater than 1 foot above the bottom of the casing) bridging between the temporary casing and riser pipe may occur. Centralizers may be used at the geologist's discretion, one above and one below the screen, to assure enough annular space for sand pack placement.

After the sand pack is installed to the desired depth (at least 1 foot above the top of the screen), then the bentonite pellet seal (or equivalent), can be installed in the same manner as the sand pack. At least 1 to 3 feet of bentonite pellets should be installed above the sand pack. Pellets should be added slowly and their fall monitored closely to ensure that bridging does not occur.

The cement-bentonite grout is then mixed and tremied into the annulus as the temporary casing or augers are withdrawn. Finally, the protective casing can be installed as detailed in Section 5.2.4.

5.3.2 Confining Layer Monitoring Wells

When drilling and installing a well in a confined aquifer, proper well installation techniques must be applied to avoid cross contamination between aquifers. Under most conditions, this can be accomplished by installing double-cased wells. This is accomplished by drilling a large-diameter boring through the upper aquifer, 1 to 5 feet into the underlying confining layer, and setting and pressure grouting or tremie grouting a large-diameter casing into the confining layer. The grout material must fill the space between the native material and the outer casing. A smaller diameter boring is then continued through the confining layer for

installation of the monitoring well as detailed for overburden monitoring wells. Sufficient time (determined by the field geologist), must be allowed for setting of the grout prior to drilling through the confined layer.

5.3.3 Bedrock Monitoring Wells

When installing bedrock monitoring wells, a large diameter boring is drilled through the overburden and approximately 5 –10 feet into bedrock. A casing (typically steel) is installed and either pressure grouted or tremie grouted in place. After the grout has cured, a smaller diameter boring is continued into bedrock to the desired depth. If the boring does not collapse, the well can be left open, and a screen is not necessary. If the boring collapses, then a screen is required and can be installed as detailed for overburden monitoring wells. If a screen is to be used, then the casing which is installed through the overburden and into the bedrock does not require grouting and can be removed when the final well installation is completed.

5.3.4 Drive Points

Drive points can be installed with either a sledge hammer, drop hammer, or a mechanical vibrator. The screen section is threaded and tightened onto the riser pipe with pipe wrenches. The drive point is simply pounded into the subsurface to the desired depth. If a heavy drop hammer is used, then a tripod and pulley setup is required to lift the hammer. Drive points typically cannot be manually driven to depths exceeding 10 feet.

Direct push sampling/monitoring point installation methods, using a direct push rig or drilling rig, are described in SOP SA-2.5.

5.3.5 Innovative Monitoring Well Installation Techniques

Certain innovative sampling devices have proven advantageous. These devices are essentially screened samplers installed in a borehole with only small-diameter tubes extending to the surface. This reduces drilling costs, decreases the volume of stagnant water, and provides a sampling system that minimizes cross-contamination from sampling equipment. Four manufacturers of these samplers include Timco Manufacturing Company, Inc., of Prairie du Sac, Wisconsin, BARCAD Systems, Inc., of Concord, Massachusetts, Westbay Instruments Ltd. of Vancouver, British Columbia, Canada and the University of Waterloo at Waterloo, Ontario, Canada.. Each manufacturer offers various construction materials.

5.4 Well Development Methods

The purpose of well development is to stabilize and increase the permeability of the gravel pack around the well screen, and to restore the permeability of the formation which may have been reduced by drilling operations. Wells are typically developed until all fine material and drilling water is removed from the well. Sequential measurements of pH, conductivity, turbidity, and temperature taken during development may yield information (stabilized values) regarding whether sufficient development has been performed. The selection of the well development method shall be made by the field geologist and is based on the drilling methods, well construction and installation details, and the characteristics of the formation that the well is screened in. The primary methods of well development are summarized below. A more detailed discussion may be found in Driscoll (1986).

5.4.1 Overpumping and Backwashing

Wells may be developed by alternatively drawing the water level down at a high rate (by pumping or bailing) and then reversing the flow direction (backwashing) so that water is passing from the well into the formation. This back and forth movement of water through the well screen and gravel pack serves to

remove fines from the formation immediately adjacent to the well, while preventing bridging (wedging) of sand grains. Backwashing can be accomplished by several methods, including pouring water into the well and then bailing, starting and stopping a pump intermittently to change water levels, or forcing water into the well under pressure through a water-tight fitting ("rawhiding"). Care should be taken when backwashing not to apply too much pressure, which could damage or destroy the well screen.

5.4.2 Surging with a Surge Plunger

A surge plunger (also called a surge block) is approximately the same diameter as the well casing and is aggressively moved up and down within the well to agitate the water, causing it to move in and out of the screens. This movement of water pulls fine materials into the well, where they may be removed by any of several methods, and prevents bridging of sand particles in the gravel pack. There are two basic types of surge plungers; solid and valved surge plungers. In formations with low yields, a valved surge plunger may be preferred, as solid plungers tend to force water out of the well at a greater rate than it will flow back in. Valved plungers are designed to produce a greater inflow than outflow of water during surging.

5.4.3 Compressed Air

Compressed air can be used to develop a well by either of two methods: backwashing or surging. Backwashing is done by forcing water out through the screens, using increasing air pressure inside a sealed well, then releasing the pressurized air to allow the water to flow back into the well. Care should be taken when using this method so that the water level does not drop below the top of the screen, thus introducing air into the formation and reducing well yield. Surging, or the "open well" method, consists of alternately releasing large volumes of air suddenly into an open well below the water level to produce a strong surge by virtue of the resistance of water head, friction, and inertia. Pumping of the well is subsequently done using the air lift method.

5.4.4 High Velocity Jetting

In the high velocity jetting method, water is forced at high velocities from a plunger-type device and through the well screen to loosen fine particles from the sand pack and surrounding formation. The jetting tool is slowly rotated and raised and lowered along the length of the well screen to develop the entire screened area. Jetting using a hose lowered into the well may also be effective. The fines washed into the screen during this process can then be bailed or pumped from the well.

6.0 RECORDS

A critical part of monitoring well installation is recording of all significant details and events in the site logbook or field notebook. The geologist must record the exact depths of significant hydrogeological features, screen placement, gravel pack placement, and bentonite placement.

A Monitoring Well Sheet (see Attachments to SOP SA-6.3) shall be completed, ensuring the uniform recording of data for each installation and rapid identification of missing information. Well depth, length, materials of construction, length and openings of screen, length and type of riser, and depth and type of all backfill materials shall be recorded. Additional information shall include location, installation date, problems encountered, water levels before and after well installation, cross-reference to the geologic boring log, and methods used during the installation and development process. Documentation is very important to prevent problems involving questionable sample validity. Somewhat different information will need to be recorded, depending on whether the well is completed in overburden (single- or double-cased), as a cased well in bedrock, or as an open hole in bedrock.

The quantities of sand, bentonite, and grout placed in the well are also important. The geologist shall calculate the annular space volume and have an idea of the quantity of material needed to fill the annular

space. Volumes of backfill significantly higher than the calculated volume may indicate a problem such as a large cavity, while a smaller backfill volume may indicate a cave-in or bridging of the backfill materials. Any problems with rig operation or down-time shall be recorded and may affect the driller's final fee.

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ATTACHMENT A

RELATIVE COMPATIBILITY OF RIGID WELL CASING MATERIAL (PERCENT)

Potentially-Deteriorating Substance	Type of Casing Material						
	PVC 1	Galvanized Steel	Carbon Steel	Lo-carbon Steel	Stainless Steel 304	Stainless Steel 316	Teflon*
Buffered Weak Acid	100	56	51	59	97	100	100
Weak Acid	98	59	43	47	96	100	100
Mineral Acid/ High Solids Content	100	48	57	60	80	82	100
Aqueous/Organic Mixtures	64	69	73	73	98	100	100
Percent Overall Rating	91	58	56	59	93	96	100

Preliminary Ranking of Rigid Materials:

1 Teflon®
2 Stainless Steel 316
3. Stainless Steel 304
4 PVC 1
5 Lo-Carbon Steel
6 Galvanized Steel
7 Carbon Steel

* Trademark of DuPont

RELATIVE COMPATIBILITY OF SEMI-RIGID OR ELASTOMERIC MATERIALS (PERCENT)

Potentially-Deteriorating Substance	Type of Casing Material								
	PVC Flexible	PP	PE Conv.	PE Linear	PMM	Viton®*	Silicone	Neoprene	Teflon®*
Buffered Weak Acid	97	97	100	97	90	92	87	85	100
Weak Acid	92	90	94	96	78	78	75	75	100
Mineral Acid/ High Solids Content	100	100	100	100	95	100	78	82	100
Aqueous/Organic Mixtures	62	71	40	60	49	78	49	44	100
Percent Overall Rating	88	90	84	88	78	87	72	72	100

Preliminary Ranking of Semi-Rigid or Elastomeric Materials:

1 Teflon®
2 Polypropylene (PP)
3. PVC Flexible/PE Linear
4 Viton®
5 PE Conventional
6 Plexiglas/Lucite (PMM)
7 Silicone/Neoprene

* Trademark of DuPont

Source: Barcelona et al., 1983

ATTACHMENT B

COMPARISON OF STAINLESS STEEL AND PVC FOR MONITORING WELL CONSTRUCTION

Characteristic	Stainless Steel	PVC
Strength	Use in deep wells to prevent compression and closing of screen/riser.	Use when shear and compressive strength are not critical.
Weight	Relatively heavier.	Light-weight; floats in water.
Cost	Relatively expensive.	Relatively inexpensive.
Corrosivity	Deteriorates more rapidly in corrosive water.	Non-corrosive -- may deteriorate in presence of ketones, aromatics, alkyl sulfides, or some chlorinated hydrocarbons.
Ease of Use	Difficult to adjust size or length in the field.	Easy to handle and work with in the field.
Preparation for Use	Should be steam cleaned if organics will be subsequently sampled.	Never use glue fittings -- pipes should be threaded or pressure fitted. Should be steam cleaned when used for monitoring wells.
Interaction with Contaminants*	May sorb organic or inorganic substances when oxidized.	May sorb or release organic substances.

* See also Attachment A.

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1.0 PURPOSE

Well abandonment is that procedure by which any monitoring well is permanently closed. Abandonment procedures are designed to prevent fluids from entering or migrating within the monitoring well. Therefore, an abandoned monitoring well must be sealed in such a manner that it can not act as a conduit for migration of contaminants from the ground surface to the water table or between aquifers.

It is important that the appropriate state or local agency be notified of monitoring well abandonment. The application of and adherence to this SOP must be tailored to applicable state, local, and Federal regulatory requirements.

2.0 SCOPE

The methods described in this procedure shall be used for all projects requiring well abandonment where specific state, local, or Federal regulations are unavailable. An abandoned well shall be filled and sealed so that it will not act as a pathway for the interchange of water between the surface and subsurface or present a hazard to the environment.

3.0 GLOSSARY

Well - Any constructed access point to an aquifer, confined or unconfined, including, but not limited to, test borings, hydropunch holes, monitoring points, and production wells.

Abandon - To permanently discontinue the use of a well. Any well shall require abandonment when it is no longer serving as a monitoring point or is in such a state of disrepair that continued use for the purpose of obtaining groundwater is impracticable, or when it has been permanently disconnected from any water supply system or irrigation system.

4.0 RESPONSIBILITIES

Project Manager - It shall be the responsibility of the Project Manager and/or Project Hydrogeologist to determine the applicability of well abandonment, based on the established scope and objective of the project and program-specific requirements. It shall be the responsibility of the Project Manager (or designee) to ensure that the procedures established for well abandonment are thoroughly specified and/or referenced in the relevant project planning documents. It shall be the responsibility of the Project Manager to ensure that the Field Operations Leader is familiar with the proper procedures for well abandonment and confirm the supervising project geologist or the subcontractor performing the well abandonment are qualified to perform such activities.

Field Operations Leader (FOL) - It shall be the responsibility of the Field Operations Leader to ensure that all field technicians and/or drilling personnel are thoroughly familiar with this Standard Operating Procedure. It shall be the responsibility of the FOL to ensure that the procedures identified in this SOP are used during well abandonment.

5.0 PROCEDURES

5.1 General

Well abandonment is warranted when the project team has reason to believe, on the basis of local conditions, that the well is causing or is a potential source of pollution to an aquifer; is a production well that is producing water that is polluted; or does not have a certificate of potability, if required. Wells may

also be abandoned once their designed purposes have been fulfilled and are determined to no longer be of use.

Well abandonment is conducted to eliminate physical hazards, prevent groundwater contamination, prevent intermixing of aquifer waters, and conserve aquifer yield and hydrostatic head.

Please note Federal, state, and local regulations concerning this activity may vary. Therefore, applicable regulatory requirements should be reviewed to determine the need for Licensed/Certified Well Drillers to complete/oversight this activity.

5.2 Material for Sealing

Acceptable sealing materials include concrete, portland cement grout, sodium-base bentonite clay, or combinations of these materials. These materials are defined as follows:

- Concrete may be used for filling the upper part of a well or water bearing formation, or plugging short sections of casing and filling large diameter wells.

- Portland cement grout is superior for sealing small openings, penetrating any annular space outside the casing, and for filling voids in the surrounding formation. Portland cement grout shall be composed of one bag of Type I cement per 6 to 8 gallons of water. Two parts sand to one part cement may be added.

- Bentonite clay, when applied as a heavy mud-laden fluid under pressure, has most of the advantages of cement grout, but under some conditions may be carried away into the surrounding formation. A bentonite clay mixture shall be composed of not less than 2 pounds of clay per gallon of water. Bentonite clay may not be used where it will come in contact with water of a pH below 5.0 or total dissolved solids (TDS) content greater than 1,000 mg/L or both. Bentonite may also be added to cement grout to add flexibility.

Fill materials include clay, silt, sand, gravel, crushed stone, or a mixtures of these materials may be used as a filler in sealing a well when used in conjunction with the sealing materials described above. Organic material may not be used and fill material may be required to be disinfected or certified clean prior to use. Spent drilling muds or drill cuttings are not to be used to seal a well.

5.3 Procedures for Sealing Wells

5.3.1 Preliminary Considerations

Several factors should be considered to determine the appropriate well abandonment method. These factors include:

- Conditions of the well.
- Details of well construction, including casing material, diameter of casing, depth of well, and well plumbness.
- Obstructions within the well that may interfere with filling or sealing.
- Hydrogeologic setting.
- Level of contamination and the zone or zones where it occurs.
- Regulatory requirements.

Degraded wells may not permit casing removal by pulling. Also, the casing material may dictate whether a casing can be removed intact. Stainless steel will have a higher tensile strength than PVC and may hold

together while pulling the casing; PVC well casing may break under pulling and may need to be overdrilled to remove it. The depth of the well and well plumbness may limit casing removal depending on whether a casing is pulled or overdrilled. In some cases, casings can be left in-place if they are properly filled with appropriate backfill.

The formation lithology influences the selection of casing removal. Unconsolidated materials can be drilled with hollow-stem augering techniques whereas consolidated materials cannot. Unconsolidated materials may also cave-in during well casing removal.

5.3.2 Filling and Sealing Procedures

Drilled wells (all wells not dug) shall be filled with sealing material or a combination of sealing material and fill material.

In some cases, well casing removal is necessary for well abandonment. If the borehole is unstable and may cave-in, sealing material will be emplaced simultaneously during casing removal. If the well is not grouted, casing may be pulled with hydraulic jacks or a drilling rig. It may also be pulled by sandlocking. Sandlocking consists of lowering a pipe wrapped with burlap approximately 2/3 of the well depth and filling the burlap wrap with sand. The pipe is slowly lifted and locks the sand, pulling the casing. Well casings can also be removed by overdrilling. Wells can be overdrilled with larger diameter hollow steam or solid stem augers or direct rotary techniques, using air or mud. Augers used for overdrilling should be at least 2 inches larger in diameter than the diameter of the well casing.

If well casing is in poor condition or is grouted in place, the casing may be ripped or perforated and filled and pressure grouted in place.

Abandoned wells shall be filled with the appropriate filling and sealing material placed from the bottom of the well upward. When Portland cement grout or concrete is used, it shall be placed in continuous operation using a tremie pipe. Sealing material shall be placed in the interval or intervals to be sealed by methods that prevent free fall, dilution, and/or separation of aggregates from cementing material.

A well constructed in unconsolidated material in an unconfined groundwater zone shall be filled and sealed by placing fill material in the well to the level of the water table, and filling the remainder of the well with sealing material. If the water table is at a depth greater than 40 feet, a minimum of 40 feet of sealing material shall be required.

A well which penetrates several aquifers or formations shall be filled and sealed in such a way as to prevent the vertical movement of water from one aquifer or formation to another. If the casing has been removed, sealing material shall be placed opposite the confining formations and from the surface down to the first confining formation. Sand and other suitable fill material may be placed opposite the producing aquifer. Ideally, the entire well can be filled with sealing material. If the casing has not been removed, the entire well shall be fill with sealing material.

A well penetrating creviced or cavernous rock shall be filled using coarse fill material opposite the cavernous or creviced rock portions of the well. Sealing material shall extend from the top of the unfractured rock portion of the well or base of the casing, whichever is deeper, to the surface. The minimum depth of sealing material may not be less than 10 feet.

In the case where wells penetrate specific aquifers where conditions necessitate the sealing of specific aquifers or formations, the annular space in the area of the specific aquifer or formation shall be sealed during the abandonment of the well.

A dug well exceeding 24 inches in diameter shall be filled and sealed by placing fill material (excluding clay or silt) in the well to a level approximately 5 feet below the land surface, and placing a 3 foot plug of sealing material above the fill. The remainder of the well shall be back filled with soil material.

6.0 REFERENCES

Maryland Department of the Environment (MDE Regulations); Title 26, Subtitle 04; Regulation of Water Supply, Sewage Disposal, and Solid Waste; Chapter 4--Well Construction.

U.S. EPA, February 1990. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells.

26.04.04.11

.11 Abandonment Standards.

A. In this regulation, the term "well" shall also include all test holes drilled in the exploration of coal, oil, and gas, or for gas storage, which penetrate into or through an aquifer, confined or unconfined.

B. "Abandon" means to permanently discontinue the use of a well. Any well shall be deemed abandoned when it is in such a state of disrepair that continued use for the purpose of obtaining ground water is impracticable, or when it has been permanently disconnected from any water supply system or irrigation system.

C. Objective. The objective of the standards described in this regulation is to restore as nearly as possible those subsurface conditions which existed before the well was constructed, taking into account changes, if any, which have occurred since the time of construction.

D. General Requirements.

(1) An abandoned well shall be filled and sealed in such a way that it will not:

(a) Act as a channel for the interchange of waters of undesirable quality with those whose quality is desirable; or

(b) Present a hazard to the safety and well-being of humans or animals.

(2) The Department or Approving Authority may require the well owner to have a well abandoned and sealed if it:

(a) Is causing or is a potential source of pollution of waters of the State;

(b) Is producing water that is polluted; or

(c) Does not have a certificate of potability, if required.

(3) Any well abandoned shall be sealed only by a well driller licensed by the Maryland State Board of Well Drillers or under the supervision of a master well driller or a representative of the Department or Approving Authority.

(4) Abandonment Approval. When the Department or Approving Authority has reason to believe on the basis of local conditions that abandonment of a well necessitates close supervision, it may require the submission of sealing plans and specifications for approval before abandonment operations.

(5) Observation Wells. Wells used for the investigation or management of ground water are not considered "abandoned" so long as they are maintained for this purpose. Wells without pumps shall be covered with a secure cap when measurements are not being made.

(6) Reports on the Abandonment of Wells. When a well is abandoned, the person abandoning it, or the owner, shall notify the Approving Authority of this action by completing an Abandoned Well Report form provided by the Approving Authority. This report shall be submitted not later than 30 days after abandonment of the well or test hole.

E. Materials for Filling and Sealing Wells.

(1) Sealing Materials.

(a) Concrete, Portland cement grout, sodium-base bentonite clay, or combinations of these materials may be used to seal a well.

(b) Used drilling muds are not to be used to seal a well.

(c) Concrete. Concrete may be used for filling the upper part of the well or water bearing formation, or plugging short sections of casing and filling large diameter wells.

(d) Portland cement grout is superior for sealing small openings, penetrating any annular space outside the casing, and for filling voids in the surrounding formation. Portland cement grout shall be composed of one bag of cement per 5 to 8 gallons of water. Two parts sand to one part cement may be added.

(e) Bentonite clay, when applied as a heavy mud-laden fluid under pressure, has most of the advantages of cement grout but under some conditions may be carried away into the surrounding formation. A bentonite clay mixture shall be composed of not less than 2 pounds of clay per gallon of water. Bentonite clay may not be used where it will come in contact with waters of a pH below 5.0 or total dissolved solids content greater than 1,000 mg/l or both.

(2) Fill materials. Clay, silt, sand, gravel, crushed stone, mixtures of these materials, and sealing materials described in § D(1) may be used as a filler in sealing a well. In the abandonment of an unsuccessful well, the drill cuttings may be used as fill material. Material containing organic matter may not be used. The Department or Approving Authority may require that fill material be disinfected.

F. Procedures for Sealing Wells.

(1) Preliminary Work.

(a) Before filling the hole, the well should be investigated to determine its condition, details of construction, and if there are obstructions which will interfere with the process of filling and sealing.

(b) If there are any obstructions, they shall be removed, if possible, by cleaning the hole or by redrilling.

(c) The casing shall be removed. If sidewall cave-in is likely to occur, the casing shall be removed gradually as the well is filled.

(d) In drilled wells, if it is not possible to remove the casing, the casing may be ripped or perforated to assure that sealing material fills all annular spaces and voids.

(2) Filling and Sealing Wells.

(a) A dug well exceeding 24 inches in diameter shall be filled and sealed by placing fill material (excluding clay or silt) in the well to a level approximately 5 feet below the land surface, and placing a 3 foot plug of sealing material above the fill. The remainder of the well shall be back filled with soil material.

(b) For other than dug wells, a well shall be filled with sealing material or a combination of sealing material and fill material as described below:

(i) A well in unconsolidated material in an unconfined ground water zone (Hydrogeologic Area 1) shall be filled and sealed by placing fill material in the well to the level of the water table, and filling the remainder of the well with sealing material. If the water table is at a depth greater than 40 feet, a minimum of 40 feet of sealing material shall be required.

(ii) Well Penetrating Several Aquifers or Formations.

(aa) A well penetrating several aquifers or formations (Hydrogeologic Area 2) shall be filled and sealed in such a way as to prevent the vertical movement of water from one aquifer or formation to another.

(bb) If the casing has been removed, sealing material shall be placed opposite confining formations, and from the surface down to the first confining formation. Sand and other suitable fill material may be placed opposite the producing aquifer. The driller has the option to fill the entire well with sealing material.

(cc) If the casing has not been removed, the entire well shall be filled with sealing material.

(iii) Well Penetrating Creviced or Cavernous Rock. In Hydrogeologic Areas 3 and 4, coarse fill material may be used opposite the cavernous or creviced rock portions of the well. Sealing material shall extend from the top of the hard rock portion of the well or base of the casing, whichever is deeper, to the surface. The minimum depth of sealing material may not be less than 10 feet.

(iv) Well Penetrating Specific Aquifers--Local Conditions. If local conditions necessitate the sealing of specific aquifers or formations, the Department or Approving Authority may require that the annular space in the area of the specific aquifers or formations be sealed during abandonment of the well.

G. Placement of Material. The following standards shall be met in placing fill or sealing materials:

(1) The well shall be filled with the appropriate material placed from the bottom of the well upward;

(2) When Portland cement grout or concrete is used, it shall be placed in one continuous operation;

(3) Sealing material shall be placed in the interval or intervals to be sealed by methods that prevent free fall, dilution, and/or separation of aggregates from cementing materials;

(4) For artesian aquifers with a large hydraulic (pressure head), it may be necessary to control the head or flow while placing the sealing material. In these cases, the casing shall be ripped or perforated opposite the area to be sealed and the sealing material shall be forced under pressure into the surrounding formation.

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1.0 PURPOSE

The purpose of this guideline is to provide a general description of, and technical management guidance on, the use of Resistivity and Electromagnetic Induction (Ground Conductivity) surveys during hazardous waste site investigations.

2.0 SCOPE

This guideline provides a description of the principles of operation, instrumentation, applicability, and implementability of geophysical methods used during hazardous waste site investigations to determine subsurface resistivity or conductivity. Measurements of subsurface conductivity or resistivity can be used to determine the presence and approximate extent of subsurface contaminants, buried drums, and metal containers. In addition, the depth to the water table, and structural characteristics of the subsurface environment can be determined.

This document is intended to help develop a sufficient understanding of each method to assist in proper work plan development and scheduling, resource planning, subcontractor procurement and evaluation, and manipulation and use of the technical data during remedial investigations and feasibility studies. This guidance is not intended to provide a detailed description of methodology and operation. The highly specialized nature of these methods requires inclusion of project-specific, site-specific, and subcontractor-specific information prior to development of detailed operating procedures. Specialized expertise during both planning and execution of these geophysical methods is also required.

The description focuses on methods and equipment that are readily available and typically applied; it is not intended to provide a complete discussion of the state of the art.

3.0 GLOSSARY

Apparent Conductivity - The quantity measured during an electromagnetic induction survey; proportional to the actual conductivities of subsurface materials.

Apparent Resistivity - The quantity actually deduced during a resistivity survey; proportional to the actual resistivities of subsurface materials.

Conductivity - Intrinsic property of a substance, equal to the reciprocal of resistivity.

Current - The quantity of charge transmitted per unit time.

Electromagnetic (EM) Induction Survey - A geophysical exploration method whereby electromagnetic fields are induced in the ground and the resultant secondary electromagnetic fields are detected as a measure of ground conductivity.

Potential - Intrinsic property of electrical fields, equating to the ability to do work. A potential field can induce a potential difference (voltage) between two electrodes.

Resistivity - Intrinsic property of a substance, equal to the resistance of a body multiplied by its cross-sectional area and divided by its length.

Resistivity Survey - A geophysical exploration method whereby an electrical current is transmitted into the ground and the resultant potential field is measured to deduce the apparent subsurface resistivity.

4.0 RESPONSIBILITIES

Project Manager - responsible for the scoping of geophysical surveys during development of the Work Plan, with the help of the Field Operations Leader, site geologist, and site geophysicist.

Field Operations Leader (FOL) – Responsible for overall management and coordination of the field work.

Site Geophysicist - as a specialist in this field, the site geophysicist plays a central role in determining the appropriateness of these techniques for providing necessary data. Field work for these surveys is supervised by the site geophysicist.

5.0 PROCEDURES

5.1 Electromagnetics

The electromagnetic induction (EM) method provides a means of measuring the electrical conductivity of subsurface soil, rock, and groundwater. Electrical conductivity is a function of the type of soil and rock, its porosity, its permeability, and the fluid composition and saturation. In most cases the conductivity of the pore fluids will be responsible for the measurement. Accordingly, the EM method applies both to assessment of natural geohydrologic conditions and to mapping of many types of contaminant plumes. In addition, trench boundaries, buried wastes, drums, and utility lines can be located with EM techniques.

5.1.1 Applicability

Although EM is not a definitive technique, it is useful for several reasons. First, an EM survey can be conducted over an entire site very quickly. In addition, EM methods are generally inexpensive, even for coverage of large areas. Often, 100 acres or more may be surveyed in just a few days time (depending on desired detail). More importantly, EM data can be used to focus the more expensive phases of an investigative project, potentially resulting in a large cost savings. For example, rather than drilling several dozen monitoring wells while searching for groundwater contamination, an EM conductivity unit may be used to survey for a conductive (or resistive) plume. Several EM survey lines may be run to provide definition of the plume and an indication of its source area, reducing the number of exploratory wells required and potentially resulting in better well placement providing a potentially significant cost savings. Another reason why EM should be considered is to fill in data gaps and to reduce the risk of missing a facet of the investigation, such as the presence of undetected refuse trenches, buried drums, or changing hydrologic conditions.

Electromagnetic methods may be used in many situations for a variety of purposes. The following list includes major uses related to investigations of hazardous waste sites:

- Defining the location of a contaminant plume [This could lead to the identification of downgradient receptors, source areas, and flow directions if the conductivity of the plume (target) is distinct in comparison to the host (background), hydrogeologic setting.]
- Locating buried metal objects (e.g., drums, tanks, pipelines, cables, monitoring wells).
- Addressing the presence or location of bedrock fault/fracture systems (This is important for identification of groundwater preferential pathways in bedrock.)
- Mapping grain size distributions in unconsolidated sediments.
- Mapping buried trenches and contaminated fill materials.

- Mapping saltwater intrusion.
- Defining lithological (unit) boundaries.
- Determining the rate of plume movements by conducting multiple surveys over time.

The above list is only partial; in fact, EM methods may be used wherever a significant change in conductance can be measured. EM should be considered for use when a suspected target is anticipated to have a conductivity significantly different from background values. Factors such as cost, site-specific conditions, and equipment availability should also be evaluated before deciding to proceed with an EM survey.

5.1.2 General

5.1.2.1 Objectives

The site geophysicist should evaluate the objectives of the site investigation in light of EM capabilities. If the purpose of the site investigation is to confirm the presence of contaminants with minimal effort, EM methods may provide too much detail and no direct evidence. Direct methods, on the other hand, such as installing monitoring wells with limited sampling, may be more suitable. If a site is to be characterized in detail and if assessment of hydrogeologic conditions and identification of all source areas, plumes, and receptors are a priority, then EM (and other geophysical methods) may be a more cost-effective way of selecting strategic locations for monitoring wells, directing test pit operations, efficiently selecting sampling points, and providing information between site sampling points.

5.1.2.2 Existing Data

If EM equipment is identified as a viable alternative for providing the type of information desired, the user should further evaluate the equipment to determine whether it is appropriate for use under the conditions found at a particular site. Evaluation of existing data can identify problems that may be encountered in the field:

- Variations in hydrogeologic conditions (e.g., varied water table conditions or changes in rock or sediment) can result in a conductivity range that envelopes the response of the target (e.g., plume) and effectively masks or blocks out any signals.
- Scattered, near-surface metal may mask buried targets such as drums or trenches.
- Anthropogenic features such as overhead powerlines, buried metallic pipes, etc., may decrease the signal to noise ratio making the technique ineffective.

An analysis of the site history might more closely define a survey area, thereby cutting survey costs by reducing the size of the survey. Deep targets may be out of the penetration range for many EM units, and specialized equipment may be required. It is difficult for EM systems to detect a groundwater contaminant plume through 100 feet of unsaturated overburden. A site reconnaissance should be conducted to identify other site conditions that may affect the data. Drastic topography changes can affect the quality of EM data obtained with some systems, and this possibility should be considered at each site.

5.1.3 Survey Design

Once the EM survey objectives have been defined, existing information has been reviewed, and reconnaissance of the site has been conducted, attention should be given to the design of the geophysical survey. The detail required of an EM survey is a primary factor in designing and planning fieldwork. If the purpose of performing EM work on site is to define a large geologic feature, then a grid using a wide (100- to 1,000-foot) line spacing may be needed. Some instruments are capable of providing a continuous data profile, which makes it less likely to miss small conductors than the typical discrete measurement EM instruments. The importance of designing and implementing a grid system tied into existing "permanent" features (such as roads and buildings) cannot be overstated. This permanent feature will allow the grid to be re-established in the field at a later time in order to place drill holes and monitoring wells. Furthermore, additional surveys may be conducted on the site over time using other geophysical techniques or the same technique to provide an indication of plume movement. These surveys will help in orienting maps and diagrams that are produced later and in defining targets.

5.1.3.1 Background Noise

Background noise can be a significant factor in the success of an EM survey. Evaluation of existing data and a site reconnaissance will help to identify the probable background noise level. A high noise level can make interpretation difficult and may actually cause an anomaly to be overlooked. It is difficult to delineate a conductive contaminant plume contained in overburden that has a wide natural variation in conductivity.

Noise can be divided into two groups: (1) natural, such as changing grain size distributions, steeply dipping strata, undetected mafic dikes, karstic topography, unexpected fault zones; and (2) cultural, such as power lines, houses, railroads, surface metal debris, cars, radio transmission towers, and other metal objects which are not intended to be located by the survey. Some instruments are more sensitive to certain types of noise sources than others. Because there is little published information on this subject, appropriate experience is essential.

5.1.3.2 Limitations

All EM instruments have varying limitations with regard to sensitivity and penetration. Published references, operator's manuals, and field experience should be used to evaluate instrumentation versus capability. Table 1 lists several commercially available instruments along with operator requirements and productivity estimates.

5.1.3.3 Instrumentation

Table 2 provides guidance for EM equipment selection. These instruments may not be suitable to specific site conditions and investigation objectives. The decision to use a specific instrument is dependent upon site factors.

Electromagnetic techniques have also been adapted for downhole applications. These techniques can be useful in defining the vertical extent of a contaminant zone. Some systems work inside polyvinyl chloride (PVC) or Teflon monitoring well casings (see SOP GH-3.5, Borehole Geophysical Surveys).

TABLE 1

COMMON EM AND RESISTIVITY EQUIPMENT

Instrument	Manufacturer	Minimum No. of Operators	Typical Daily Line Miles (50-ft readings)	Notes
EM-16-R	Geonics	2	2	2
EM-38	Geonics	1	3 - 4	2
EM-31-D	Geonics	1	3 - 4	2
EM-34-3	Geonics	2	2	2
PROTEM47P	Geonics	2	0.25	1
EM-61	Geonics	1	3 - 4	3
T-VLF	Iris Inst.	1	3 - 4	2
CEM	Crone	2	2	1
Max Min II	Apex	2	3	1
Syscal Resistivity Meter	Iris Inst.	2	0.5	2

Notes:
1. Primarily useful for geologic features only.
2. Useful for geologic and cultural features.
3. Primarily useful for mapping buried metals.

Designations such as EM-31 or EM-61 are the manufacturer's model numbers and do not imply equipment complexity or capability.

Table 2
Application Guidelines for Equipment Use

	Technique and Instrumentation							
Application	VLF	VLF Resistivity	Frequency Domain EM	Time Domain EM Soundings	Time Domain EM Metal Detection	Resistivity Sounding	Resistivity Profiling	Azimuthal Resistivity Surveying
Archeological Studies								
Locate Single Buried Steel Drum			X					
Locate a Cluster of Buried Steel Drums			X					
Delineate a Landfill							X	
Delineate Contaminated Soil and Fill								
Map Groundwater Contamination		X		X		X	X	
Locate Metallic Pipelines and Utilities	X		X					
Delineate USTs			X		X			
Map Stratigraphy		X	X				X	
Map Joints and Faults			X					

Notes:
- (blank) Not applicable
- X Sometimes applicable but other techniques may be more cost effective
- (shaded) Often Applicable and cost effective

5.2 Electrical Resistivity

Electrical resistivity surveys provide information about the subsurface distribution of the ground resistivity. The information can be used to infer groundwater quality, lithologic, and geologic information. Both horizontal and vertical changes in ground resistivity can be mapped by resistivity surveys. In practice, resistivity surveys are mostly used to determine the vertical resistivity changes. Lateral resistivity changes are more easily mapped by electromagnetic surveys.

5.2.1 Applicability

Electrical resistivity (ER) data are subject to interpretation; therefore, ER field results should be checked periodically and confirmed by direct methods, such as sampling or drilling.

Although ER is not a definitive technique, the data are useful for several reasons. Typical productivity with conventional resistivity equipment is several thousand line-feet per day. This high productivity rate allows a large amount of useful data to be collected in a relatively short period of time. For example, rather than drilling several dozen monitoring wells or test borings to develop a complete picture of the site stratigraphy and structure, a few wells can be drilled (for control) and information about the rest of the site can be obtained by using resistivity methods. Method integration such as this can reduce the amount of time and the costs required for a project.

Resistivity methods may be used in a wide array of situations and for a variety of purposes. The following is a partial list of major uses related to investigations of hazardous waste sites:

- Definition of a contaminant plume. (This could lead to the identification of downgradient receptors and source areas.)
- Waste pit delineation.
- Definition of bedrock fault/fracture systems.
- Water table mapping (for contour maps).
- Stratigraphic mapping of soil layers (particularly useful in overburden, discriminating clays from sands and establishing their thicknesses).
- Defining bedrock topography (valleys).

Resistivity methods may be used whenever the feature to be mapped has a contrasting resistivity with the background material.

5.2.2 General

Electrodes are typically arranged in one of several patterns, called electrode arrays, depending on the desired information. Electrical resistivity techniques can determine the vertical subsurface resistivity distribution beneath a point. In this type of survey, called vertical electrical soundings, the electrode array is expanded systematically and symmetrically about a point. For each set of electrode spacings, apparent resistivity is determined from measurements of potential and input current. The resultant plot of apparent resistivity versus electrode spacing is interpreted to provide the subsurface resistivity with depth distribution at that one particular point. Examples of three common arrays are given in Figure 1. The Wenner and Schlumberger arrays are somewhat more common than the Dipole-Dipole and other arrays. These arrays (Wenner, Schlumberger) start with a small electrode spacing that is increased to permit deeper penetration for sounding.

The manner in which the apparent resistivity changes with the electrode separation can be used to determine formation conductivity and layer thickness. To increase accuracy, the user should evaluate the interpretation of resistivity data against the existing subsurface information. With any set of apparent resistivity readings, a number of solutions are possible, so existing data must be used to select the one that fits best. A formation resistivity may be assigned, but without geological control the material is not known. Resistivity electrode arrays can also be used with constant inner-electrode spacing to develop a lateral picture of the site through profiles. Stratigraphic control is even more important when mapping lateral changes with constant electrode spacings, because layer thickness changes alone can cause changes in apparent resistivity. The desired resolution is a major factor in deciding how closely to space measurements for a given survey.

In practical application, a resistivity survey target (such as a plume or clay lens) should have a resistivity contrast (positive or negative) of 20 percent from background. This change in resistivity should be 50 percent or more to provide proper detection and delineation. For example, if a resistivity survey were conducted to delineate a groundwater contaminant plume (in overburden) with a resistivity of 200 ohm-meters, a background, saturated overburden resistivity of over 400 ohm-meters (for a conductive plume) or under 100 ohm-meters (for a resistive plume) would probably allow detection of the plume, providing other factors (such as depth) are not detrimental.

When depth sounding, resolution of individual layers has an accuracy generally around 20 percent; accuracy can be substantially more or less depending on the site conditions and operator expertise. Vertical resistivity sounding is usually less accurate than seismic refraction work, which is often conducted within a 10 percent error tolerance. However, geologic units may be distinguishable (by geophysics) only with the use of resistivity methods at some sites.

5.2.3 Survey Design

Data can be collected at randomly located stations or along survey lines. If vertical electrical soundings are performed to obtain resistivity changes with depth, then the soundings are positioned where the information is most useful. If measurements are made to map lateral resistivity changes, then the survey is best performed on a grid or on survey lines. The station spacing will be determined from the target size.

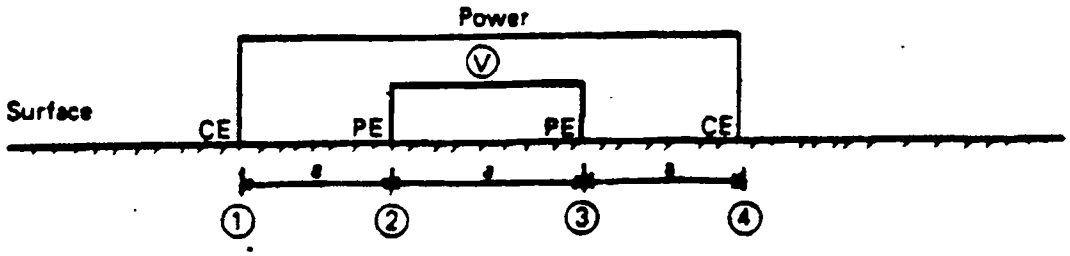
5.2.3.1 Background Noise

Evaluation of existing data and a site reconnaissance will help to identify the possible background noise level. A background high noise level can make interpretation difficult and may mask an anomaly. It would be difficult to delineate a slightly conductive contaminant plume contained in overburden that has wide natural variations in conductivity. Noise can be divided into two groups: natural, such as discontinuous clay layers, undetected mafic dikes, karstic topography, unexpected fault zones, variable water table, and lightning; and cultural, such as power lines, railroad tracks, and radio transmission towers. Since there is little published information on instrument noise sensitivity, appropriate experience is essential .

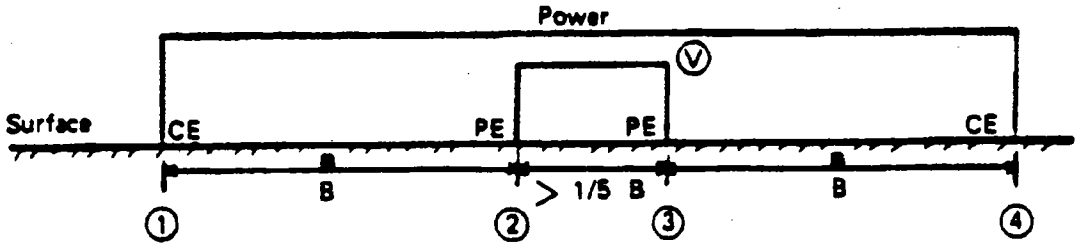
FIGURE 1

EXAMPLES OF COMMON ER ARRAYS

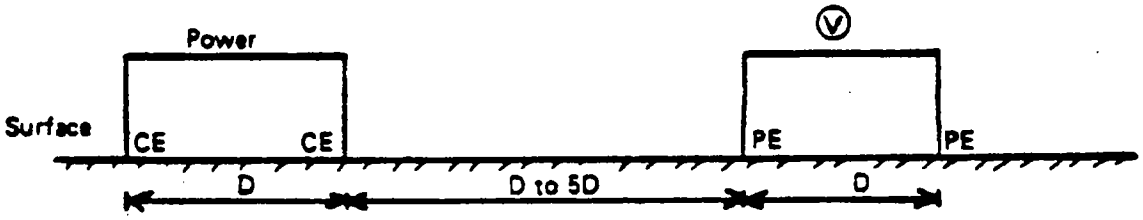
WENNER ARRAY



SCHLUMBERGER ARRAY



DIPOLE-DIPOLE ARRAY



1 Electode Number
PE Potential Electrode
CE Current Electrode
V Voltmeter

Source: Based in part on W. M. Telford et al., Applied Geophysics, 1976, and R. E. Sheriff, Encyclopedic Dictionary of Exploration Geophysics, 1984.

5.2.3.2 Depth of Investigation

As a rule of thumb when a lateral resistivity survey is being conducted , the array should be spaced four or five times the distance from the ground surface down to the desired target. For vertical sounding, this suggested spacing should be about ten times the anticipated target depth. These suggestions should be used only as general guidance.

5.2.4 Miscellaneous Considerations

5.2.4.1 Instrumentation

For most shallow work at hazardous waste sites, most resistivity systems will suffice. Generally, equipment capability becomes important only when the desired investigative depth exceeds 70 to 100 feet. Larger power sources are needed to provide a measurable electrical potential with a wider electrode spacing. Some newer resistivity units are capable of electronic data storage, and other features. Often, the peripheral capabilities of an ER system may be the deciding factor when purchase is considered.

Borehole resistivity equipment has been used (in fluid filled uncased boreholes) to determine relative formation porosity and other factors. For more information on this equipment, the reader should refer to the borehole geophysics subsection of this compendium.

5.2.4.2 Calibration

ER equipment requires calibration, either in the field or in the laboratory; dated records of this calibration should be kept in the equipment management file and in the appropriate project file. Calibration is used to establish the reliability and accuracy of the equipment; calibration typically includes an internal circuit check or actual field trials (e.g., tests over a known target). Equipment that historically exhibits fluctuations in calibration should not be used. The equipment serial number should be recorded on the calibration records. If the manufacturer recalls equipment, this fact should be explained and documented for instrument maintenance in the proper file. The current source and potentiometer must be calibrated on any type of resistivity equipment. The instrument's current source may be calibrated by placing a reference ammeter in series with the electrode cables. The reading obtained on the reference ammeter is compared with the value read from the instrument's current source ammeter. The current source ammeter is then adjusted accordingly.

The potentiometer is calibrated by either of two methods. The preferred field method, which is similar to the calibration of the current source, is done by comparing the instrument's indicated potential to that potential measured with an independent voltmeter. An alternative means of calibration, which can be performed in the laboratory, involves placing a precision resistor of a known value in series with the current load. A potentiometer is then placed across the resistor. The potential measured should be equal to the product of the known resistance and indicated current.

5.2.4.3 Data Reduction

Direct current (DC) and low frequency alternating current (AC) resistivity meters measure two values:

(1) the amount of current injected into the subsurface via the current and sink electrodes; and,
(2) the potential (voltage) between two or more electrodes that are separated a known distance apart (a-spacing).

The resistance (ohms) can be calculated from these known values using Ohm's law.

Ohm's law states the following:

$$v = ir \text{ or rearranged: } r = v/i$$

where:

v	=	voltage (volts)
i	=	current (amperes)
r	=	resistance (ohms)

Resistivity is a measurement of resistance across a distance and over a cross-sectional area. Resistivity is calculated by the following equation that assumes that the resistor is a rectangular block:

$$R = ra/L$$

where:

R	=	resistivity (commonly expressed in units of ohm-meters or ohm-feet)
r	=	resistance (v/I, in units of ohms)
a	=	cross-sectional area of the resistor
L	=	length of the resistor

When calculating resistivity in the three-dimensional earth, the resistor becomes hemispherical. Ohm's law becomes the following:

$$R = (r * 2\Pi d^2)/d \text{ or } R = (r * 2\Pi d)$$

where:

r	=	resistance (ohms)
$2\Pi d^2$	=	surface area of a hemisphere
d	=	diameter of sphere

The value for the diameter of the sphere is analogous to the distance between the potential electrodes. This distance is referred to as the "a-spacing" when using the Wenner resistivity array and is measured in units of meters or feet.

Apparent resistivity (ρ) is determined from a single measurement because the earth is heterogeneous, and horizontal layers of earth act as a circuit with resistors in parallel. True resistivity is found by performing a resistivity sounding. Resistivity soundings are produced by determining the apparent resistivity across successively increasing electrode separation distances. The results of the resistivity soundings are plotted on semi-log paper. Apparent resistivity values re plotted on a linear scale and the potential electrode separation distance is plotted on a log scale for the Wenner array. The resulting curve is then matched to a master set of curves to determine true resistivity. Alternatively, a mathematical model can be used to determine the true resistivity of each layer that is within the depth of investigation of the instrument.

Most modern resistivity meters contain a data logger that records voltage, amperes, and a-spacing values. These resistivity meters often contain processors that calculate apparent resistivity (ρ) and monitor levels of signal noise that are due to anthropogenic features or changes in geology across the measurement area. Apparent resistivity values calculated with these instruments should also be spot checked to ensure the data quality.

Several forward and inverse modeling software packages (e.g., RESIX™) exist that can be used to calculate the true resistivity of the subsurface layers. These computer models require some knowledge of the geology of the site where data collection occurs. Electric log records or estimates of the corresponding geologic layers' electrical resistivity are also required for calibration of the computer model. Typical resistivity values for various types of soil and rock are published in most geophysical textbooks.

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Steward, M. T. "Evaluation of Electromagnetic Methods for Rapid Mapping of Salt-Water Interfaces in Coastal Aquifers." Groundwater, Vol. 20. September-October 1982.

6.1.3 Manufacturers

Aerodat Limited
3883 Nashua Drive
Mississauga, Ontario L$V 1R3
416/671-2446 (airborne EM systems)
systems)

Crone Geophysics Limited
3607 Wolfedale Road
Mississauga, Ontario L5C 1V8
416/270-0096 (surface EM systems)
systems)

Geonics Limited
1745 Meyerside Drive
Mississauga, Ontario L5T 1C5
416/676-9580 (borehole and surface EM systems)

Phoenix Geophysics Limited
200 Yorkland Boulevard
Willowdale, Ontario M2J 1R5
416/493-6350 (surface EM

Scintrex
222 Snidercroft Road
Concord, Ontario L4K 1B5
416/669-2280 (surface EM

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6.2.1 Electrical Resistivity (ER) Theory and Interpretation Textbooks

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Underwood, J. W., K. J. Laudon, and T. S. Laudon. "Seismic and Resistivity Investigations near Norway, Michigan." Ground Water Monitoring Review. Fall 1984.

6.2.5 Manufacturers

ABEM-Atlas Copco
Distributed by Geotronic Corp.
10317 McKalla Place
Austin, Texas 78758

Bison Instruments, Inc.
570-8 West 36th Street
Minneapolis, Minnesota 55416

BRGM-Syscal
Distributed by EDA Instruments
5151 Ward Road

Phoenix Geophysics Limited
200 Yorkland Boulevard
Willowdale, Ontario M2J 1R5

Scintrex Limited
222 Snidercroft Road
Concord (Toronto), Ontario L4K 1B5

Wheat Ridge, Colorado 80033

7.0 RECORDS

The following information will be recorded in the field log book.

- Date
- Equipment operators
- Name and project number of site
- Position and instrument readings
- Position-specific information

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1.0 PURPOSE

The purpose of this guideline is to provide a general description of, and technical management guidance on, the use of Magnetic and Metal Detection Surveys for site investigations.

2.0 SCOPE

This guideline provides a description of the principles of operation, instrumentation, applicability, and implementability of standard geophysical methods used during site investigations to determine site features related to magnetic anomalies and buried metal. This document is intended to be used by the project manager, field operations leader, or site geologist to develop a sufficient understanding of each method and to assist in proper work plan development and scheduling, resource planning, subcontractor procurement and evaluation, and manipulation and use of the technical data during remedial investigations and feasibility studies. This guidance is not intended to provide a detailed description of methodology and operation. The highly specialized nature of the subject geophysical methods requires inclusion of project-specific, site-specific, and subcontractor-specific information prior to development of detailed operating procedures, during both planning and execution.

The description focuses on methods and equipment that are readily available and typically applied; it is not intended to provide a complete discussion of the state of the art.

3.0 GLOSSARY

Magnetic Survey -- A geophysical survey method that depends on detection of magnetic anomalies caused by the presence of buried ferromagnetic objects.

Magnetic Susceptibility -- Property of a material corresponding to its ability to distort an applied magnetic field.

Magnetometer -- A device used for precise and sensitive measurements of magnetic fields.

Magnetometry -- The science of measuring variations in the earth's magnetic field.

Metal detection -- A geophysical survey method that is based on electromagnetic coupling caused by underground conductive objects.

Vertical Gradiometer -- A magnetometer equipped with two sensors that are vertically separated a fixed distance apart. It is best suited to map near surface features and is less susceptible to deep geologic features.

4.0 RESPONSIBILITIES

Project Manager -- responsible for scoping the magnetic or metal detection surveys during development of the Work Plan with the help of the site geologist and site geophysicist.

Field Operations Leader (FOL) – responsible for overall management and coordination of the field effort.

Site Geophysicist -- central role in determining the technique used for providing necessary data. Field work for these surveys is supervised by the site geophysicist, with support from geophysical technical specialists and other personnel as needed. Data reduction and interpretation are performed by the site geophysicist or technical specialists.

5.0 PROCEDURES

5.1 Description of Methods

5.1.1 Theory and Principles of Operation

5.1.1.1 Magnetometry

Materials subject to a magnetic field will develop an induced magnetization, proportional to the applied magnetic field and the magnetic susceptibility of the material.

Induced magnetization in an object produces a local magnetic field which either reinforces (positive magnetic susceptibility) or reduces (negative susceptibility) the external applied field. The variations in an otherwise homogenous field caused by the presence of the object is called a magnetic anomaly, and observations of such anomalies can be used to infer the presence of magnetic objects.

Because there are numerous factors that affect magnetic fields there is no unique interpretation of a set of magnetometry data. Conversely, there is no unique magnetic anomaly produced by a particular kind of buried object. Factors that influence the response of a magnetometer to buried objects include the size, shape, depth, orientation, and magnetic susceptibility of the buried material. Various magnetometers are available such that many objects of interest at hazardous waste sites (particularly buried ferromagnetic materials such as drums, tanks, pipes and iron scrap) are detectable. While the location of ferromagnetic material can be detected to the precision of the survey, difficulties may be encountered in interpreting and attempting to identify the source of magnetic anomalies.

5.1.1.2 Metal Detection

When a radio frequency electromagnetic field generated by a transmitter coil encounters a highly conductive object such as metal (not necessarily ferromagnetic), alternating currents are induced in the object that, in turn, generate alternating secondary magnetic fields that are detected as alternating voltages by a receiver coil. The presence of the metal object effectively "couples" the transmitter and receiver coils, which otherwise are oriented so that little or no coupling exists. The principles of metal detector operation are very similar to those associated with electromagnetic induction instruments.

A number of factors influence the response of a metal detector. The receiver response increases with the size and surface area, and decreases with the depth of a buried object. Factors such as soil properties and object shape complicate detectability and interpretation. Certain shapes, such as elongated metal rods, are difficult to detect. Iron minerals and conductive fluids will affect the detector response in much the same manner as a target of interest. Generally, metal detectors show greater response to smaller nearby targets than to larger targets at greater depth, and the presence of widespread metallic debris at a site can interfere with attempts to detect buried drums and other objects.

5.1.2 General Applicability

5.1.2.1 Magnetic Surveys (Magnetometry)

Magnetometer and gradiometer surveys are useful in environmental and engineering projects that require a technique for mapping buried vertically oriented metallic pipe (e.g., locating a buried water well casing), or mapping stratigraphy or geologic structure in an igneous settings. Magnetometers are also a useful tool for mapping buried metallic debris, metallic utilities or metallic containers.

Magnetic surveys can more readily detect metallic masses than identify or characterize targets. Calculations of the mass or size of detected objects generally yield only approximate results.

Magnetic surveys may be impractical in areas where metal pipes, fences, railroad tracks, metal buildings, and other ferrous metal artifacts are abundant. However, proper selection of equipment and survey techniques can often alleviate some of these problems.

5.1.2.2 Metal Detectors

Metal detectors (MDs) can be used for locating buried metallic containers of various sizes; defining the boundaries of trenches containing metallic containers; locating buried metallic storage tanks; locating buried metallic pipes; avoiding buried utilities when drilling or trenching; or locating utility trenches which may provide a permeable pathway for contaminants.

The detection range of a MD is relatively short. Its sensitive areas are focused directly above and below the coil providing good definition of object location. Quart-sized metal objects can be detected at a distance of about 1 meter; objects the size of a 55 gallon drum can be detected up to 3 meters; and massive piles of metals can be detected at depths of 3 to 6 meters. Deeper objects are difficult to detect with an MD. Although most MDs are operated on foot, some can be vehicle-mounted if desired.

5.1.3 Instrumentation

5.1.3.1 Magnetometers

Three types of magnetometers, the fluxgate, proton precession, and the cesium vapor magnetometers, are commonly used at hazardous waste sites. The fluxgate magnetometer uses an iron core of high magnetic susceptibility as a sensor. The amount of coiled electrical current necessary to induce magnetic saturation of the rod is directly dependent upon, and thus measures, the strength of the ambient magnetic field. In a proton precession magnetometer a strong magnetic field is applied to a sensor filled with proton-rich fluid (e.g., kerosene) that realigns the protons. The field is then turned off and the frequency of the signal generated by the protons as they realign themselves ("precess") to the earth's magnetic field is dependent upon and measures the strength of the field at that point. The third common type of magnetometer is the cesium vapor (alkali-vapor) magnetometer. The cesium vapor magnetometer is capable of obtaining an order of magnitude greater sensitivity than the proton precession magnetometer. The cesium vapor magnetometer operates via a beam of polarized light from a cesium vapor lamp that is passed through a cell of cesium vapor. The atoms of the vapor become excited as they absorb greater amounts of the polarized light. The vapor in the cell eventually reaches an energy state that can no longer absorb the light and renders the cell transparent. A radio-frequency magnetic field causes the atoms of the vapor to shift back to an energy state that allows the vapor to again absorb the polarized light. The frequency required to return the vapor to an energy state that allows the cell to absorb light is a function of the ambient magnetic field. Some magnetometers, such as the fluxgate, are extremely sensitive to orientation during measurement. In order to alleviate this problem, two sensors are connected by a rigid pole to form a "gradiometer" that measures only a certain directional component of the earth's magnetic field. These gradiometers are commonly used at hazardous waste sites.

The type of magnetometer best suited for a particular site investigation depends upon characteristics of that site and should be chosen by a person familiar with the different instruments available. Proton precession magnetometers, while very useful in many situations, will cease to function in an area with high magnetic gradients such as a junkyard or near a steel bridge.

Different instruments have different levels of sensitivity. Whereas in some cases, high sensitivity may be desired to detect deeply buried objects, in other instances, a low sensitivity instrument may be desired to reduce the effects of "noise" from nearby fences or cars. Furthermore, the size of the survey area and the

resolution required will determine whether the magnetometer used is hand-held for stationary measurements or a vehicle-mounted continuous sensor model.

5.1.3.2 Metal Detectors (MDs)

Three general classes of metal detectors are commonly used in hazardous waste site studies: pipeline/cable locators, conventional "treasure hunter" detectors, and specialized detectors. The pipeline/cable detectors are commonly used by EPA field investigation teams. They do not respond to small objects like soda cans. Although most of the "treasure hunter" type detectors are used for locating coin-sized objects, some can be fitted with larger sensor coils suitable for detection of larger objects at greater depths. Some of these models also can operate under adverse soil conditions such as soils high iron content. Specialized detectors are also available to operate to greater depths, over a wide sweep area, operate continuously, cope with special field problems, or operate while vehicle-mounted. These special MDs require an experienced operator and are not commonly available.

5.2 Data Acquisition

5.2.1 Field Procedures

5.2.1.1 Magnetics

Magnetic measurements are generally made in a cross-grid pattern, or if a continuous sensor is used, in a series of parallel lines across the survey area. The desired resolution (reconnaissance or high density) and the size and depth of the objects sought, determines the spacing of measurement stations or survey lines. Because of the phenomenon of temporal magnetic drift, a magnetic survey must include a base station where magnetic measurements are made at regular intervals. A separate base station magnetometer is used to monitor fluctuations in the earth's magnetic field. The base station magnetometer is time synchronized with the mobile magnetometer and placed in an area of the site believed to be free of metals or other anthropogenic features. The base station magnetometer is configured to record one data point at a set time interval (e.g., every 5 seconds). At the completion of the survey, the base station magnetometer is interfaced with the mobile magnetometer and the total field magnetic data are automatically corrected for any observed diurnal drift.

Special care must be taken with handling of the magnetometer during use. The operator must not take measurements with the sensor near ferromagnetic objects such as belt buckles or steel-toed boots. The orientation of the magnetometer and its height from the ground must also be carefully controlled during operation. Recorded data must be annotated with station locations to allow construction of a site magnetic map.

5.2.1.2 Metal Detector

Surveys with metal detectors are similar in planning to those with magnetometers. A grid pattern of evenly spaced parallel lines is used. Desired resolution and the size of objects determine spacing. In some cases, elevating the MD a few feet off the ground may help to eliminate noise from small surface objects. An experienced operator is recommended. Recorded data must be annotated with station locations to allow construction of a site metal detection map.

5.2.2 Data Format

5.2.2.1 Magnetics

Most magnetometers are equipped with a solid state data logger that records the total field magnetic and/or the vertical gradient values, the survey line location, the survey station location and the time of the reading. The common units (SI) for total field magnetic data are Teslas (T). Magnetometers record total field data in units of nanoTeslas (nT). However, older texts may also refer to magnetic values as gammas (one gamma equals one nanoTesla). Vertical gradient data are commonly recorded in units of nanoTeslas per meter (nT/M).

5.2.2.2 Metal Detection

The data provided by a metal detector is less quantitative than that of a magnetometer. The MD signal strength may vary (depending on the instrument) with object depth, size, and shape, but this signal does not translate into a quantity such as field strength. It merely indicates the presence of a metal object. This on/off type of signal is useful because it can indicate the boundaries of a metal-bearing zone more clearly than some quantitative data such as magnetometer recordings.

5.3 Data Interpretation

5.3.1 Magnetics

5.3.1.1 Correction of Diurnal Variations

Diurnal drift is automatically corrected for by interfacing the mobile magnetometer with the base station magnetometer. However, all of the diurnal corrections should be checked to verify the values and insure against instrument malfunction.

5.3.1.2 Depth Estimates from Total Field

The width of a magnetic anomaly is proportional to the depth (or distance) of the source from the magnetometer sensor; the deeper the source, the broader the anomaly. This relationship is of primary importance in interpreting the results of a magnetic survey. The proportion between the width of an anomaly and the depth of the source is a function of the fall-off rate, or the variation of anomaly amplitude with distance(d). For a dipole, the total-field anomaly amplitude varies as $1/d^3$, and for a monopole as $1/d^2$. In actual practice, source orientation and other factors may result in fall-off rates from 1/d to $1/d^3$. The shape of the magnetic profile of an anomaly and knowledge of the source object help in selecting the proper fall-off rate for depth estimation. A range of depths determined from several fall-off rates may be the most appropriate way to present depth estimates.

In general the anomaly width is on the order of one to three times the depth of the source. Thus, for an anomaly with a width of 100 feet, the source is probably between 30 and 100 feet deep (or distant). Several methods, including the half-width rule and the slope technique, can be used to estimate source depths from total field profiles.

5.3.1.3 Half-Width Rule

The half-width ($x_{1/2}$) of an anomaly on a total field profile is the horizontal distance between the principal maximum (or minimum) of the anomaly (assumed to be over the center of the source) and the point where the total field value is exactly one-half of the principal maximum (Figure 3.2-1). A profile that is

used for depth estimation by using the half-width rule should be oriented perpendicular to the long axis of the anomaly to give the narrowest profile. This rule is valid only for forms such as spheres, cylinders, and other simple shapes. For example, a single upright 55-gallon steel drum can be approximated as a vertical cylinder (monopole) and the depth (d) = $1.3\,x_{1/2}$. A buried trench filled with drums can be approximated by a horizontal cylinder, where $d = 2\,x_{1/2}$.

5.3.1.4 Slope Techniques

Depth of the source can be estimated using the slope of the anomaly at the inflection points of the profile. The horizontal extent (X_z) of the "straight" portion of the slope is determined as shown in Figure 3.2-1. The depth is then estimated by the equation,

$$d = KX_z \text{ where } 0.5 < K < 1.5$$

5.3.2 Metal Detection

Very little interpretation is necessary for metal detection surveys performed to provide qualitative data on the presence of metallic objects in the survey area, as a precursor to more detailed subsequent geophysical surveys. For these cases, the positive audible responses or meter deflections are recorded on site grid maps and no further processing or interpretation is made. More detailed metal detection surveys using strip-chart or magnetic tape recording are possible. Typically, data are plotted on site grid maps following computer processing. Corrections for nonlinearities and smoothing of the data to eliminate small-target responses can be accomplished.

5.4 Applications Management

5.4.1 Prerequisites

As described in Section 5.1.2, appropriate planning of magnetic and metal detection surveys requires at least a basic understanding of general site features and hydrogeologic characteristics, as well as the probable variability in conditions. The Work Plan should describe, in as much detail as possible, the known site conditions which may affect the measurements, and the objectives of proposed survey efforts. The type and degree of data interpretation and the desired format for data presentation should be specified if possible.

5.4.2 Work Planning and Scheduling

Magnetic and metal detection surveys may be performed concurrently with field investigations, in which case on-site interpretation of data may provide real-time guidance for well drilling activities. Ideally, however, these geophysical surveys should be conducted in advance, allowing sufficient time for data interpretation and use of the results in planning other field exercises.

The time and effort required by these geophysical surveys vary greatly depending on the site-specific objectives and site conditions. Typically, 2 to 10 acres of metal detection can be performed by one person per day, depending on the complexity of the site. Additionally, 2 to 3 linear miles of magnetometer data can be collected by 1 person per day. Data reduction and interpretation will require at least an equivalent amount of time to the field work. Weather conditions, terrain, and obstructive site features cause considerable variability in these estimates.

5.5 Calibration

5.5.1 Magnetic Survey

Magnetometer readings should be compared regularly to readings of a reference base station magnetometer; this procedure is necessary if corrections are to be made for changes in the earth's magnetic field over time.

5.5.1.1 Daily Quality Control

All data sets should be accompanied by quality control data that indicates the level of quality of each individual data point. Periodically, replicate measurements should be made so that measurement precision can be established. This procedure also requires corrections for variations in the earth's magnetic field with time. Each data set should be referenced to the most recent calibrations. All data obtained prior to a calibration requiring significant changes in instrument controls are suspect, and the measurements should be repeated or otherwise validated. Data should be preliminarily reduced and plotted during the field program to determine the overall quality of the data and whether the survey results are consistent with the site conceptualization. Data points representing discontinuities in the curves should be validated by repetition and, if necessary, a fine grid of measurements made to determine whether the anomaly represents a site feature of interest, a spurious reading, or an obstructive interference.

The earth's magnetic field varies constantly due, primarily, to solar activity. These natural fluctuations must be accounted for and removed from the survey data. A second magnetometer will be used as a base station to measure and record these fluctuations. These data will subsequently be used to drift correct the survey magnetometer data. In addition, the U.S. Space Environmental Agency should be contacted daily to obtain the latest solar activity forecasts. Data acquisition will cease in the event of a magnetic storm. The phone number for the U.S. Space Environmental Agency is (303) 497-3171.

5.5.2 Metal Detection

5.5.2.1 Calibration

Metal detectors normally are not calibrated, and only relative response is of interest. Periodically, the sensitivity should be checked by nulling the instrument at a fixed location known to be free of metal, and adjusting the gain to provide a proper response over a known target.

5.5.2.2 Daily Quality Control

Metal detector data should be accompanied by sufficient quality control data to verify that the instrument was operating properly. Occasional repetitive measurements and a log of the sensitivity adjustments usually suffice for this purpose.

5.6 LIMITATIONS

Magnetometer data may be adversely affected by the presence of anthropogenic surface features such as buildings, fences, power lines, vehicles, reinforced concrete, and other metal objects. The magnetic response from these surface features can be much larger than that due to a single buried steel drum, and thus can mask the response of a drum. Magnetometer surveys should not be conducted in urban areas or areas where surface anthropogenic features are prevalent.

Data interpretation is not always straightforward with magnetic data. Metallic drums that are buried at the same depth but at different orientations can yield very dissimilar instrument responses. Data that are collected along survey lines oriented east-west can appear very different than data that are collected along survey lines oriented north-south (the preferred survey orientation).

6.0 REFERENCES

Good discussions of various geophysical survey techniques and applications are found in the following references:

Benson, R. C., R. A. Glaccum and M. R. Noel, 1982. Geophysical Techniques for Sensing Buried Wastes and Waste Migration, Technos, Inc., Miami, Florida, Contract No. 68-03-3050, U.S. EPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

Costello, R. L., 1980. Identification and Description of Geophysical Techniques, Report No. DRXTH-TE-CR-80084, U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland; Defense Technical Information System Number ADA 123939.

McKown, G. L., G. A. Sandness and G. W. Dawson, 1980. Detection and Identification of Buried Waste and Munitions, Proceedings of the 11th American Defense Preparedness Association Environmental Systems Symposium, Arlington, Virginia, 1980.

Ward, Stanley, H. 1990. Geotechnical and Environmental Geophysics, Society of Exploration Geophysicists. Tulsa, Oklahoma.

7.0 RECORDS

The following information will be recorded in the field logbook.

- Date
- Equipment operators
- Name and project number of site
- Position and instrument readings or responses if not recorded by a data logger
- Position-specific information
- Field sketches

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1.0 PURPOSE

The purpose of this guideline is to provide a general description of, and technical management guidance on, the use of Ground-Penetrating Radar (GPR) Surveys.

2.0 SCOPE

This guideline provides a description of the principles of operation, instrumentation, applicability and implementability of standard GPR methods used during site investigations, to determine subsurface stratigraphic and other interfaces discernable by GPR. The document is intended to be used by the Project Manager (PM), Field Operations Leader (FOL), or site geophysicist to develop an understanding of each method sufficient to permit work planning, scheduling, and resource planning. This guidance is not intended to provide a detailed description of methodology and operation. The highly specialized nature of GPR surveys requires inclusion of project-specific, site-specific, and subcontractor-specific information prior to development of detailed operating plans, during both planning and execution.

3.0 GLOSSARY

Dielectric Constant. Property of a medium that determines reflection, absorption, and transmission characteristics of a radar signal; a measure of the ability of a material to store charge when an electric field is applied. Also known as permittivity.

Depth of Investigation. The depth at which an object of interest can be detected in a GPR survey.

Radar Trace. A display of reflected signal strength on a graph of lateral distance along the ground versus the radar signal travel time (corresponding to vertical distance of penetration).

Two-Way Travel Time. The time required for a radar signal to travel from the antenna to a target and return to the antenna. Travel time is a function of the depth of an object and the dielectric constant (permittivity) of the medium (soil, rock, etc.).

4.0 RESPONSIBILITIES

Project Manager - Responsible for scoping of the ground-penetrating radar surveys during development of the Work Plan, with input from the FOL, site geophysicist, and site geologist.

Field Operations Leader (FOL) - Responsible for overall management and coordination of the field work.

Site Geophysicist - As a specialist in this field, the site geophysicist plays a central role in determining the appropriateness of this technique for providing necessary data. Field work for these surveys is supervised by the site geophysicist, with support from geophysical technical specialists and other personnel (i.e., site geologist) as needed. Data reduction and interpretation are performed by the site geophysicist or technical specialist.

5.0 PROCEDURES

5.1 Description of Methods

5.1.1 Theory and Principles of Operation

Commercially-available GPR units operate on the principle of time-domain reflectometry, in which the difference in strength and the time delay between a transmitted electromagnetic pulse and its reflection

from an object are measured. The time delay or two-way travel time, t, is directly related to the propagation velocity of the electromagnetic waves, v, and to the distance between the transmitter and the object, D, as follows:

$$t = \frac{2D}{v}$$

Because GPR is normally used at or near the surface of the ground, the distance D corresponds to the depth of buried target(s) that reflect the radar signals.

The strength of a radar signal is a complex function of the distance traveled through the medium and the dielectric constant, the magnetic permeability, and the electrical conductivity of the medium. Radar signals are attenuated rapidly in materials with high dielectric constants. This attenuation in subsurface media is a function of the mineralogy and the water content. Thus, materials such as dry sands and gravels are least absorptive of radar signals, whereas wet clays are highly absorptive. The absorptive properties of the medium limits the depth of investigation, e.g., the depth at which targets can be detected.

Radar antennas are available which operate at frequencies centered on 25-900 MHz. Whereas the higher frequencies are able to detect smaller targets, the penetration depth is roughly inversely proportional to frequency. Thus, any GPR survey requires an analysis of the trade-off between resolution and depth of penetration so that the optimal frequency can be selected.

The amplitude of a radar reflection is a function of the composition, size shape, and depth of the target and contrast between permittivity of target and permittivity of surrounding material. High amplitude reflections are from objects exhibiting large differences in dielectric constant from the surrounding medium, and are large in size compared to the radar signal wave length.

5.1.2 General Applicability

GPR signals are reflected from any interface which corresponds to an abrupt change in dielectric constant. Therefore, both metallic and nonmetallic objects (including voids) as well as changes in geologic structure can be detected by this method. Because of the higher frequencies used, target resolution is considerably improved over seismic or resistivity sounding methods. However, the high frequencies also result in strong attenuation of the signals, particularly in clay materials with high moisture content. At 100 MHz, the depth of investigation in clay soil with 20 percent moisture content is 3 feet or less, whereas in dry clay, or a sand with 20 percent moisture, the penetration depth can extend to approximately 30 feet.

GPR can be a powerful method for locating and mapping buried drums, wooden objects, foundations, non-containerized wastes, underground utilities, and many other artifacts (including historical artifacts) at a site. Depending on whether sufficient depth of investigation can be achieved, the method can also be used to map saturated zones and bedrock contours, and locate sinkholes or fracture systems.

A major limitation to applicability is the degree of subjective interpretation that is employed. The problem of noting a small signal disturbance in a sea of clutter can be overcome somewhat by simultaneous observation of a large number of parallel tracks.

5.1.3 Instrumentation

The standard array of GPR instrumentation consists of a transmitter/antenna unit which is pulled along the ground; a control unit, containing a power supply and signal processing circuitry which is connected to the antenna by a cable; and a laptop computer or analog tape recorder. The system can be vehicle-mounted, and the transmitter can be connected via radio link to the signal processing and recording equipment.

5.2 Data Acquisition

5.2.1 Field Procedures

GPR surveys are performed by establishing a grid of parallel survey lines across the site and moving the radar antenna along each of these lines. A suitable means must be provided for determining the location of the radar unit along each of the lines, and for documenting this information on the recording medium. Typical systems measure the time and velocity of antenna motion, or determine the position of the antenna by synchronization signals from the wheels or tracks of the vehicle used to tow the antenna.

To determine the depth of anomalies noted on radar traces, it is necessary to convert the travel time data that are actually recorded. The velocity of electromagnetic waves in the subsurface medium at the site is determined by excavation to observed targets and measuring their depths. The velocity should be determined at several points in the area of interest. Depths to targets can be estimated by using published values of dielectric constants for a range of different earthen materials and the following formula:

$$D = \frac{ct}{2\sqrt{\varepsilon_r}} = \frac{V_m t}{2} \qquad V_m = \frac{c}{\sqrt{\varepsilon_r}}$$

Where:

D = depth to target (feet)
t = two-way travel time (nanoseconds)
c = velocity of light (1 foot/nanosecond)
ε_r = dielectric constant (dimensionless)
V_m = velocity of electromagnetic waves

Two-way travel times can also be calculated by collecting GPR data over targets of known depth (e.g., trenches, buried pipes/culverts).

Specific procedures for data acquisition are as follows:

1. The time scale of the GPR unit shall be checked regularly for accuracy. This can be done either on or off the site by placing the GPR unit at a known distance from the ground, a wall, etc., and measuring the two-way travel time to that reflecting surface in the air. The velocity of electromagnetic waves in air is 1 foot per nanosecond ($3x10^8$ m/sec.). The following equation shall be used:

$$t = 2d/c$$

where:

t = two-way travel time from antenna to the surface, (nanoseconds)
d = distance of antenna to the surface, (feet)
c = velocity of light in air, (1 foot/nanosecond)

2. Prior to conducting a survey, a GPR traverse should be conducted over a buried object of known depth (if available). From the two-way travel time and the measured burial depth of the object, the average electromagnetic wave velocity (V) in soil can be calculated from the following equation:

$$V = 2d/t$$

3. A short GPR traverse shall be repeated twice daily over a known feature prior to and after conducting daily operations. Technical judgment shall be exercised to ensure that variations between repeat readings are a result of changing soil conditions rather than the electronics.

5.2.2 Data Format

Reflected radar signals are electronically processed and displayed as an intensity-modulated time spectrum, where the time corresponds to target depth as described above. The series of signals corresponding to the reflected pulses as the antenna moves along a path forms a three-dimensional data set containing distance of traverse, depth, and intensity information.

Typically, the data are recorded on a personal computer with distance displayed along the X-axis, time (depth) displayed along the Y-axis, and the intensity given by the degree of amplitude of the reflection. In a typical survey, a series of parallel tracks are traversed by the GPR, and the series of resulting oscillograph traces provides XYZ locational information and intensity of reflection from targets of interest.

Although much of the data obtained in a GPR survey is automatically recorded by the instrument, additional information to identify and interpret each trace should be recorded in a field notebook or on log sheets. At a minimum the data records should contain the following information:

1. Project name, number and location.
2. Company or organization.
3. Date and time of day.
4. Operator's name.
5. Line and trace designation (also recorded directly on the signal recording medium).
6. Equipment serial numbers.
7. Antenna frequency.
8. Direction and speed of antenna movement.
9. Weather and temperature.
10. Site map coordinates at the beginning and end of the trace.
11. Notes, remarks or comments.
12. Electromagnetic velocity in the subsurface medium at the nearest calibration point.

5.3 Data Interpretation

Except for those systems which provide extensive data processing, interpretation of anomalies in GPR traces require considerable subjective evaluation by a trained geophysicist. Extensive experience is essential to distinguish target reflections from inherent system noise and interferences. In many cases, the anomalies due to targets of interest are small compared to varying reflections from the antenna system, the ground surface, geologic perturbations, and other interferences. Similarly, an acceptable interpretation of target depth from travel time data requires a knowledge of geophysical characteristics across the site.

A radar antenna transmits a "cone," rather than a thin beam of electromagnetic energy, so that reflections are obtained from objects not directly below the antenna. As the antenna moves across the plane of an object, reflections are obtained for a considerable distance along the antenna path. The signal travel times will vary during this process, corresponding to the distance between the antenna and the object. A discrete spherical target would exhibit a hyperbolic reflection pattern on the radar trace, with the apex of the hyperbola corresponding to the location and depth of the object. Multiple or odd-shaped targets, or targets of considerable size (compared to the radar wavelength) will exhibit complex reflection patterns consisting of overlapping hyperbolas. Thus, a true "picture" of subsurface objects is not obtained, and

experience is necessary to translate the complex tracings into information indicating the target depth, size, and shape.

5.4 Applications Management

5.4.1 Prerequisites

Appropriate planning of GPR surveys requires at least a basic understanding of the geophysical characteristics of the site. The type and structure of soils and geologic formations should be known. A description of the site should include the depth, size, shape, and type of potential targets to be detected, as well as obstructive site features such as rough or wet terrain and underground utilities and/or structures. The existence of, and depth to known buried objects should be listed and mapped. Other specifications include the degree of locational resolution desired, probable weather conditions during site activities, and the type and sophistication of software required for data interpretation and presentation.

5.4.2 Work Planning and Scheduling

If possible, GPR surveys should be performed concurrently with other geophysical surveys. Radar data complement information from other geophysical methods such as seismic refraction, magnetometry, and resistivity in arriving at an interpretation of subsurface geohydrologic features and location of buried waste materials. This information is important in locating and selecting the appropriate type of monitoring wells.

The time and effort required to perform GPR surveys vary greatly depending on the sophistication of the available equipment and the complexity of the site. Assuming a 2-person team, simple hand-operated radar systems can cover from 1/4 to 1/2 acre per day, proper documentation, and simple interpretation. Vehicle-mounted systems with automatic data recording and processing can cover from 2 to 5 acres per day. Sophisticated data processing, detailed interpretations, and high-quality displays require considerable computer usage and approximately twice the time required for the actual field survey.

The specific objectives of the GPR survey should be defined in the Work Plan and should include the following elements:

1. Type of survey (level of detail) to be accomplished, and area to be covered.
2. Type, depth, size, and composition of targets of interest (if known).
3. Locational accuracy required.
4. Schedule limitations.
5. Degree of sophistication required for data presentation and interpretation.
6. Specific deliverables required.

5.5 Quality Control (QC)

5.5.1 General

Because of the specialized nature of the method and the highly subjective interpretations needed to process the data, GPR surveys are subject to misapplication, erroneous interpretation, and collection of inadequate or incomplete data. This susceptibility to misuse requires that an adequate quality control program be established. Quality control aspects include the following :

- Insistence on a defined scope of work, specifications, and data validation procedures.
- No data point should be rejected from a data set without appropriate justification; field data sheets should contain all observed data and the conditions that could impact data validation.

- All field data should be recorded in permanent ink in a bound field logbook, and each page signed and dated by the operator. The original unaltered field logbook should be retained in the project file.

- In general, the objectives of geophysical surveys can be met by relative measurements across an area or with depth. Absolute calibration is therefore of lesser importance than precision of measurements. However, a properly calibrated instrument provides an added measure of data validity and permits correlation and comparison of the associated data with site features and hydrogeologic characteristics not evident at the time of the field effort.

- An evaluation should be made of background noise, interferences, and obstructions at a site. These items should be recorded in the field logbook. These real-time quality control procedures aid field personnel in correction of noise sources over which they have control, in validating suspected external sources, and in early detection of problems that may jeopardize the survey results.

5.5.2 Daily Quality Control

All radar traces and interpreted data sets should be accompanied by quality control data that indicate the level of quality of the data. Periodic replicate measurements should be made so that measurement precision can be established. Time and/or depth calibrations should be performed on a daily basis.

A calibration that yields significant changes in instrument parameters or travel time may indicate the need for repetition of data or increased density of travel time calibrations in the area of interest. Graphical data should be reviewed during the field activities to determine that data quality is adequate, and whether the survey results appear to be consistent with geophysical conceptual model of the site.

5.6 Potential Problems

A wide variety of problems may be encountered during performance of a GPR survey. Problems can be expected to arise in the following areas:

5.6.1 Planning and Execution

Rarely is a GPR survey accomplished exactly according to the original plan. Site features not previously specified and other variations can occur that force changes in the details of the approach. However, the objectives of the survey, the general methodology, the amount and quality of data required, and the degree of data interpretation requested should remain unchanged. Project work scopes should be written with some degree of latitude to allow a change in plans whenever justified.

5.6.2 Noise and Interferences

Measurements can be affected severely by natural and by man-made sources of interference. Sources of system noise that degrade the quality of radar traces include improper spacing of antennas above ground, improper cable placement, location of antennas too close to other system components, and faulty instrument operation. Because reflections are obtained from any objective with a dielectric constant differing from the surroundings, large masses or high density of buried or surface rocks, metal, debris, wet soil, or structures can mask targets of interest. Some antennas are not shielded on top, and similar interfering reflections will be obtained from overhead objects such as trees, power lines and buildings. The site personnel must recognize the limitations posed by these obstructions, and take steps to minimize these interferences.

Topographic and geologic features can also interfere with acquisition of high-quality target detection data. Small depressions in the ground surface, the presence of boulders, clay lenses and moist soil zones affect both the detectability of a target and determination of its depth from the travel time.

Sources of electromagnetic energy in the vicinity, such as radio or television transmitters, or navigational radar antennas can result in spurious signals in the radar traces. In some cases, these problems can be minimized by judicious selection of radar and/or data communications frequency, and by scheduling the surveys during periods of transmission inactivity.

5.6.3 Weather Conditions

Because water is a good absorber of radar signals, wet weather has a very serious effect on the ability to perform GPR surveys. Physical difficulties in executing a survey over wet terrain also may be expected. The field activities should be planned, if possible, during periods when dry weather is expected. Schedules for surveys should account for the probability that moist soil conditions will exist.

5.6.4 Technical Difficulties

Preventable difficulties include equipment malfunction, or misapplication, poor operator training, and lack of applications experience. Other difficulties may arise because the geophysical character of the site is not as initially conceptualized. The effect of these problems can be minimized by early recognition, using responsive and responsible technical management. Interim, real-time scrutiny of the data by the site geophysicist and management personnel is essential. The site geophysicist or geophysical subcontractor must be responsive regarding equipment replacement, repair, or changes in personnel. The Project Manager and the FOL should be cognizant of technical difficulties beyond the control of the field personnel, and should recognize the need to change plans, change performers, or cancel a survey, as appropriate.

6.0 REFERENCES

Good discussions of various geophysical survey techniques and applications are found in the following references:

1. Benson, Richard C., Robert A. Glaccum and Michael R. Noel, Geophysical Techniques for Sensing Buried Wastes and Waste Migration. U.S. EPA Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

2. Costello, Robert L., 1980, Identification and Description Geophysical Techniques, Report No. DRXTH-TE-CR-80084, U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland; Defense Technical Information System Number ADA 123939.

3. McKown G. L., G. A. Sandness and G. W. Dawson, Detection and Identification of Buried Waste and Munitions, Proceedings of the 11th American Defense Preparedness Association Environmental Systems Symposium, Arlington, Virginia.

7.0 RECORDS

The following information will be recorded in the field logbook.

- Date
- Type of equipment
- Name and project number of site

- Site conditions that may affect data collection
- Depth and location information regarding known targets used for determining the wave velocity
- Additional items mentioned in Section 5.2.2

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1.0 PURPOSE

The purpose of this document is to describe the procedure for the analysis of volatile organic compounds by headspace gas chromatography using a portable gas chromatograph. This procedure may be used on site during a field investigation to provide analytical results on quick turnaround basis.

2.0 SCOPE, APPLICATION, AND LIMITATIONS

2.1 Scope of Method

This field method covers the determination of volatile organic compounds in aqueous and solid samples by headspace gas chromatography. Table 1 lists the volatile organic compounds (VOCs) that may be determined by this method and their practical quantitation limits (PQLs). The MDLs for a specific sample may differ from those listed, depending on the nature of interferences in the sample matrix. In particular, the analyst must be aware that instrument sensitivities for methylene chloride, 1,1-dichloroethane, 1,2-dichloroethane, and 1,2-dichloropropane are approximately one-fiftieth of the sensitivities for most other compounds. Therefore, reported detection limits for these compounds will have to be adjusted (elevated) whenever other sample components elute near their expected retention times (RTs), even when such interferences are on scale and less than internal standard (IS) heights.

2.2 Target Compound List (TCL)

To utilize this field method to provide analytical data in the most timely and efficient manner for guidance of ongoing work, the project planning phase must identify the target compounds that are likely to be present and their general expected concentration ranges. The site work plan (WP) and quality assurance project plan (QAPP) should specify the selected subset of the target compound list (TCL) that is required to be determined and reported. This will expedite the analysis and reporting of samples by tailoring the quality control (QC) criteria for this method to the site-specific compounds instead of all compounds.

2.2.1 Calibration/Reporting Options

In general, two options are suggested for calibration and reporting purposes: first, only the site-specific compounds would be present in all calibration and QC standards; only these compounds would be quantitated and reported. Or all compounds listed in Table 1, including all site-specific compounds, would be present for the initial calibration analyses and continuing calibration analyses but only the site-specific compounds would present in all other QC analyses and would be subject to the stated QC criteria; other compounds would be quantitated and reported as estimated. The WP and/or the QAPP should state which option will be used.

2.3 Analysis of Solid Samples

The analysis of solid samples by the headspace method does not determine the true concentration of contaminants in soil. The analysis determines only the concentration of contaminants that will dissolve into water under the conditions of the analysis (mild heating). Due to the effects of the soil/water equilibrium, the soil concentration can be substantially higher than the water concentration, causing results to be biased to an extent that cannot be reliably predicted. Therefore, results are essentially semi-quantitative and are useful chiefly to establish the presence or absence of target compounds and to estimate the ratio of contaminant levels in one sample relative to another.

TABLE 1

TARGET COMPOUND LIST AND PRACTICAL QUANTITATION LIMITS (PQLS)

Volatile Organic Compound	CAS Number	PQLs	
		Water (µg/l)	Soils (µg/kg)
chloromethane	74-87-3	5	15.0
vinyl chloride	75-01-4	5	15.0
bromomethane	74-83-9	5	15.0
chloroethane	75-00-3	5	15.0
acetone	67-64-1	5	15.0
1,1-dichloroethene	75-35-4	1.0	3.0
methylene chloride	75-09-2	1.0	3.0
carbon disulfide	75-15-0	1.0	3.0
trans-1,2-dichloroethene	156-60-5	1.0	3.0
1,1-dichloroethane	75-34-3	1.0	3.0
2-butanone	78-93-3	5.0	15.0
cis-1,2-dichloroethene	156-59-4	1.0	3.0
chloroform	67-66-3	1.0	3.0
1,1,1-trichloroethane	71-55-6	1.0	3.0
carbon tetrachloride	56-23-5	1.0	3.0
benzene	71-43-2	1.0	3.0
1,2-dichloroethane	107-06-2	1.0	3.0
trichloroethene	79-01-6	1.0	3.0
4-methyl-2-pentanone	108-10-1	5.0	15.0
toluene	108-88-3	1.0	3.0
1,1,2-trichloroethane	79-00-5	1.0	3.0
2-hexanone	591-78-6	5.0	15.0
tetrachloroethene	127-18-4	1.0	3.0
chlorobenzene	108-90-7	1.0	3.0
ethylbenzene	100-41-4	1.0	3.0
m,p-xylenes	1330-20-7	1.0	3.0
o-xylene	95-47-6	1.0	3.0
styrene	100-42-5	1.0	3.0
bromoform	75-25-2	1.0	3.0
1,1,2,2-tetrachloroethane	79-34-5	1.0	3.0

2.3.1 Analysis of Aqueous Samples

In the analysis of aqueous samples, quantitation is based upon the assumption that the concentrations of compounds found in the headspace over the sample are directly proportional to the actual concentrations of compounds in the sample. This assumption is valid mainly for clean matrices. Interferences such as high levels of dissolved salts, suspended solids, oil, or other solvents can alter the assumed partitioning between the liquid and vapor phases and substantially bias quantitative results.

2.3.2 Method Limitation

A limitation of the headspace method, which also holds true for purge-and-trap analyses as well, is the dissolution of the volatile compounds in water prior to analysis. For hydrophobic volatile compounds such as the ketones, the air/water partition is very low; these compounds tend to remain in the water phase and do not readily volatilize under the moderate heating of the headspace method, although recoveries can be somewhat higher than that of the purge-and-trap method.

2.4 High-Level Contamination

The efficiency of the field analysis will be adversely affected by unexpected high levels of contaminants that require dilutions and system bakeout. Therefore, samplers must provide information as to suspected contaminated samples and useful field observations such as total organic vapor readings.

2.5 Target Analyte Identification

When this method is used to analyze unfamiliar samples for any or all of the compounds in Table 1, compound identifications should be supported by at least one additional qualitative technique. Compound identities are most often corroborated by confirmatory analyses of a representative subset of samples collected, taking into account the proximities and matrix similarities within groups of samples, the sample-specific complexity of chromatographic interferences, and the different target compounds identified in the various field samples. Gas chromatography/mass spectrometry (GC/MS) techniques generally provide reliable confirmation data, particularly when replicates or duplicates of field samples are collected and analyzed using the protocols of the EPA Contract Laboratory Program (CLP).

2.6 Confirmation Samples

The required type and frequency of confirmation will depend on the objectives of the sampling investigation and the intended use of the data. For example, the client may require that a rigorous type of confirmation (e.g., GC/MS) be utilized whenever results are meant to be used in certain critical data categories for risk assessment or other decision making.

2.7 Client Review of WP/QAPP

The client will approve the site-specific WP and QAPP before on-site analysis and will approve the confirmation requirements for each site. No general confirmation scheme that applies to all circumstances is provided in this SOP because the combination of site-related and sample-specific data quality needs may be unique to each sampling investigation. Confirmation requirements that are proposed in the above documents will specify the objectives, mechanisms, and guidelines for confirmational analysis. Consideration should be given to the need for any pre-determined sampling locations for GC/MS or other confirmation and also for an overall frequency for GC/MS or other confirmation of field results. To achieve maximum confidence in particular field sample results used to support important findings or site-related decisions, the confirmation scheme may also require in-field

evaluation of GC results in order to identify the most significant results and/or unusual results that will be scheduled for GC/MS or other confirmation.

2.8 Analyst Training

This method is to be used only by trained analysts under the supervision of a chemist experienced in the operation of a GC using headspace methodology and in the interpretation of gas chromatograms. Analysts must be aware that, in order to achieve acceptable accuracy and precision using manual headspace injections, particular attention must be paid to the techniques of sample handling and injection.

3.0 GLOSSARY

TCL - Target Compound List. A complete listing of chemicals that can detected and reported using this SOP.

MDL - Method Detection Limit. The anticipated detection limit using the equipment and method specified under this SOP.

PQL - Practical Detection Limit. The actual detection limit established prior to the start of sample analysis using the site-specific equipment and chemical standards.

RT - Retention Time. The time it takes a compound from injection to elution at the detector, usually measured in minutes.

ECD - Electron Capture Detector. Responsive to halogenated compounds (F, Cl, Br, and I ions in decreasing sensitivity)

PID - Photoionization Detector. Responsive to aromatic and unsaturated aliphatic compounds.

IS - Internal Standard. A solution of non-target compounds that is injected into the sample container just prior to sample analysis. Necessary for the internal standard method of sample quantitation. See Section 12.

RRF - Relative Response Factor. Calculation of the response (measured as area counts/ concentration) of the compound standard as compared with the response of the internal standard. See Section 12.

PD - Percent Difference. Calculation of the change in response between the average RRF for a compound in the initial calibration standard curve compared with the response for the same compound in the continuing calibration standard. See Section 12.

RPD - Relative Percent Difference. Used to calculated the difference in concentration between the initial sample analysis and the duplicate sample analysis.

RTW - Retention Time Window. Calculation of the expected "window" or range of retention times expected to allow for a 95 percent confidence level that the compound eluting in that retention time window is the expected compound. This is very important for gas chromatographic systems.

RSD - Relative Standard Deviation. Calculation that measures the linear fit of the target compounds in the initial calibration curve. See Section 12.

4.0 RESPONSIBILITIES

GC Analyst/Chemist - Responsible for all aspects of sample preparation and analysis including equipment maintenance. Also responsible for maintaining chain-of-custody and refrigeration of samples once they are received from sampling personnel.

5.0 PROCEDURES

5.1 Summary of Method

5.1.1 Soils

A measured amount of soil (approximately 12 grams) is placed into a 40-ml volatile sample bottle containing 23 ml of reagent water and sealed. The ratio of the headspace volume to the liquid volume is kept constant for all samples and standards. Each sealed sample container is shaken to extract VOCs and then placed in a heated water bath or oven for a specified period of time. A measured volume of the headspace is withdrawn into a gas-tight syringe and injected onto a GC column. The GC is temperature programmed to separate the VOCs. The VOCs are then detected with a PID and an electron capture detector (ECD), which are arranged in series to accept the effluent gas from the GC.

5.1.2 Aqueous

A 30-ml aliquot of a water sample is placed into a 40-ml volatile sample bottle and sealed. The ratio of the headspace volume to the liquid volume is kept constant for all samples and standards. Each sealed standard or sample container is placed in a heated water bath or oven for a specific period of time. A measured volume of the headspace is withdrawn into a gas-tight syringe and injected onto a GC column. The GC is temperature programmed to a separate the VOCs. The VOCs are then detected with a PID and an electron capture detector (ECD), which are arranged in series to accept the effluent gas from the GC.

5.1.3 Quality Control

The Quality Control requirements for this method are summarized in chart form in Figure 3 of this SOP.

5.2 Interferences

5.2.1 Contamination Sources

Impurities in the carrier gas, syringe contamination, organic compounds outgassing from the plumbing ahead of the column or temperature-programmed sections of transfer lines, and solvent vapors in the laboratory account for the majority of contamination problems. The analytical system must be demonstrated to be free from contamination under the conditions of the analysis by running laboratory reagent blanks, as described in Section 5.9.3. The use of non-Teflon tubing, non-Teflon thread sealants, or flow controllers with rubber components should be avoided.

5.2.2 VOCs (Trip Blanks)

Samples can be contaminated by diffusion of VOCs (particularly fluorocarbons and methylene chloride) through the septum seal into the sample during storage and handling. A trip blank prepared from reagent water and carried through the field activity and the analysis protocol serves as a check on such contamination. The trip blank must be prepared by the field analyst according to the frequency specified

in the WP or QAPP.

5.2.3 Contaminant Carry-Over

Contamination by carryover can occur whenever high-level and low-level samples are sequentially analyzed. To reduce carryover, the sampling syringe should be rinsed with VOC-grade methanol and dried for at least 15 minutes at 60°C to 70°C with the plunger removed from the syringe between sample analyses. Whenever analysis of an unusually concentrated sample (or series of samples, each having similar concentrated contaminant levels) indicates that any target analyte is present at a level of more than 60 times the method reporting limit, then this contaminated sample (or series of samples) should be followed by an analysis of reagent water to check for cross contamination. In addition to preventative measures, if carry-over is suspected after the fact [as defined by a sample containing a positive (reportable) target contaminant level that is less than 1.7 percent of the level detected in the preceding analysis of a higher concentration sample], then the sample in question shall be rerun after the system has been decontaminated and a reagent blank has been acceptably analyzed. For samples containing high VOC levels, it may be necessary to rinse the syringe with methanol several times and then dry it in an oven between analyses as described above.

5.2.4 Solvents

The laboratory where volatile analysis is performed should be completely free of solvents.

5.2.5 Soil Sample Bias

For soils, quantitative bias is expected because the characteristics of each individual soil matrix can alter, to a different extent, the nature of the partitioning of analyte between three separate phases (soil/water/air) during analysis. Henry's Law states that the concentration of the volatile analyte in the headspace above a solution is proportional to the concentration of the analyte in solution. However, dissolved solids can alter air/water partition ratios; also, the proportionality that exists between the concentration of analyte in the solution and the concentration of analyte in the soil sample immersed in solution is not constant but varies with the sorptive properties of the type of soil involved, the extent to which the soil is dispersed and in equilibrium with the solution, and the concentration of other dissolved components in solution with the analyte. Because the ratio of headspace concentration to the total concentration in the soil is not constant, calibration is accomplished in the absence of soil, using only pure water/air, and results are calculated as if all of the analyte in the soil were to enter the solution. Therefore, quantitative results can be biased to a considerable extent, despite the use of internal standards with this method. The use of matrix spikes with this method serves to monitor for the possible effects of individual soil matrices; however, it is possible that the recovery behavior of an analyte spiked into the soil/water mixture will not be completely representative of the recovery behavior of the same analyte when it is originally sorbed onto the soil in the environment.

5.2.6 Aqueous Sample Bias

For aqueous samples, Henry's Law states that the concentration of the volatile analyte in the headspace above a solution is proportional to the concentration of the analyte in solution. However, chemical interferences can cause the observed partition ratio in a sample to be different than that in the pure water matrix of the calibration standard. For example, the presence of high concentrations of dissolved salts can increase the headspace concentration in a sample and thereby cause results to be biased high. Conversely, results can be biased low when VOCs are absorbed onto suspended solids or oil droplets in a sample or if the sample contains high levels of co-solvents that enhance VOC solubilities. In this method, the use of matrix spikes serves to monitor for the possible effects of matrix interferences.

5.3 Safety

5.3.1 Reagent Toxicity

The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined. However, each compound should be treated as a potential health hazard, and exposure to these chemicals should be minimized. The laboratory is responsible for maintaining an awareness of applicable Occupational Safety and Health Administration (OSHA) regulations.

5.3.2 Material Safety Data Sheets

Material safety data sheets (MSDS) must be available at each location of use or storage (mobile laboratory or fixed laboratory) for each chemical used and stored in the laboratory.

5.3.3 Protective Equipment

Analysts must wear appropriate protective equipment when handling samples, standards, or chemical reagents. At a minimum, this will include eye protection. Disposable plastic gloves must be worn whenever sample aliquots are being transferred from one vessel to another and whenever pure or high-concentration chemical standards are being opened or transferred. Pure analytical standards must be opened only under a hood or outdoors, in a restricted-access situation, while wearing respiratory protection to prevent inhalation of organic vapors.

5.3.4 Eyewash Facilities

Eyewash facilities must be available.

5.3.5 Fire Extinguisher

Fire extinguisher, must be present and in good working order.

5.3.6 Spill Control

Spill-control pillows or equivalent spill-control systems must be present and in good working order.

5.4 Apparatus and Materials

5.4.1 Gas Chromatograph

An analytical system, complete with a temperature-programmable GC suitable for on-column injection, is required, and all necessary accessories including injector and detector systems must be designed or modified to accept the appropriate analytical column (packed or megabore). The system shall have a data-handling system attached to the detectors that is capable of labeling, relative retention time (RRT) comparisons, and providing relative and absolute peak height and/or peak area measurements.

5.4.1.1 Capillary Column

Capillary Column: 30 m x 0.53 mm I.D. DB-624 or RT_x 624 fused silica megabore column or equivalent.

5.4.1.2 Detectors

A Tracor PID or its equivalent with a 10.2 eV lamp is connected in series to an ECD.

5.4.1.3 Gas Supply

The carrier gas (helium) and the make-up gas (nitrogen) must be of ultra-high purity grade or better. All gases should pass through oxygen traps before the analytical system to prevent degradation of the column analytical coating. A hydrocarbon trap is recommended ahead of each oxygen trap to extend the life of the oxygen trap and to further reduce interferences causing elevated baseline.

5.4.2 Sample Injection Syringes

Sample injection syringes must be gas tight, with Teflon-tipped plungers and 25-gauge replaceable needles. A 500-ul size is most frequently used for samples and standards; smaller sizes (250 ul, 100 ul, 50 ul, and 25 ul) are required for sample dilutions.

5.4.3 Standard Solution Syringes

For transfer of standard solutions, microliter syringes are required in sizes of 10 ul, 25 ul, 50 ul, 100 ul, 250 ul, and 1,000 ul.

5.4.4 Volumetric Flasks

Class A Volumetric Flasks with Ground Glass Stoppers: 10 ml, 25 ml, 50 ml, 100 ml, and 250 ml, as needed.

5.4.5 Screw-Cap Vials

Forty-ml screw-cap vials with Teflon septa are required for working aqueous standards. One-ml screw-cap vials with Teflon septa are required for methanolic standards.

5.4.6 Drying Oven

5.4.7 Water Bath (Optional)

5.4.8 Bubble Flow Meters

One 25-ml capacity volumetric burette is required.

5.4.9 Leak Detector-Solutions for Detecting Gas Leaks

"Snoop" or an equivalent liquid forms bubbles at the source of the leak and should be used on hot surfaces except at or near column head fittings and injector ports. N-propanol should be used on cool surfaces or, if an electronic leak detector is not available, at or near column fitting sand injector ports.

5.4.10 Electronic Leak Detector

The GOW MAC model 21-150 or its equivalent is recommended for use near injectors, columns, or detectors.

5.4.11 Balance

Capable of accurately weighing 0.01 gram.

5.5 Reagents and Consumable Materials

5.5.1 Reagent Water

Reagent Water - Reagent water is defined as water in which levels of site-specific target compounds are below the MDLs. Reagent water may be generated using a carbon filter bed or a water-purification system or may be purchased.

5.5.2 Purge-and-Trap Grade Methanol, or Equivalent

5.5.3 Stock Standard Solutions

These solutions should be purchased in methanol as manufacturer-certified solutions, if available; otherwise, stock solutions will be prepared from pure standard materials. Manufacturer-certified stock solutions are available for several internal standards and for all target compounds (although target compound stock mixtures must be custom ordered, as described in Section 5.5.3.2). Several internal standards may not be available as manufacturer-certified stock solutions; if so, these must be prepared from pure liquids. The recommended concentrations of all stock standards, together with their current availability status, are listed in Table 2.

Stock standards and pure reference materials will be documented in a standards preparation logbook (see Figure 1). All standards will be assigned an index/identification number that is listed in this logbook and on the label of the container in which the standard is stored. Purchased material certificates supplied by the manufacturer will be maintained and filed in order of date of receipt for all standards. All stock standards must be stored in a freezer at approximately -10 to 20°C and protected from light. Stock standards will be assigned an expiration date of no more than six months following date of preparation and must be replaced if degradation (color change or evaporation) is indicated. Before the first use of a new target compound stock standard, it must be diluted according to Table Nos. 2 and 3 and analyzed in sequence along with current standards (if they are still considered valid) to verify correct concentrations. If the response for any compound is more than 35 percent different from the old standard, then check the dilution procedures and integration data to verify calculations. If there is still greater than 35 percent difference, then re-analyzed the new and old standards several times in sequence until a minimum of 6 total analyses have been completed and perform a t-test for means (see Section 6.0, Reference No. 9) for each of the non-compliant compounds. If the means of the values obtained for the 2 stock solutions are considered different at the 96 percent level of confidence, then obtain and analyze standards from another source to determine whether the new or the old stock is inaccurate.

TABLE 2
SUGGESTED INTERNAL STANDARDS

Type of Stock Standard Preparation*	Compound(s) in Stock Standard Solution	Concentration of Stock Solution	Concentration of Secondary Dilution Mixture	Type of Working Standard
P	3-Cl-2-me propene	2,000 µg/ml	250 µg/ml	Capillary column internal standard mixture
P	4-Br butene	2,000 µg/ml	250 µg/ml	
P	1,3-Br_2-1-propene (cis/trans)	25,000 µg/ml	2,500 µg/ml	
MC	bromochloromethane	2,000 µg/ml	250 µg/ml	
MC	2-bromo-1-chloropropane	2,000 µg/ml	2,000 µg/ml	

P: Prepared from pure standard materials.
MC: Manufactured-certified stock solutions.

5.5.3.1 Primary Dilutions of Neat Standards

Pure compound should be opened in a hood (or using appropriate respiratory protection in a ventilated area). Dilutions of neat standards may be performed using one of two acceptable procedures. If a 0.1-mg-accuracy analytical balance is available, then the required procedure is to add several drops of the pure material after tarring a volumetric flask nearly filled with methanol. Alternatively, if a 0.1-mg-accuracy analytical balance is not available, the following procedure shall be followed to achieve dilution of pure components in a quantitative manner. Place approximately 90 ml of methanol into a 100-ml volumetric flask and tare using a top-loading balance that is accurate to ± 0.01 gram. Using a 1,000 ul syringe, add a measured quantity (700 ul, for example) of each desired pure compound, recording the exact weight and re-tarring after each addition. If the measured density of each compound is not within ± five percent of the literature value, then the standard must be re-prepared. Adjust the final volume to 100 ml with methanol, insert the stopper, and mix by inverting the flask several times. Transfer the stock solution carefully (minimizing agitation) into several Teflon-lined screw cap vials with minimal headspace. Primary dilution standards will be prepared in this manner for internal standards that are not available as manufacturer-certified solutions (see Table 2 for concentrations).

5.5.3.2 Manufacturer-Certified Solutions

Upon opening ampoules, these solutions shall be used immediately or else transferred carefully (minimizing agitation) into Teflon-lined screw cap vials with minimal headspace.

5.5.4 Secondary Dilution Standards

Using stock standard solutions, prepare in methanol secondary dilution standards, in mixtures indicated by the groupings in Table 3. These secondary dilution standards shall be prepared by volumetric dilution to yield the concentrations indicated in Table 3. This will enable the aqueous calibration standards prepared in Section 5.5.5 to bracket the working range of the analytical system. Secondary dilution standards prepared in methanol shall be stored, handled, and documented in the standards logbook as described above for stock standards. Secondary dilution standards should be checked frequently for signs of degradation (color change or evaporation), especially just before preparing calibration standards from them. If degradation is suspected, discard the solution, unless standard integrity is verified by means of analysis of a fresh dilution compared to the suspect standard. If the response of the fresh dilution is not within 35 percent of the suspect standard, then the old solution must be discarded. Secondary dilution standards are valid for six months from the date of preparation or two months from the date of first use, whichever occurs first.

5.5.5 Calibration Standards

Initial calibration standards for each analyte of interest will be prepared and analyzed at a minimum of three concentration levels by dilution using a microliter syringe to aliquot secondary dilution standards into a flask or vial containing reagent water. (The number of solution transfer steps will be minimized if the microliter volumes of standard solutions are added directly to a 40-ml VOA vial containing 30 ml water previously added with a graduated cylinder.) The lowest concentration should not be greater than 2.5 times the MDLs listed in 1. Concentration intervals between adjacent levels of standards should not exceed 50 µg/L or a factor of five, whichever is greater. To minimize dilutions of samples, the working range should be defined using at least one standard at or above 25 times the MDLs in Table 1. The continuing calibration standard must be at a fixed concentration within the working range. Aqueous standards can be stored up to 24 hours only if held at 4°C in Teflon-sealed vials with zero headspace. If

TABLE 3

Compound	Concentration in Standard (µg/l in 30 ml Water) Heated Headspace Detector Calibration (P - PID; E - ECD)													
	ECD Level 1		ECD Level 2		ECD Level 3		ECD Level 4 PID Level 1 (also PID/ECD CC Daily Std.)		ECDoption Lev. 5 PID Level 2		PID Level 3		µg/ml CONC. of stock & secondary MeOH STDS.	
STANDARD MIXTURE NO. 1			µL added to 30 ml:	3.6	µl added to 30 ml:	12.0	µl added to 30 ml:	24.0	µl added to 30 ml:	48.0	µl added to 30 ml:	96.0	µl into 10 ml:	500
tetrachloroethene			0.6	E	2	E	4	PE	8	PE	16	P	100	5
trichloroethene			0.6	E	2	E	4	PE	8	PE	16	P	100	5
1,1,1-trichloroethane			0.6	E	2	E	4	E	8	E			100	5
chloroform			0.6	E	2	E	4	E	8	E			100	5
carbon tetrachloride			0.06	E	0.2	E	0.4	E	0.8	E			10	0.5
STANDARD MIXTURE NO. 2					µl added to 30 ml:	3.6	µl added to 30 ml:	12.0	µl added to 30 ml:	24.0	µl added to 30 ml:	120.0	µl into 10 ml:	500
1,1-dichloroethene					3.6	E	12	PE	24	PE	120	P	600	30
cis-1,2-dichloroethene							10	P	20	P	100	P	500	25
trans-1,2-dichloroethene							10	P	20	P	100	P	500	25
STANDARD MIXTURE NO. 3	µl added to 30 ml:	30	µl added to 30 ml:	75			µl added to 30 ml:	225					µl into 10 ml:	400
1,2-dichloroethane	20	E	50	E			150	E					500	20
1,1-dichloroethane	20	E	50	E			150	E					500	20
STANDARD MIXTURE NO. 4							µl added to 30 ml:	6.0	µl added to 30 ml:	12.0	µl added to 30 ml:	45.0	µl into 10 ml:	500
acetone							100	P	200	P	750	P	10000	500
2-butanone							100	P	200	P	750	P	10000	500
STANDARD MIXTURE NO. 5							µl added to 30 ml:	3.6	µl added to 30 ml:	10.8	µl added to 30 ml:	54.0	µl into 10 ml:	500
benzene							6	P	18	P	90	P	1000	50
toluene							6	P	18	P	90	P	1000	50
ethyl benzene							6	P	18	P	90	P	1000	50
o-xylene							6	P	18	P	90	P	1000	50
m-xylene							6	P	18	P	90	P	1000	50
p-xylene							6	P	18	P	90	P	1000	50
styrene							6	P	18	P	90	P	1000	50
Methanol Volume in 30 ml	Std. No. 1	6.0	Std. No. 2	18.6	Std. No. 3	15.6	Std. No. 4	90.6	Std. No. 5	94.8	Std. No. 6	315.0	---	---

not so stored, they must be discarded after one hour. Headspace vials are considered invalid after 30 minutes of heating and cannot be reheated/reinjected. Relatively lower sensitivity on the ECD shall be calibrated using a separate low-concentration standard, followed by middle- and high-level standards in which these low-sensitivity compounds are present at concentrations appropriately higher than other analytes in order to prevent masking by other compounds. The recommended initial calibration series is given in Table 3.

5.5.6 Quality Control (QC) Check Standard

A QC check standard solution should be prepared in methanol using standards prepared independently from those used for calibration. The concentration of this solution must be such that addition of no more than 300 ul to 30 ml water is required to achieve a concentration within the calibrated range.

5.5.7 Internal Standards (IS)

The recommended ISs for this method are shown in Tables 2 and 4. The same amount (micrograms) of ISs must be added to all samples, blanks, and calibration standards. The IS solution should be a single mixture that is prepared using secondary dilutions of either commercially obtained standards or primary dilutions of pure reference materials. The recommended IS solution should be nominally 250 µg/ml so that addition of 12 ul of this solution to 12 grams of solid sample or 30 ml of aqueous sample will result in a sample concentration of 250 µg/kg (equivalent to an instrument level of 100 µg/L, assuming a 30-ml solution).

5.5.7.1 Alternative ISs

If the ISs listed in Table 4 are not available, other ISs may be substituted only if the following criteria are met: there must be three ISs for each detector that have similar sensitivity to most analytes; ISs should elute at similarly spaced intervals; ISs must be chromatographically resolved to 25 percent valley from all target compounds and to 5 percent valley from target compounds that are expected to occur or that commonly are found at hazardous waste sites; and ISs must be chemically stable.

5.5.7.2 Handling and Use of IS Solutions

IS solutions shall be prepared, labeled, handled, stored, and documented exactly as described for other standard solutions. Stock IS solutions must be stored at -10 to -20°C. Working IS solutions may be stored at 4°C while in use in the field; otherwise, they must be stored at -10 to -20°C, as with stock solutions. A six-month expiration date is applicable to IS solutions that are not in daily use (stock standards). A one-week expiration date is applicable to working IS solutions (measured from whenever usage begins for spiking of samples and standards). Working IS solutions should be monitored closely for signs of degradation. Deterioration is indicated if evaporation is noted or suggested if internal standard area criteria for a blank are exceeded. If blank IS area criteria are exceeded, check the syringe and rerun the blank. If out-of-control areas recur, run a continuing calibration standard to determine whether the IS solution (as opposed to instrument instability) is responsible for the area shift. Deterioration of the IS solution is confirmed if nearly all (more than 70 percent) of the compounds associated with the suspect IS have out-of-control percent differences (PDs) in response factors in the test continuing calibration, with the direction of bias for PDs of associated compounds opposite that of the IS area shift and with the extent of bias in percent differences similar (within ± 30 percent) for all or nearly all associated compounds.

TABLE 4

RECOMMENDED INTERNAL STANDARDS

Column:	Megabore	
Detector:	PID	ECD
IS_1	3-Cl-2-me propene	BrCl methane
IS_2	4-Br butene	2-Br-1-Cl propane
IS_3	1-3-Br_2-1-propene	1,3-Br_2-1-propene
Conc. IS_1	100 µg/l	100 µg/l
Conc. IS_2	100 µg/l	400 µg/l
Conc. IS_3	1,000 µg/l	1,000 µg/l

* Compound has lower sensitivity due to an ionization potential of 10.13.

5.5.8 Matrix Spike Solutions

Matrix spike solutions must be prepared in methanol, labeled, and stored according to the requirements specified for other standard solutions. Matrix spike solutions are valid for six months from the date of preparation or, in the case of working solutions, two months from the date of first use, whichever occurs first. Solutions must also be replaced if consistently low/high recoveries indicate that deterioration is occurring (as per Section 5.9.4). Matrix spike solutions shall be prepared by volumetric dilution of stock standards into methanol so that addition of no more than 300 ul to a sample is required to achieve a spiking level within the calibrated range. Matrix spike solutions will contain all the method target compounds.

5.6 Sample Collection, Preservation, and Handling

A complete discussion can be found in the standard operating procedures for sample collection. The analyst is responsible for maintaining chain-of-custody and for refrigeration of all samples until all analyses have been successfully completed. All analyses shall be completed within seven days of sample collection or as specified by project schedules, whichever is sooner.

5.7 Configuration, Setup, and Preventive Maintenance of the GC System

5.7.1 Configuration

Chromatographic columns will be installed according to the manufacturer's instructions. The PID shall be connected in series to the ECD. Recommended guidelines for gas flow rates, GC temperature programs, GC columns, and temperatures of heated zones are shown in Table 5. Other settings may be utilized if equivalent performance can be demonstrated and all QC criteria can be met. Other GC columns or temperature programs may be utilized if equivalent or superior resolution between target compounds and equivalent or superior peak width and symmetry can be achieved.

5.7.2 Instrument Set-Up

5.7.2.1 Installation of GC Columns

Installation of the GC column should follow the GC manufacturer's instructions. if the suggested megabore column is to be installed, request from the GC manufacturer or GC owner the prior installation of the megabore connections in the GC oven. Do not have the GC manufacturer or owner install the column prior to shipping to the site. The shock of shipping can cause a break in the column or worse, a hairline fracture that can seriously affect instrument performance and can lead to an outright break later during usage. Be sure to use the recommended ferrules for installation. Do not over-tighten the fittings because this will cause the fused silica tubing of the column to break or fracture either right away or in the future, when it will be hard to diagnose.

Be sure to cut new ends on the column before connection. The new cuts should be at right angles to the column and be burr-free. It is usually a good idea to practice cuts on a scrape piece of fused silica. If, under examination, the cut is not clean and at right angles to the column, cut again until it is. The chromatographic response is very sensitive to proper and leak-free connections of the column in the GC.

Newly installed GC columns must be conditioned for at least 8 hours at typical carrier gas flow rates at a temperature between 10 degrees below the upper operating temperature of this method and the maximum operating temperature for the column. Thereafter, a brief column conditioning equivalent to one method

TABLE 5

GC SYSTEM SETTINGS

Unit/Parameter	Specification/Setting
Column	RT_x 624 or DB 624 or Equivalent 30m x 0.53 mm I.D.
Carrier gas	ultra high priority (UHP) helium
Carrier 5PC	27.9 psi
Anode purge	23 ml/min
BCD aux.	30 ml/min
PID sweep	20 ml/min
PID aux.	20 ml/min
Inlet temperature	200° C
PID temp.	220° C
OCD temp.	210° C
Oven equilibrium time	0.0 min
Oven max. temp.	240° C
Initial oven temp.	42° C
Initial time	2.0 min
First ramp rate	80° C/min
First temp.	54° C (no hold)
Second ramp rate	22° C
Second temp.	130° (hold 0.40)
Inlet pressure	45.0 psi
Operation mode	constant pressure

temperature program cycle must be employed if a column is removed from the instrument or exposed to ambient air. If this occurs, carrier gas must be flushed through a column for at least 20 minutes before heating to prevent oxidative decomposition of the stationary phase.

5.7.2.2 Fittings and Ferrules

Brass fittings should generally be used on copper tubing and copper or brass components, and stainless steel fittings should be used on fused silica and stainless steel components unless otherwise recommended by the manufacturers. Ferrules should match the fittings except where special temperature considerations and/or special connections (such as the column connections to the fused silica column) apply. Special ferrules such as graphite, vespel, vespel-graphite, kevlar, kelvex, etc. may be required for use with either brass or stainless nuts. Most ferrules, especially metal ferrules, should never be reused unless suggested by the manufacturer. Tying to reuse ferrules is often the cause of serious leaks.

Remember to turn swagelok fittings 1-1/2 turns past finger tight for 1/2 inch and 1/4 inch fittings and 1-1/4 turns past finger tight for 1/8 inch and 1/16 inch fittings. Tighten beyond this only if the fittings is found to be leaking, and then only slightly, checking frequently to see if the leaking has stopped. Over-tightening fittings can lead to leaking connections that are impossible to fix, fittings that are impossible to loosen, and damaged connections that are difficult or impossible to replace. Never force a nut and ferrule onto a connection; this leads to stripping the threads of the nut and often the connection as well, making it impossible to obtain a non-leaking seal without complete replacement of all components.

5.7.2.3 Transfer Line from the PID to the ECD

Most GCs are constructed to accept up to two columns and as many as three detectors. To connect the PID to the ECD in series, a special transfer line must be installed from the exhaust of the PID to the inlet of the ECD. This transfer line must be contained within the GC oven compartment if at all possible; or run immediately into the oven compartment if the PID design doesn't permit this. This is vital for proper GC separation on the ECD.

The transfer line should be composed of aluminized fused silica, or fused silica, or if necessary, deactivated nickel. There is a gradual build up of certain compounds on the nickel line that makes it the least favorite choice. Aluminized fused silica has a greater tendency to snap than plain fused silica if the location of the PID exhaust is too close to the ECD inlet. Use of a section of the megabore capillary column (fused silica) can be used for the transfer line. If a section of the column is to be used for the transfer line, it is best that it be cut prior to the column installation.

A 16-inch section is the average length used in the transfer line. Follow the GC manufacturer's, or PID manufacturer's, or the owner's recommendations for recommended lengths and materials.

5.7.2.4 Leak Testing

Before initial instrument start-up, thoroughly leak test the system beginning at the gas cylinders and follow the gas flow, finishing at the ECD vent, with the system under pressure but with the heated zones still unheated. Repair any leaks and then repeat the operations with the instrument, PID, and ECD turned on and all heated zones heated at the recommended operating temperatures. Again, repair any leaks. The use of an electronic leak detector and helium as the carrier gas are preferred for all leak testing operations. If an electronic gas leak detector is not available, Snoop™ or soap bubbles can be used for exterior plumbing but must NOT be used for interior components. Instead, a solution of 50-70 percent alcohol (methyl or isopropyl) in water or the manufacturer's suggestions are to be used.

Each time the gas cylinder is changed or another connection is broken then reconnected (such as cleaning the PID lamp), leak testing of the affected connections is required before commencing analysis.

Monitor the contents of the gas cylinders on a daily basis and replace the cylinder when the remaining pressure reaches approximately 250 psig. Even UHP gases build up impurities in the bottom of the cylinder and should be replaced before the contaminants get into the GC system.

5.7.2.5 Flow Measurements

After the leak testing procedure outlined above, conduct flow measurements following the GC manufacturer's instruction. Proper gas glow is essential to proper resolution of target compounds. Be sure to record the flow measurements in the daily log or in the injection logbook and to record any subsequent adjustment or changes. If the flow measurements vary from the manufacturer's suggestions or those listed in Table 5 by a significant amount, recheck all system components, especially the transfer line, for leaks. Fix, remeasure flows, and record them in the daily log.

5.7.3 Electron Capture Detector (ECD)

The ECD contains a radioactive source, Ni_{63}. DO NOT ATTEMPT TO OPEN THE ECD CASING UNDER ANY CIRCUMSTANCES! If the ECD is not operating properly and all troubleshooting efforts fail, remove the entire unit and return to the owner or instrument manufacturer for replacement and/or repair.

The results of a recent radiation "wipe test," which checks for radiation leaks, should be available for any newly purchased or leased instrument. This test must be performed at a minimum once every 3 years and may be required as frequently as once every six months, depending in which "state" (US states, territories, military bases, Indian reservations) the instrument manufacturer or owner resides. The leak test information should be posted near the instrument at all times. The Nuclear Regulatory Commission (NRC) will provide information on leak test frequency if consulted.

If the instrument is to be used on a military base or on an Indian reservation, or in certain states called "agreement states," written notification and permission to transport and operate the instrument must be obtained prior to shipping. Many agreement states require 30 days written notice and the payment of fee if operated in the state more than 30 days under a specific license. Again, the NRC will provide the necessary information and contacts for agreement states. Exempt radiological instruments such as the ECD may be under either a general or specific license. A general license is held by the ECD manufacturer and allows the owner or leasee agrees to perform wipe tests at required intervals, return the unit for all repairs, source replacement or disposal. A specific license is held by the owner (not the leasee) and requires the owner to provide a fee, maintain a safety program, have an assigned radiation safety officer, provide training to all maintenance personnel, and perform wipe tests at required intervals, with the results being sent on to the state in which the owner resides. The specific license holder must return the ECD to the instrument manufacturer for source replacement and disposal and may only perform repairs if authorized by the instrument manufacturer.

5.7.4 ECD Maintenance

The ECD's response can be negatively impacted through oxygenation of the source at operating temperatures. The use of ultra high purity (UHP) gases and/or an oxygen trap installed on the gas line between the gas cylinder and the GC can help minimize this problem. If moisture and hydrocarbon traps are also to be installed, install the oxygen trap after the moisture and hydrocarbon traps in the gas supply line. Monitor the contents of the gas cylinder on a daily basis and replace the cylinder when the remaining pressure reaches approximately 250 psig. Even UHP gases build up impurities in the bottom of the cylinder and should be replaced before the contaminants get into the GC system.

Before initial instrument start-up, thoroughly leak test (use of an electronic leak detector and helium as the carrier gas are preferred) the system from the gas cylinder to the ECD vent under pressure but with the

heated zones still unheated (see Section 5.7.2.4). Repair any leaks and then repeat the operations with the heated zones heated at operating temperatures. If an electronic gas leak detector is not available, Snoop™ or soap bubbles can be used for exterior plumbing but must NOT be used for interior components. Instead, a solution of 50-70 percent alcohol (methyl or isopropyl) in water or the manufacturer's suggestions are to be used.

If the ECD is totally non-responsive, check the following:

- That the power is on for the GC. Check that the instrument is turned on, both at the instrument itself and in the computer program if one is being used. Also check that the plug is plugged in, and the circuit breaker is not tripped. Remember these can happen to even the most experienced chromatographer; it is better to look for yourself than to have someone else discover it for you.

- That the power is on for the ECD. Check the detector section of the GC to be sure the ECD is turned on there and on the ECD power source if it is separate from the GC. If the ECD is being operated from a computer program such as STAR™ or HP's Chem Station™, check the appropriate screen to be sure the program calls for the detector to be on and at the proper operating temperature.

- That the correct operating temperature has been set for the ECD and all other heated zones.

- That the gas cylinder regulator is set to the correct pressure and the cylinder valve has been fully opened.

- That the transfer line between the PID and ECD is intact and doesn't have a major crack or hairline fracture. A complete break will be readily visible; use the electronic leak detector or alcohol solution to check for cracks or hairline fractures. This is the most common cause of ECD failure once the GC is operating on a daily basis. If it is leaking, replace the entire transfer line.

- Check the solution preparation to be sure that ECD compounds were included in the preparation of the standard solutions. Check for the presence of chlorobenzene, TCE, and PCE on the PID if contained in the same mixture; check that standard preparation log and count ampoules if it is not. If no obvious problem is found, re-prepare and reanalyze the standard compound solution. Preparing and analyzing only the mixture containing the missing ECD compounds can also be performed if this is the first time the lot has been analyzed. Occasionally the standard manufacturer mis-prepares the stock solutions, in which all compounds may or may not be present. it is also useful to analyze a standard solution prepared by a separate manufacturer to ensure correct operation of the GC, PID, ECD, and data acquisition systems.

If the ECD has less response (as evidenced by lower area counts in chromatogram):

- Check to see if the transfer line between the PID and ECD is slightly cracked or has a hairline fracture by leak testing with the electronic leak detector or alcohol solution. If it is leaking, replace the entire transfer line.

- See if the PID compounds are similarly affected. This may indicate a leak prior to the PID, or, most likely, degradation of standard solutions. If the preparation and analysis of fresh solutions do not improve the response, search for leaks in the PID seal (especially if the lamp has recently been cleaned and/or replaced), the column, the injection port septum seal if recently replaced, and then begin at the ECD vent and work your way through the plumbing back to the gas cylinder. Occasionally, this may occur if the gas cylinder regulator is not fully open. The solution is to fully open the gas cylinder regulator.

If only some ECD compounds have low or no response:

- Check the preparation of the standard solution if freshly remade, or for solution degradation if the solution has been successfully analyzed previously. Re-prepare the solution in accordance with Section 5.8.

5.7.5 Photoionization Detector (PID)

5.7.5.1 PID Lamps

If an 11.7 electron-volt (eV) lamp is used for the PID, the lamp window material is extremely sensitive to any moisture in the system. A moisture trap must be installed in the gas supply line between the gas cylinder and the GC prior to the installation of the lamp. The lamp window will become opaque and useless once exposed to ambient atmosphere for any length of time (if installed, its expected life is 1 to 3 months). If a moisture trap is used on the gas lien to the GC and the lamp promptly installed once unsealed, moisture is usually not as serious problem in headspace analysis as it would be in purge-and-trap analyses. However, it is important to note that the lamp window must not be exposed to water and should be cleaned, when necessary, with a cesium oxide compound. Even the purest of alcohols and other solvents contain significant amounts of water and should not be used.

if a 10.0 or 10.2 eV lamp is used, moisture sensitivity is not a problem but it does have a lesser sensitivity to certain compounds such as methylene chloride.

5.7.5.2 Hydrocarbon Trap

Use of a hydrocarbon trap on the gas supply line between the gas cylinder and the GC is recommended where UHP gases are not used or are not available. If UHP gases are used, the hydrocarbon trap is not necessary but can be installed if desired. If the oxygen trap is also installed, place the hydrocarbon and moisture traps before it in the gas supply line to remove most impurities to increase the effective life of the oxygen trap. See the trap manufacturer's instructions before installation.

5.7.5.3 PID Maintenance

If the PID is totally non-responsive, check the following:

- That the power is on for the GC. Check that the instrument is turned on, both at the instrument itself and in the computer program if one is being used. Also check that the plug is plugged in, and the circuit breaker is not tripped. Remember these can happen to even the most experienced chromatographer; it is better to look for yourself than to have someone else discover it for you.

- That the power is on for the PID. Check the detector section of the GC to be sure the PID is turned on there and on the PID power source if it is separate from the GC. If the PID is being operated from a computer program such as STAR™ or HP's Chem Station™, check the appropriate screen to be sure the program calls for the detector to be on and at the proper operating temperature.

- That the correct operating temperature has been set for the PID and all other heated zones.

- That the gas cylinder regulator is set to the correct pressure and the cylinder valve has been fully opened.

- Check the solution preparation to be sure that PID compounds were included in the preparation of the standard solutions. Often most of the PID compounds (benzene, toluene, chlorobenzene, ethyl benzene, and xylenes) are contained in one solution. Check for the presence of chlorobenzene on the ECD if contain in the same mixture, check the standard preparation log and count ampoules if it

is not. If no obvious problem is found, re-prepare and reanalyze the standard compound solution. Preparing and analyzing only the mixture containing the missing PID compounds can also be performed if this is the first time the lot has been analyzed. Occasionally the standard manufacturer mis-prepares the stock solutions, in which all compounds may or may not be present. It is also useful to analyze a standard solution prepared by a separate manufacturer to ensure correct operation of the GC, PID, ECD, and data acquisition systems.

If the PID has less response (as evidenced by lower area counts in chromatogram);

- The PID lamp window may require cleaning. This would be especially likely if all of the ECD compounds show normal responses. To remove and clean the lamp, follow the manufacturer's instructions. Be sure to cool down the detector before starting to clean the lamp. It is recommended that the lamp window be cleaned either last thing at night or early in the morning, and that the entire instrument be cooled to prevent excessive contamination of the system during the cleaning process. However, turning off the PID and cooling down its heated zone is acceptable if suggested by the instrument manufacturer. It is often safest to turn if off and on at the instrument or power supply rather than using the software if possible. Pulling out the plug on the power supply is also good practice.

- See if the ECD compounds are similarly affected. This may indicate a leak prior to the PID (such as the column or injection port) or, most likely, degradation of standard solutions. If the preparation and analysis of fresh solutions do not improve the response, search for leaks in the PID seal (especially if the lamp has recently been cleaned and/or replaced), the column, the injection port septum seal if recently replaced, and then begin at the ECD vent and work your way through the plumbing back to the gas cylinder. Occasionally, this may occur if the gas cylinder regulator is not fully open. The solution is to fully open the gas cylinder regulator.

If only some PID compounds have low or no response:

- Check the preparation of the standard solution if freshly remade, or for solution degradation if the solution has been successfully analyzed previously. Re-prepare the solution in accordance with Section 5.8.

5.7.6 Preventative Maintenance

5.7.6.1 <u>Once Per Project</u>

- Leak test entire GC system

5.7.6.2 <u>On a Daily Basis</u>

- Check the contents of the gas cylinders. Replace when approximately 250 psig remains.
- Check the pressure of the gas regulators.
- Check and record the temperatures of the heating oven, water bath (if used), refrigerator, freezer or cooler, and ambient room temperature.
- Replace the injection port septum at the end of the day.
- Back up all chromatographic and other computer data on floppy disks (or CD if available).

5.7.7 Critical Spare Parts

The following are suggested critical spare parts:

- 2 Swagelok fittings connecting gas regulator with 1/8 inch copper tubing
- 1/8 copper tubing, pre-cleaned, approximately 10 to 50 feet
- 2 or more capillary column repair connectors (Alltech or equivalent)
- one spare cylinder of UHP helium
- one spare cylinder of UHP nitrogen
- 50-100 Thermogreen™ or equivalent low-bleed septa for the injection port
- 1 spare PID lamp
- 1 spare set PID seals
- 2 sets of the ferrules required for capillary column installation
- 2 sets of the ferrules required for PID to ECD transfer line
- Fused silica for transfer lines (2 to 10 feet)
- 4 each 1/8 swagelok caps and nuts
- 4 each 1/16 swagelok caps and nuts
- 2 each 1/8 to 1/16 swagelok reducing unions
- 2 each 1/8 swagelok unions
- 2 each 1/16 swagelok unions
- 1 full set of fuses for all electrical equipment
- Back up copy of all computer programs, especially the data acquisition program
- Copies of the manuals for all equipment

5.8 Calibration

The calibration program required for this method consists of an initial multi-level calibration to establish linearity within the working range, followed by continuing calibration standards before and after each sample analysis period of up to 12 hours. Calibration QC criteria for this method are summarized in Figure 3.

5.8.1 Initial Calibration

5.8.1.1 Calibration Requirements

A multi-level calibration sequence that meets the requirements of Section 5.5.5 must be analyzed before the analysis of any samples. This initial calibration must be performed each time a new GC column is installed, whenever column flow rates are changed by more than 10 percent, after any maintenance that might conceivably alter the linear dynamic range, or every 30 days, whichever is more frequent. In addition, a new initial calibration must be performed when the continuing calibration criteria described in Section 5.8.2 cannot be met.

5.8.1.2 Initial Calibration Run

Prepare a low-concentration aqueous calibration standard in a 40-ml VOA vial according to the procedure in Section 5.5.5. Upon completion of aliquot addition, immediately replace the Teflon-lined septum and screw-cap top. Inject 12 ul of the internal standard solution described in Section 5.5.7 through the septum of the VOA bottle, holding the tip of the syringe needle just beneath the surface of the water. Proceed with heating, sample injection, and analysis following the procedure in Section 5.10.

5.8.1.3 Evaluation of Chromatogram

Evaluate the chromatogram from the first initial calibration standard to make sure that peak tailing, symmetry, width, and retention times indicate typical system performance. All peaks contained in the standard chromatogram must be sharp and symmetrical. Peak widths should be less than 0.40 minute in the early part of the megabore capillary chromatogram or poor injection focusing may be indicated. (The sharpness and width of peaks may need to be optimized by adjustment of injection technique, flow rates, and GC temperature program following instrument operations procedures.) Significant peak tailing must be corrected. All analytes must be visible in the low-concentration standard at least 10 times the baseline noise level. (This will be established for all compounds if the peak height of the smallest peak in the standard chromatogram is greater than five times the height that envelopes peak-to-valley noise fluctuations.) If any significant adjustments are made, repeat the prior initial calibration standard(s).

5.8.1.4 Response Factors

Analyze the remaining initial calibration standards in the order of ascending concentration levels. After all standards have been analyzed, calculate the relative response factor (RRF) for each of the target analytes. The RRF, the average of the initial calibration RRFs, and the relative standard deviation (RSD) of the RRF s for each analyte must be calculated using the formulas in Section 5.11.1. The closest eluting internal standard shall be utilized to compute response factors for each target compound, unless it can be shown over three or more initial calibration data sets that smaller percent differences in response factors are achievable by using the other adjacent internal standard.

5.8.1.5 RSD/RRF Criteria

The RSD of the RRF for each of the site-specific target compounds should not exceed 30 percent. The percent RSD of non-target compounds that are to be quantified should not exceed 35 percent.

5.8.1.6 Corrective Actions

If any target compound percent RSD exceeds the acceptance criteria, first verify the associated chromatographic data and calculations for the errant analyte, then prepare fresh standards and reanalyze. If the errant compound performs similarly, then analysis of the QC check solution can serve as verification of the presence or absence of a target compound in the standards. If the compound performs similarly in both solutions, then check the entire chromatographic system and make any necessary repairs. After adjustments are complete, repeat the initial calibration sequence until the calibration criteria in Section 5.8.1.5 are met for the target analytes.

5.8.1.7 Detector Selection

For compounds with similar sensitivity on both detectors (specifically, methylene chloride, trichloroethene, and tetrachloroethene), quantitation should be pre-selected for routine reporting of results from one detector or the other at the time of initial calibration. RSD criteria must be met for the detector used for quantitation. Note that the data system should calculate RRFs and levels on both detectors as a form of corroboration and to allow alternate quantitation for samples with interfering peaks on one detector.

5.8.2 Continuing Calibration

5.8.2.1 Calibration Requirements

A calibration standard (containing all target analytes) that meets the requirements of Section 5.5.5 must be analyzed at the beginning and end of each period of up to 12 hours of sample analysis. In addition, this

continuing calibration standard must be analyzed after every 20 analytical runs or after any system adjustments or maintenance that might alter quantitative response or retention times, whichever is more frequent.

5.8.2.2 Response Factors

After the continuing calibration standard has been analyzed following the procedures in Section 5.10, calculate the RRF for each target analyte and compute the percent difference (%D) for each RRF relative to the initial calibration RRF, according to the formula presented in Section 5.11.2. Note that, if samples are to be analyzed in the 12-hour period following an initial calibration, there is no requirement to compute the %D from any standard run before the samples, as long as quantitation for this group of samples is performed using the average RRF. Alternatively, if the data system is not capable of quantitation using the average RRF, quantitation may be performed using one of the mid-range initial calibration standards. However, in this case, the %D of RRFs in this standard, relative to the average RRFs from all standards, must be computed and evaluated.

5.8.2.3 Percent Difference (%D)

The absolute percent difference (%D) between the initial and the continuing calibration standard for each of the site-specific target compound should not exceed 25 percent. The %D of non-target compounds that are to be quantified should not exceed 30 percent.

5.8.2.4 Corrective Actions

If any target compound %D exceeds the acceptance criteria, first verify the associated chromatographic data an calculations for the errant analyte. If out-of-control system response if confirmed, check the system and make any necessary repairs. If only minor adjustments are required (i.e., cleaning the PID window) that do not mandate a new initial calibration as per Section 5.8.1.1, then a new continuing calibration standard may be analyzed. All sample analyses since the last acceptable calibration standard must be repeated after appropriate correctable action and acceptable calibration analyses have been performed. Sample reanalysis may not begin until an acceptable calibration standard that meets the requirements established above has been performed.

5.8.3 Calibration Using External Standards

When sample-specific interferences exist with an internal standard, the analyst may choose to quantitate using the external standard method. If the external standard method is selected, initial calibration data and the continuing calibration standards run before and after the sample must be reprocessed to generate and compare calibration factors (CFs) instead of RRFs, using the formulas presented in Sections 5.11.4 and 5.11.5. Quantitation may not be performed using the external standard method unless the RSDs of the CF (from the initial calibration) for the target analyte(s) being quantitated are all less than or equal to 30 percent and unless the CFs for these analytes in the standards run before and after the sample in question all exhibit a %D less than 25% relative to the initial calibration average CF.

5.9 Quality Control

The QC program required for this method includes analysis of QC check standards, trip blanks, equipment rinsate blanks (where appropriate), laboratory reagent blanks, spiked samples, laboratory duplicate samples, field duplicate samples, retention time window monitoring, internal standard monitoring, and maintenance of a QC records database. For all the above areas, any identified problems and corrective action must be documented in the instrument run log, analysis narrative report, and instrument maintenance log or standards log (as applicable). Temperatures of the oven and/or waterbath,

freezer, refrigerator, and room used for analysis will also be recorded in the log book on a daily basis. An example page format for the instrument run log is shown in Figure 4 and a standards log is in Figure 1. A summary of the QC requirements for this method is provided in Figure 3.

5.9.1 QC Check Standard

A QC check standard solution, prepared as in Section 5.5.6, must be analyzed at least once each field analysis project or once each initial calibration, whichever is more frequent. The results of the QC check standard must fall within 50 percent to 150 percent of the true value. If these criteria are not met, check the entire analytical procedure to locate and correct the problem source. Corrective action may include preparation and/or analysis of a new QC check standard or new calibration standards followed by re-analysis of the QC standard.

5.9.2 Field Quality Assurance Blanks

Trip blanks and equipment rinsate blanks must be prepared according to the frequency specified in the WP or QAPP. If any of these blanks are contaminated with target analytes at levels greater than five times the method reporting limits, the problem must be investigated, corrected, and reported to the project leader for the sampling investigation. These blank data should be evaluated immediately after analysis in sufficient time to allow re-analysis or other corrective action. If any of these blanks are found to be contaminated with target analytes above ten times the MDLs, then a laboratory reagent blank shall be prepared and analyzed immediately following the field QC blank to test whether the problem can be traced to the laboratory procedure. If the associated laboratory reagent blank is also contaminated, the trip blank and any affected samples associated with the contaminated laboratory blank must be re-analyzed according to the requirements of Section 5.9.3. Affected samples are defined as those with instrument levels less than five times the instrument level in the associated laboratory blank.

5.9.3 Laboratory Reagent Blanks

A laboratory reagent blank must be analyzed after each initial calibration sequence, after each continuing calibration standard that precedes associated sample analyses, after any sample run that might be high enough to produce instrument carryover at reportable levels in a subsequent sample (see Section 5.2.3 for criteria), and whenever a new batch of reagents (e.g., methanol or reagent water) is introduced. The results of the laboratory reagent blank must be evaluated before analysis of any subsequent samples. If any target analytes are present at levels greater than five times the method reporting limits, then sample analysis may not proceed until the problem has been corrected and an acceptable reagent blank has been analyzed.

5.9.4 Matrix Spike Samples

Spiked sample analysis shall be performed at the frequency specified in the WP or QAPP. Samplers will identify samples to be used for spiking on the chain-of-custody form and will supply additional containers for such samples. If samplers do not designate samples to be matrix spiked, then the analyst shall select one sample to be spiked per each group of 1 to 20 solid or aqueous samples of a similar matrix. The corresponding unspiked sample should be analyzed first in order to allow calculation of an appropriate level of spike to be added (within the calibrated range but greater than three times the indigenous concentration of the same analytes). Inject an appropriate quantity of the spiking solution described in Section 5.5.8, containing all site-specific target compounds (at the minimum) through the septum of the sample bottle, with the tip of the syringe needle beneath the surface of the water. Add 12 ul of the internal standard solution in the same manner and proceed with sample heating, aliquot injection, and analysis of the spiked sample following the procedures specified in Section 5.10. After completion of both the spiked and unspiked analysis, calculate the percent recovery for each analyte added according to the formula presented in Section 5.11.7. If the recovery of any analyte is outside the control limits of 50 to

150 percent, then investigate and correct the problem following the decision scheme given below:

- Double check the chromatographic identification and integration data and recalculate the spike results.

- If the out-of-control analyte was positive in the unspiked sample and if all spike analytes that are not found in the unspiked sample are in control, then repeat the spike analysis using a five times higher relative spiking level by reducing the sample volume and/or increasing the amount of spike added. Note that the volume of spike solution added should not exceed 300 ul and spike results should be within the calibrated range.

- If only the more volatile spike compounds have low recoveries (those with boiling points under 75°C) and internal standard areas are acceptable, then deterioration of the spiking solution shall be investigated. A new spiking solution should be prepared and the spiked sample should be re-analyzed. Alternatively, a reagent water spike may be performed to verify the integrity of the spiking solution. If the reagent water spike exhibits similar performance, then a fresh spiking solution must be prepared and a new spiked sample analysis performed.

- If spike results from the current sample and the most recent previous sample spiked with the same solution all exhibit out-of-control recoveries for the same analytes, with a comparable direction and extent of bias (within ±30 percent), then the integrity of the spiking solution shall be investigated as described in bullet No. 3.

- If spike recoveries are all high or all low with a similar extent of bias (within ±30 percent), but internal standards are within control limits, then a spiking error is suggested and the spiked analysis shall be repeated.

- If the recovery for any analyte is outside the limits 50 percent to 150 percent and if the preceding steps do not resolve the problem, then a repeat of the matrix spike shall be performed to verify a matrix effect (if not already conducted per the preceding bullets).

5.9.5 Laboratory Duplicate Samples

Laboratory duplicate sample analysis shall be performed at the frequency specified in the WP or QAPP. Samplers will identify samples to be used for laboratory duplicate analysis on the chain-of-custody form and will supply extra volume for such samples. Analyze the same aliquot size that was used for the initial sample analysis. Calculate the relative percent difference (RPD) using the formula presented in Section 5.11.8. If the RPD for any analyte is not within warning limits of ±50 percent or if any analyte is present at a level greater than five times the MDL in one analysis but not detected in the other analysis, then data shall be further scrutinized according to the following scheme and appropriately discussed in the narrative report:

- Verify that sample labeling, chromatographic identification and integration data, and calculation of duplicate results are correct.

- If any of the three largest component peaks in the sample are above the MDL in both analyses but exhibit an RPD of greater than 150 percent (a factor of 4 disagreement), then the project leader shall be informed and a third aliquot or a fresh sample obtained from the same location shall be analyzed.

- If any target compound is detected in one analysis at a level above five times the MDL but not found in a duplicate analysis, then the project leader shall be informed in sufficient time to allow re-analysis or other corrective action. (These options depend on site-specific objectives, which are beyond the scope of this analysis SOP.)

5.9.6 Field Duplicate Samples

Field duplicate samples will be collected at the frequency specified in the WP or QAPP. Evaluation and corrective action shall be handled as for laboratory duplicates, as discussed in Section 5.9.5.

5.9.7 Retention Time (RT) Monitoring and Control

Since analyte identification is based solely upon RT matching, established procedures must be followed to determine the width of RT windows. If the widths of RT windows used for identification are unrealistically narrow, false negatives may occur. Conversely, windows that are too wide will increase the likelihood that interfering compounds will elute within analyte identification windows.

5.9.7.1 Calibration Standard Runs

To establish the width of the RT window for each analyte on a given GC column and under a particular set of operating conditions, before any samples are analyzed, at least five calibration standards must be analyzed over the course of a 7- to 12-hour period. These standards must be representative of RT behavior over a typical analysis period (analogous to samples run at various intervals). Therefore, between 20 and 60 percent of the total number of standards used to develop each RT window must consist of standards analyzed within the middle one-third of the time interval between the first and the last standard for the 7- to 12-hour period.

5.9.7.2 Compound Identification

After the above standards have been run, carefully evaluate all standards to make sure that no compounds have been misidentified. Whenever any doubt exists about the identity of a component peak, an individual standard containing only the component in question must be analyzed to confirm elution times. Elution orders of previous standard chromatograms obtained on the same column should be compared as a check against misidentification each time new RT windows are established.

5.9.7.3 Calculation of RT Window Width

Using retention time data from the above-referenced standards, the width of RT windows shall be calculated as described in Sections 5.11.9 and 5.11.10, based upon an IS method for RT prediction. The formula in Section 5.11.9, which uses the Relative Retention Time (RRT) method, shall be used for all analytes. Section 5.11.10 also contains an alternate calculation technique for computing the width of the RT windows based upon an external standard method for RT prediction, which shall be used for target compounds only in situations where sample components obscure ISs.

5.9.7.4 RT Window Widths for Target Analytes

Using the formula in Section 5.11.9.2, compute the width of the RT window for each target analyte as plus or minus the square root of the variance of the observed minus the predicted RTs within the standard set, multiplied by the student's t-value using an 0.995 confidence level and given the number of degrees of freedom in the set of standards used to calculate the variance.

5.9.7.5 RT Window Width - Modification

The RT windows calculated above must be modified if they are unrealistically narrow, given the limitations of the data system and chromatographic resolution. The most important application of this principle is when two compounds co-elute in the standard chromatogram. If two separate peak maxima do not exist,

then the overall width of the combined peak shall be compared to that of a normal (fully resolved) nearby component to determine the approximate retention time error. The RT difference between the width of a "normal" peak and that of the co-elution peak shall be added to the RT window width determined above in order to obtain a realistic retention time window for both components of the co-eluting pair.

5.9.7.6 RT Window Width - Optimization

Uncertainty in RTs must also be considered for fully resolved components in the sense that locations of peak apexes are not precisely known. Therefore, the working RT window for each analyte must be greater than or equal to the maximum of the quantities: ±1.5 times the step size of the integrator or ± three times the uncertainty in the measurement of the retention time of a typical peak apex or centroid (which is a function of peak widths). When the megabore capillary column is optimized to achieve peak widths less than or equal to 0.33 minute (measured to include 95 percent of total area) and when the packed column is optimized for peak widths of 0.70 minute or less, then the calculated RT windows must be greater than or equal to ±0.02 minute on the megabore column and on the packed column. (Note that the sharpness of chromatographic peaks can be optimized by adjustment of injection technique, flow rates, etc.) If the RT windows calculated in 10.7.4 are less than the above values for any analyte, then substitute the largest of the alternate limiting values defined above.

5.9.7.7 RT Window Widths - Utilization Time Frame

Once RT window widths have been established, they may be utilized for a maximum of 90 days. (Although the widths of the RT windows remain constant over this 90-day period, the center of each compound's prediction window varies with each 12-hour calibration and with internal standard shifts in each sample.) Irrespective of this maximum, revised RT windows must be developed if the continuing calibration retention time criteria in Section 5.9.7.9 recurrently cannot be achieved, if absolute retention times shift more than 10 percent for any compound, if a new GC column is installed, if a new GC temperature program is adopted, or if carrier gas flow rates used for analysis are altered by more than 15 percent from the values used in window development, whichever occurs first.

5.9.7.8 RT Window Widths - 12 Hour Cycles

A calibration standard containing all target analytes must be analyzed at the beginning and end of each period (of up to 12 hours) of sample analysis. The standard run immediately before each group of samples will be used in conjunction with internal standard elution times in these samples, to predict the RTs for each analyte. Using the formulas in Section 5.11.9.3, the RT window for each analyte will be calculated as the predicted RT plus or minus the RT window width computed in Sections 5.9.7.1 through 5.9.7.5.

In the event of sample-specific interferences with internal standards, the center of each analyte's RT window will be defined as equal to the absolute RT from the most recent calibration standard, and the plus or minus RT window width will be calculated according to the alternate external standard formula in Section 5.11.10.2.

5.9.7.9 RT Window Widths - Corrective Actions

The calibration standard analyzed at the end of each period of up to 12 hours of sample analysis must exhibit RTs for all target analytes that fall within the windows predicted from the calibration standard run immediately before the group of samples. If any analyte in this standard elutes outside established RT windows, appropriate corrective action must be taken, after which affected samples must be re-analyzed. If criteria are exceeded, first verify associated chromatographic calculation data. If out-of-control RTs are confirmed, then check the system (flow rates, leak checks, etc.) and make any necessary adjustments or repairs. A new continuing calibration standard must be run following any minor system adjustments,

whereas a new initial calibration must be performed if any of the more serious adjustments described in Section 5.8.1.1 are made. New RT window widths must be developed if any of the major system adjustments described in Section 5.9.7.7 are made or if repetitive problems with out-of-control RTs are experienced.

5.9.7.10 RT Window Widths - Revisions

Revision of RT window widths may be performed by the analysis of five or more standards in one 7- to 12-hour period (as described in Section 5.9.7.1).

5.9.8 Internal Standard (IS) Monitoring and Control

IS retention times and area response shall be monitored and controlled in all analytical runs. IS retention times in all sample runs must fall within established RT windows to ensure that overall retention time performance for the GC system is stable and in control and to ensure that nearby co-eluting compounds are not mistaken for an internal standard (thereby causing erroneous analyte RT prediction or quantitation). Similarly, all IS area responses must fall within established QC limits to ensure stable and accurate quantitative performance of the headspace injection technique, GC, and detectors and to ensure that unknown compounds co-eluting with an IS cannot cause seriously biased quantitation.

5.9.8.1 Calculation of IS Retention Time Window Width

IS retention time window widths shall be established concurrently, using the same calibration standard run data and whenever RT windows are established for target analytes. Therefore, all procedures specified in Sections 5.9.7.1 through 5.9.7.10 for target analyte RT windows are also applicable to the establishment and control of RT windows for ISs with one exception: the calculation techniques and formulas referred to as the "external standard technique" in Section 5.9.7.3 shall be used to establish the width of RT windows for internal standards and in Section 5.9.7.8 to establish the center of the RT windows for ISs. This is necessary because IS elution times in sample analyses are predicted using data from only the calibration standard runs (as opposed to using one IS in a sample to predict the RT for another IS in the same sample).

5.9.8.2 IS Performance

IS performance in each analytical run must be evaluated and compared to the most recent calibration standard (run at the beginning of the 12-hour period). If any IS elutes outside its established RT window, first check the associated chromatographic data to determine whether IS retention times (or IS areas) are obscured by an unknown co-eluting sample component.

5.9.8.3 IS Performance - Retention Times

If IS areas are within the control limits specified in Section 5.9.8.5 and if peak width and symmetry for the IS with out-of-control retention times appear normal, then the sample must be rerun under the assumption that the actual elution times for the IS have shifted and are out of control. If this occurs, first check the system for malfunctions. If any adjustments are made, then the appropriate recalibration must occur before sample re-analysis.

5.9.8.4 IS Performance - Alternate Quantitation

Conversely, if peak shape is atypical (unusually wide or asymmetric) for the IS with out-of-control RTs or if IS areas are high (above limits) for the IS with noncompliant RTs, then a co-eluting interference is suggested. In this case, the alternate quantitation (external standard) option shall be performed to

evaluate data associated with the noncompliant IS.

5.9.8.5 IS Performance - Area Response

Concurrent with the evaluation of RTs, the area response of each IS in each analysis must be evaluated to ensure that the percent difference in areas are between -50 percent and +200 percent of the IS areas in the most recent calibration standard. If criteria are exceeded, check the associated chromatographic data to determine if co-elutions or peak overlaps have biased the IS area response. Re-integrate the IS peak only if incorrect integration endpoints or baseline were selected by the data system. (Re-integration solely to achieve area criteria that skew or distort accurate IS area measurement is strictly forbidden.)

5.9.8.6 IS Performance - Overlapping Area Response

If out-of-control IS areas are associated with overlapping peaks having greater than 33 percent valley relative to the IS height or if a high IS area (above limits) is associated with either out-of-control retention times or wide or asymmetric peak shape, then a co-eluting chromatographic interference is suggested. In this case, the alternate quantitation (external standard) option shall be performed to evaluate data associated with the noncompliant IS.

5.9.8.7 IS Performance - Out-of-Control IS Areas

Conversely, if out-of-control IS areas exist but are not associated with the conditions specified in 10.8.6, then the sample must be rerun under the assumption that the quantitative response of the IS is biased due to matrix effects, poor injection performance, or inaccurate system performance. If this occurs, first check the system for malfunctions. If any adjustments are made, then appropriate recalibration must occur before sample reanalysis. In the special case of blank analysis, if both initial and re-analysis exhibit out-of-control IS areas, then the required corrective action will be to run a continuing calibration standard to check whether system response or IS solution integrity are at fault, following the procedure in Section 5.5.7.2.

5.9.8.8 IS Performance - Corrective Action

If chromatographic interferences are suggested for one IS and inaccurate system performance is indicated for another IS, then both types of corrective action shall be taken. System performance shall be checked first to allow adjustments to be made before reanalysis.

5.9.8.9 Analytical Results

Whenever a re-analysis is performed, the analyst shall follow the procedures for data reduction, validation, and reporting in order to determine which of the analyses (or whether both analyses) is to be reported.

5.9.9 QC Records Database

All the QC data in this section and the quantitative calibration QC data must be maintained in a QC records database for the project. Any adverse trends in QC parameters shall be investigated, corrected, and documented in the QC database for the project. QC database items shall include RT window data, initial and continuing calibration response summaries, blank results, duplicate results, matrix spike and QC check standard recoveries. In addition, any quantitative comparison data from the evaluation of standard solution integrity shall be retained. Instrument logbooks and standard preparation logbooks that are no longer in use must also be retained in the project files.

5.10 Procedure for Sample Analysis

5.10.1 GC Operating Conditions

Table 5 summarizes the recommended GC operating conditions for this method. The sample analysis sequence and analytical decision scheme shown in Figure 2 may begin after all required QC criteria have been met, procedures have been completed as specified for GC system setup and configuration (Section 5.7), calibration standards preparation (Section 5.5) and analysis (Section 5.8), and RT windows have been established as per Section 5.9.7.

5.10.2 Syringe Preparation and Handling

5.10.2.1 Syringe Preparation

The sample injection syringe must be rinsed with methanol and dried in an oven for at least 15 minutes at 65°C to 70°C (but never hotter) before each injection. The plunger must be removed from the syringe bore before baking and should be re-inserted upon removal from the oven. Sample injection must be accomplished while the syringe is warm to minimize analyte condensation losses.

5.10.2.2 Syringe Inspection/Maintenance

The syringe should be examined frequently for signs of leakage or blockage. During the methanol rinse step, as methanol is withdrawn into the syringe, there should be no air bubbles forming or entering the syringe near the plunger tip or the point of needle attachment. Leakage from the plunger tip can be remedied by replacing the Teflon tip on some syringe models. Leakage from the needle can be remedied by tightening or replacing the removable needle assembly. Blockage of the syringe needle is suggested when excessive resistance is encountered as the plunger is withdrawn or depressed or when the methanol rinse solution is expelled from the needle as an uneven spray as opposed to a steady flow. If blockage of the needle is suspected, clean the needle using the fine-gauge wire supplied with the syringe. If this is not successful, replace the needle and again clean the syringe assembly with methanol.

5.10.2.3 Sample Injection Volume

For standard injects and initial (undiluted) injections of samples, a fixed injection volume should be utilized. A 400-ul injection volume using a 500-ul gas-tight syringe is recommended for this purpose. If a dilution is indicated, a smaller injection volume will be utilized, provided that a 25-ul syringe size or larger is employed and that the volume injected is within the optimum working range of the syringe, defined as between 20 and 80 percent of the syringe capacity. (Volumes less than or greater than these criteria will be susceptible to variable efficiency or leakage during syringe loading or delivery.)

5.10.2.4 Sample Injection Technique

Withdrawal or injection of headspace must be accomplished by moving the plunger of the syringe at a steady and moderate rate to prevent imprecise volumetric transfer, molecular weight discrimination, leakage of the syringe, or uneven column pressures. For optimum performance, it is recommended that capillary column injection rates do not exceed 100 ul per second and that all headspace injections be performed at a steady rate of 20 percent of the total syringe capacity per second. Headspace withdrawals should be performed at a slow and steady rate in order to avoid a vacuum effect within the syringe (indicated by a temporary increase in plunger resistance).

5.10.3 Sample Preparation

5.10.3.1 Sample Volume

For solid samples: weigh approximately 12.0 g of solid sample. Record sample weights to the nearest 0.1 gram and carefully add to 23 mls of reagent water in a 40-ml VOA vial. For aqueous samples: add an aliquot of 30-ml to a 40-ml VOA vial.

5.10.3.2 Addition of IS Solution

Inject 12 ul of the IS solution described in Section 5.5.7 through the septum of the sample bottle, holding the tip of the syringe needle just beneath the surface of the water. Withdraw the syringe and shake the bottle moderately for one minute to disperse the soil and extract the VOCs.

5.10.3.3 Heat Bath/Oven

Place the sample or standard bottle into a water bath or oven heated to between 65°C and 70°C. If using a water bath, the water level in this bath must be equal to the level of the liquid in the sample containers (approximately two inches in depth). Note that when a sample or standard has been heated once, it may not be re-heated or re-injected.

5.10.3.4 Sample Agitation

After two-thirds of the 15- to 30-minute heating period has elapsed (approximately 5 to 10 minutes before injection), remove the bottle from the water bath or oven and shake for another minute. Return the bottle to the bath or oven for at least 5 more minutes, but keep the total time in the water bath or oven less than 30 minutes.

5.10.3.5 Syringe Re-Assembly

After the 15-minute minimum syringe heating period and the 20- to 30-minute sample heating period are complete, remove the syringe from the oven, re-assemble the syringe, and fully depress the plunger.

5.10.4 Sample Injection

5.10.4.1 Sampling Headspace Vapor

Immediately after re-assembling the syringe, remove the sample container from the water bath or oven, shake the vial for 10 to 15 seconds, and insert the needle of the syringe through the septum until the needle is approximately one-half the distance from the septum to the surface of the water. Withdraw 400 ul (or other pre-determined volume is a dilution was indicated) of the headspace vapor into the syringe at the rate specified in Section 5.10.2.4.

5.10.4.2 Sample Injection

Immediately after loading the syringe, insert the needle through the septum of the GC injector port until at least one-half the length of the needle protrudes beneath the septum, but not so far as to touch the column itself. (If the needle contacts the column, withdraw it slightly.) Immediately begin depressing the plunger at the rate specified in Section 5.10.2.4 and simultaneously start the GC temperature program and data collection. Quickly remove the needle from the injection port.

5.10.4.3 Syringe Preparation

After injection, rinse the syringe by slowly withdrawing and expelling methanol at least three times. Check that no bubbles or headspace are created after withdrawal is performed. Return the syringe to the oven for reheating before the next sample analysis.

5.10.5 Qualitative Data Evaluation

5.10.5.1 Sample Chromatogram Review

Carefully compare the sample chromatograms with those of the most recent calibration standard. Determine if any peaks interfere with or possibly prevent detection of target compounds that might be present at a level equal to the MDL.

5.10.5.2 Peak Interference

If one or more interfering peaks (as defined above) are present, notify the project leader in sufficient time to consider possible re-analysis options (CLP or dilution). (Decision criteria for these options are based upon site-specific objectives, which are beyond the scope of this analysis SOP).

5.10.5.3 Sample Dilution/Reanalysis

To prevent damage to the instrumentation and/or excessive carry-over, the analyst shall ensure that appropriate dilution levels are utilized for any required re-analyses. Any re-analysis must be performed using a dilution whenever target compounds are above the upper limit of the calibrated range or whenever non-target compounds cause gross saturation. For any dilution, no more than 25 percent of the chromatogram should consist of a peak envelope that continuously exceeds the height of the nearest IS above the baseline observed in the blank nor should more than 4 interfering peaks be present in the chromatogram of the dilution run at a peak height greater than 5 times IS heights or overrange.

5.10.5.4 Contaminant Carry-Over

High-level sample(s) (defined as containing any target compound at a level more than 300 times the MDLs) should be followed by an analysis of reagent water (and possibly additional decontamination measures) as described in Section 5.2.3. If carry-over is suspected after the fact, as defined by a sample containing a positive (reportable) target contaminant level that is less than 1.7 percent of the level detected in the preceding analysis of a higher concentration sample, then the sample that exhibits possible carry-over shall be rerun after the system has been decontaminated and a reagent blank has been acceptably analyzed.

5.10.6 Internal Standards Evaluation

5.10.6.1 RT Windows

Determine whether ISs elute within their established RT windows according to the procedures specified in Sections 5.9.8.1 through 5.9.8.4. Concurrently, evaluate whether IS areas are within control limits or are biased by peak overlaps, co-elutions, poor injection, or poor system performance, as per Sections 5.9.8.5 through 5.9.8.7.

5.10.6.2 Corrective Action

IF IS retention time or area criteria are exceeded, follow the decision scheme and specified corrective action procedures in Section 5.9.8 to determine whether to reprocess the data using the external standard method, re-analyze the sample on a second GC column, or correct system malfunctions, recalibrate, and then perform re-analysis. If IS area criteria are exceeded for a blank, follow the decision scheme and specified corrective action procedures in Sections 5.5.7.2 and 5.9.8.7.

5.10.7 Compound Identification

5.10.7.1 Target Compound Identification

Determine whether target compounds are present in the sample by comparing each analyte's predicted RT window with the observed peak RTs in the sample, following the procedure in Section 5.9.8.7 and using the formula in Section 5.11.9.3. The IS prediction technique(s) shall be used except when the interferences defined in Section 5.9.8 mandate the use of the external standard methods.

5.10.7.2 Peak Interference

If more than one peak elutes within the RT window for an analyte, then the analyst shall report the higher concentration peak and explain the possibility that a lower level may be present in the text (one of the two peaks must be an interference).

5.10.7.3 Co-elution

When two compounds co-elute in the standard chromatogram, compound identifications shall be reported for both analytes, with an explanation of the inability of the chromatography to distinguish between the two compounds. Note that this does not apply if only one of the coeluting compounds responds on two detectors, such that the second detector can determine which compound is present.

5.10.7.4 Dual Detector Response

When both detectors respond to an analyte in the standard chromatogram (specifically, for methylene chloride, trichloroethene, and tetrachloroethene), then the analyst shall check whether peaks elute within RT windows on both detectors. For any of these particular analytes to be considered present, peaks must elute within RT windows on both detectors and the computed amounts must agree within a factor of 3 or, alternatively, the lack of agreement with the second detector must be explainable by visible chromatographic interferences from compounds at nearby RTs. If the only evidence of interference consists of an abnormal concentration ratio between the two detectors, then the lower concentration shall be reported as the sample detection limit.

5.10.8 Compound Quantitation

5.10.8.1 Target Analyte Quantification

Compute the concentration of the detected target analytes using the most recent calibration standard data according to Section 5.8.2.2 and using the formula in Section 5.11.3. The IS quantitation technique shall be used except when the interferences defined in Section 5.9.8 mandate the use of external standard quantitation (Section 5.11.6).

5.10.8.2 Integration Endpoints and Baseline

Evaluate the chromatogram and integration report of the sample to ensure that correct integration endpoints and baseline were applied for each target analyte identified in Section 5.10.7.1. Re-integrate analyte peaks if errors are discovered.

5.10.8.3 Co-elution

If any interfering chromatographic peak is not resolved to less than 33 percent valley relative to the height of an adjacent peak for an identified target analyte or if any target compound exhibits an unusually wide or asymmetric peak that, in the opinion of the analyst, represents the effects of co-elution, then the project leader shall be informed in sufficient time to consider possible re-analysis options (CLP or re-analysis). (These options depend on site-specific objectives that are beyond the scope of this analysis SOP.) Any reported sample results associated with such co-elutions shall be qualified with an explanation of the influence of the co-elution on the quantitative accuracy for the analyte concentration.

5.10.8.4 Sample Dilution

If any target compound is present at a level that exceeds the calibrated range of the system, a dilution shall be required. Note that a fresh (unused) aliquot of sample must be utilized for all re-analyses or dilutions as the integrity of the sample becomes suspect with repeated heating and septum punctures. All dilutions shall be accomplished by injecting a larger volume of internal standard into the sample and then injecting a proportionally smaller aliquot of headspace vapor, down to a minimum injection volume of 5 ul. If injection of a 5-ul aliquot of headspace vapor is still above the calibrated range, then the laboratory narrative will qualify the result as having reduced accuracy due to exceeding the calibrated range.

5.11 Calculations

5.11.1 Initial Calibration Relative Response Factors (Internal Standard Method)

5.11.1.1 Relative Response Factor of Standard i (RRF_i)

$$RRF_i = \frac{A_C}{A_I} \times \frac{Q_I}{Q_C}$$

Where: A_C = area of target compound in standard
A_I = area of internal standard in standard
Q_C = amount of target compound in standard (nanograms)
Q_I = amount of internal standard in standard (nanograms)

5.11.1.2 Average Relative Response Factor (RRF_{ave}) of N Standards

$$RRF_{ave} = (I/N) \times \sum_{i=1}^{N} RRF_i$$

5.11.1.3 Relative Standard Deviation (RSD) of RRF

$$\text{percent RSD} = \frac{100}{RRF_{ave}} \times \sqrt{\sum_{i=1}^{N} (RRF_i - RRF_{ave})^2 / (N - 1)}$$

5.11.2 Continuing Calibration Percent Difference (PD) (Internal Standard Method)

$$PD = \frac{RRF_{cont} - RRF_{ave}}{RRF_{ave}} \times 100$$

Where: RRF_{cont} = RRF of continuing calibration standard

5.11.3 Concentration of Target Compound in Sample (Internal Standard Method)

$$\text{conc. (ug/kg)} = \frac{A_{C(SPL)}}{A_{I(SPL)}} \times \frac{Q_I}{RRF_{cont}} \times \frac{DF}{\text{sample wt. (g)}}$$

Where: $A_{C(SPL)}$ = area of target compound in sample
$A_{I(SPL)}$ = area of internal standard in sample
Q_I = amount of internal standard in sample (nanograms)
DF = dilution factor, if applicable (equal to standard over sample injection volume)

5.11.4 Initial Calibration - Calibration Factors (External Standard Method)

5.11.4.1 Calibration Factor of Standard i (CF_i)

$$CF_i = \frac{A_C}{Q_C}$$

Where: A_C = area of target compound in standard
Q_C = amount of target compound in standard (nanograms)

5.11.4.2 Average Calibration Factor (CF_{ave}) of N Standards

$$CF_{ave} = (I / N) \times \sum_{i=1}^{N} CF_i$$

5.11.4.3 Relative Standard Deviation (RSD) of CF

$$\text{percent RSD} = \frac{100}{CF_{ave}} \times \sqrt{\sum_{i=1}^{N} (CF_i - CF_{ave})^2 / (N - 1)}$$

5.11.5 Continuing Calibration Percent Difference (PD) (External Standard Method)

$$PD = \frac{CF_{cont} - CF_{ave}}{CF_{ave}} \times 100$$

Where: CF_{cont} = calibration factor in continuing calibration standard

5.11.6 Concentration of Target Compound in Sample (External Standard Method)

$$\text{conc. (ug/kg)} = \frac{A_{C(SPL)}}{CF_{cont}} \times \frac{DF}{\text{sample wt. (g)}}$$

Where: A_C, DF defined as in 12.3

5.11.7 Matrix Spike Recovery

$$\text{percent recovery} = \frac{\text{(conc. in spike) - (conc. in sample)}}{\text{(conc. spike added)}} \times 100$$

5.11.8 Relative Percent Difference (Rpd) of Duplicate Samples

$$RPD = \frac{\text{(conc. in sample) - (conc. in duplicate)}}{\text{(conc. in sample) + (conc. in duplicate)}} \times 200$$

5.11.9 RT Windows Using Relative Retention Times (RRTS) (An Internal Standard Method)

5.11.9.1 <u>Variance of Observed Minus Predicted Retention Time (RRT Method)</u>

The following acceptable approximation is valid when used to predict retention times using one continuing calibration standard run before a group of samples.

$$Var\left[RT_{obs} - RT_{pred}\right] = \{2/(N-1)\} \times \left\{ \sum_{i=1}^{N} \left(RT_{C(i)} - RT_{I(i)} \times M\right)^2 \right\}$$

Where:

$$M = \frac{\sum_{i=1}^{N}\left(RT_{I(i)} \times RT_{C(i)}\right)}{\sum_{i=1}^{N}\left(RT_{I(i)}\right)^2}$$

N = number of standards in set used to determine RT window width

$RT_{C(i)}$ = retention time of target compound C in standard i

$RT_{I(i)}$ = retention time of internal standard associated with compound C in standard i

The error in the above expression is nearly identical to the percent difference of the retention time of the

internal standard in the sample versus that in the prior standard. The actual equation, without approximation, is found by substituting for the numeral "2" just to the right of the equals sign with the following expression:

$$\left\{ 1 + \frac{(RT_{I(SPL)})^2}{(RT_{I(STP)})^2} \right.$$

Where: $RT_{I(SPL)}$ = retention time of internal standard in sample
$RT_{I(STD)}$ = retention time of internal standard in continuing calibration standard run prior to sample

5.11.9.2 Retention Time Window Width (RRT Method)

$$\text{RT window width} = \pm\ t_{0.995,\ N-1} \times \sqrt{Var\left[RT_{obs} - RT_{pred}\right]}$$

Where: t = value from table of student's t distribution
0.995 = confidence level for prediction interval (one-tailed)
N = number of standards used to determine RT window width

5.11.9.3 Retention Time Window for a Sample (RRT Method)

$$\text{RT window} = RT_{C(STD)} \times \frac{RT_{I(SPL)}}{RT_{I(STD)}} \pm\ t_{0.995,\ N-1} \times \sqrt{Var\left[RT_{obs} - RT_{pred}\right]}$$

Where: $RT_{C(STD)}$ = RT of the target compound in the standard run before sample
$RT_{I(SPL)}$ = RT of the internal standard in the sample
$RT_{I(STD)}$ = RT of the internal standard in the standard run before sample

5.11.10 Rt Windows Using the External Standard Method

5.11.10.1 Variance of Observed Minus Predicted Retention Time (External Standard Method)

The following expression is valid when used to predict retention times using one continuing calibration standard run before a group of samples.

$$Var\left[RT_{obs} - RT_{pred}\right] = \{2/(N-1)\} \times \sum_{i=1}^{N} \left[RT_{C(i)} - (1/N) \times \sum_{j=1}^{N} RT_{C(j)}\right]^2$$

Where: N = number of standards in set used to determine RT window width
$RT_{C(i)}$ = retention time of target compound C in standard i

5.11.10.2 Retention Time Window Width (External Standard Method)

$$\text{RT window width} = \pm\ t_{0.995,\ N-1} \times \sqrt{Var\left[RT_{obs} - RT_{pred}\right]}$$

Where: t = value from table of student's t distribution
0.995 = confidence level for prediction interval (one-tailed)

N = number of standards used to determine RT window width

5.11.10.3 Retention Time Window for a Sample (External Standard Method)

$$\text{RT window} = RT_{C(STD)} \pm t_{0.995,\,N-1} \times \sqrt{Var\left[RT_{obs} - RT_{pred}\right]}$$

Where: $RT_{C(STD)}$ = retention time of compound C in standard run before sample

6.0 REFERENCES

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Figure 1

Volatile Organic Compound Calibration Standards Logbook

Conc. X Volume ÷ Final Vol = Final Conc.

Date Prepared	Preparer's Initials	Source Standard I.D./Lot No.	Compound(s) in Source Standard	Concentration of Source Standard (include units)	Volume Taken for Dilution	Final Volume after Dilution (inlude units)	Concentration of Dilution Standards (include units)	Each Vial Assigned Separate I.D. No. (m = methanol) (A = aqueous)	Expiration Date of Dilution Standard	Modified Expiration Date (when use begins)

Figure 2

Analytical Decision Sequence

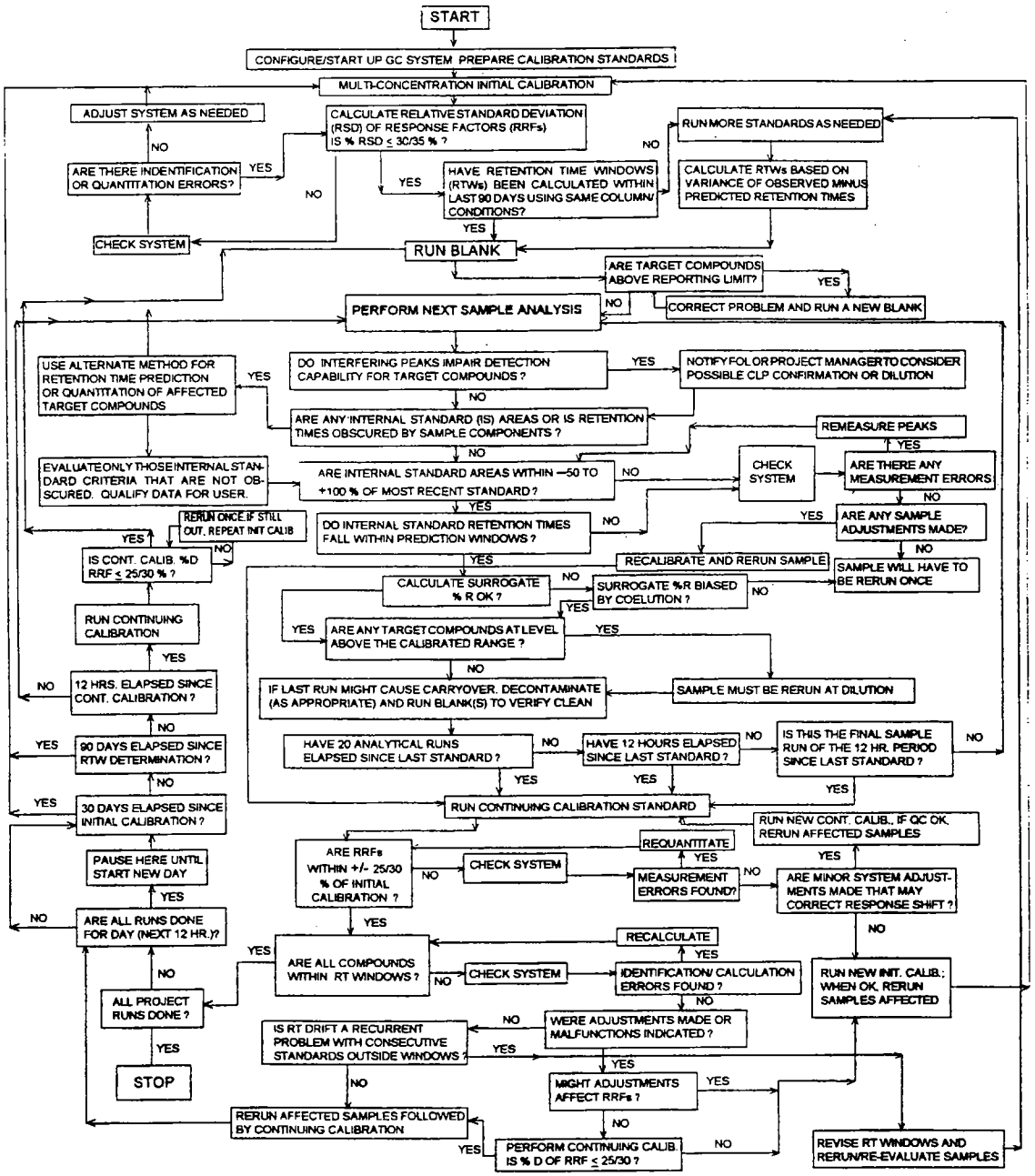

Figure 3

Summary of Quality Control (QC) Requirements

Note: This is a condensed summary. For a complete description of contingencies, etc., see the appropriate section referenced below.

Description of QC Audit Item	Required Frequency of Performance	QC Criteria Limits	Required Action if Limits are Exceeded	Reference Section Number
Stock Standard Solutions Expiration Dates	Stock standards are valid for six months from the date of preparation, unless degradation is indicated. New and old standards must be run back-to-back and compared before the first use of the new standard	Warning Limit: Response within ± 35 percent of old standard Action Limit: t-Test fails at 0.95 confidence level	If warning limit is exceeded, check dilution procedures and re-analyze new and old standards to achieve a minimum 4 degrees of freedom for t-test comparison of means with 95 percent confidence level. If suspect compounds also fail t-test, obtain and run standards from another source.	5.5.3
Secondary Dilution Standards and Matrix Spike Solutions Expiration Dates	Secondary dilution standards and matrix spike solutions are valid for six months from the date of preparation or two months from the date of first use, whichever occurs first. If degradation is suspected (color change, evaporation, percent R matrix spike low), discard the solution unless integrity is verified by the analysis of the fresh dilution versus the suspect standard.	Response of suspect standard dilution within ± 35 percent of fresh dilution	Discard the standard dilution if the comparison against the fresh dilution disagrees by more than 35 percent.	5.5.4, 5.5.5, 5.5.8, and 5.9.4
Working Internal Standard (IS) Solutions Expiration Dates	Working internal standard solutions are valid for six months from the date of preparation or one week from the date of first use, whichever occurs first. If degradation is suspected (IS area criteria is exceeded for a blank), run a continuing calibration standard and evaluate the RRF percent difference for all compounds associated with IS.	RRF percent difference for associated compounds opposite bias to IS area shift and outside criteria	Discard IS solution and prepare fresh dilution if QC criteria at left indicate deterioration of IS solution.	5.5.7 and 5.9.8

Figure 3

Summary of Quality Control (QC) Requirements

Note: This is a condensed summary. For a complete description of contingencies, etc., see the appropriate section referenced below.

Description of QC Audit Item	Required Frequency of Performance	QC Criteria Limits	Required Action if Limits are Exceeded	Reference Section Number
Aqueous Calibration Standard Solutions Expiration Dates	Aqueous calibration standards are valid for only 1 hour, unless kept at 4°C with no headspace, in which case they are valid for 24 hours.	1 hour or 24 hours (cannot be heated more than once)	Discard standard solution and prepare fresh dilution.	5.5.5
Sample Holding Times	Laboratory holding times are set at 7 days or as specified by project schedules, whichever is shorter.	7 days or less	If analyses cannot be performed within holding times, notify the project manager and project leader immediately upon discovery of the problem (to plan resampling strategies, etc).	5.6
Initial Calibration Compound Sensitivities	All compounds that are on the site-specific target compound list (TCL) must have S/N at least 10:1 in the low-concentration standard.	Peak height of compound divided by height of peak-to-valley noise fluctuations ≥ 5	Perform adjustments/check standard integrity, correct problem, and restart initial calibration sequence.	5.8.1
Initial Calibration Chromatographic Resolution	The resolution of all compounds must be equivalent to or better than the stated method.	Resolution ≥ method chromatogram	Perform adjustments and restart initial calibration sequence.	5.7.1
Initial Calibration Peak Width	Early eluting target compounds on megabore capillary column must have peak width (95 percent area) of less than 0.4 minute.	Peak width ≤ 0.4 minute	Adjust injection technique or GC parameters and restart calibration sequence.	5.8.1.3
Initial Calibration Relative Standard Deviation (RSD) of Response Factors (RRFs)	Perform after instrument alterations (see SOP), or every 30 days, whichever is more frequent. RSD criteria must be achieved for all compounds that are on the site-specific selected TCL (subset of TCL).	RSD ≥ 30 percent for site-specific targets	Check data, calculations, and system performance. Make any necessary adjustments, then repeat the initial calibration sequence.	5.8.1
Continuing Calibration (run before samples) Percent Difference (PD) of RRFs for Internal Standard Quantitation	Perform before each 12-hour period of up to 20 analytical runs. %D criteria applicable to all compounds that are on the site-specific selected TCL.	%D ≤ |25| for site-specific targets	Check data, calculations, and system performance. Rerun standard if minor adjustments may correct problem. Perform new initial calibration if problem is uncorrected.	5.8.2

Figure 3

Summary of Quality Control (QC) Requirements

Note: This is a condensed summary. For a complete description of contingencies, etc., see the appropriate section referenced below.

Description of QC Audit Item	Required Frequency of Performance	QC Criteria Limits	Required Action if Limits are Exceeded	Reference Section Number
Final Continuing Calibration (run after samples) PD of RRFs	Perform after each 12-hour period of analysis, after every 20 analytical runs, or after all runs done for current 12-hour period, whichever is more frequent.	%D ≤ |30%| for site-specific targets	Check data, calculations, and system performance. Correct problem, recalibrate, and re-analyze samples from last 12-hour period.	5.8.2
Initial and Continuing Calibration Criteria for External Standard Quantitation Using Calibration Factors (CFs)	External standard quantitation only allowed for samples with internal standard interferences. Calibration factor RSD and %D criteria applicable to all site-specific selected target compounds associated with obscured internal standard.	RSD ≤ 30%, %D ≤ |25|	Check data, calculations, and system performance. If problem persists, perform new initial calibration or run samples on optional second GC column to avoid internal standard co-elution.	5.8.3
QC Check Standard Solution Percent Accuracy (percent A)	Analyze once each initial calibration or once each project, whichever is more frequent. Percent A criteria must be achieved for all compounds that are on the site-specific selected TCL.	Percent accuracy ≥ 50 percent and ≤ 150 percent	Locate the source of the problem, correct and achieve successful analysis of QC check solution.	5.9.1
Trip Blanks and Equipment Rinsate Blanks	Analyze at frequency specified in WP or QAPP. QC criteria must be achieved for all compounds that are on the site-specific selected TCL.	Concentration ≤ 5 times MDLs	Evaluate immediately after analysis. If outside criteria, run laboratory reagent blank immediately and locate problem source. Report to project leader to allow resampling or other corrective action.	5.9.2
Laboratory Reagent Blanks	After each initial calibration sequence, after each continuing calibration standard that precedes sample analysis, after high-level samples, and whenever starting a new batch of reagent water or methanol. QC criteria applicable to all site-specific target compounds.	Concentration ≤ 5 times MDLs	Evaluate immediately after analysis. If outside criteria, correct problem and run a new blank. Criteria must be achieved before sample analysis can proceed.	5.9.3, 5.2.3

Figure 3

Summary of Quality Control (QC) Requirements

Note: This is a condensed summary. For a complete description of contingencies, etc., see the appropriate section referenced below.

Description of QC Audit Item	Required Frequency of Performance	QC Criteria Limits	Required Action if Limits are Exceeded	Reference Section Number
Matrix Spike Analysis Percent Recovery (percent R)	Analyze at frequency specified in WP or QAPP. If samplers do not designate samples to be spiked, then analyst shall select one sample per each group of up to 20 samples of a similar matrix. Percent R criteria apply to all compounds on the site-specific TCL.	Percent R ≥ 50 percent and ≤ 150 percent	Investigate problem as per SOP. Check spike solution and repeat spike analysis.	5.9.4
Laboratory and Field Duplicate Sample Analysis Relative Percent Difference (RPD)	Analyze at frequency specified in WP or QAPP. QC criteria apply to all target compounds in sample.	50 RPD warning limit; 150 RPD action limit	If warning limit is exceeded, first check sample ID, integration data, and calculations. If action limit is exceeded for any of the three largest peaks that are above the MDL in both analyses, inform the project leader and analyze a third aliquot or fresh sample from the same location. Also inform the project leader if any target compound > MDL versus not detected in duplicate.	5.9.5 and 5.9.6

Figure 3

Summary of Quality Control (QC) Requirements

Note: This is a condensed summary. For a complete description of contingencies, etc., see the appropriate section referenced below.

Description of QC Audit Item	Required Frequency of Performance	QC Criteria Limits	Required Action if Limits are Exceeded	Reference Section Number
Establish Width of Retention Time Windows for Target Compounds	Initially done when new system configuration is first established. The plus or minus window widths must be revised after 90 days (although the center of the prediction window varies with each 12-hour calibration and with each sample's internal standard shifts). Revision of windows required if recurrent problems in final calibration standards, if absolute RTs shift more than 10 percent for any compound, if new GC column or temperature program adopted, or flow rates changed > 15 percent.	RT shifts (observed minus predicted RTs) in final continuing calibration runs ≤ ± RT window for each target compound	If any site-specific target compound elutes outside its established window in the final calibration standard, then corrective action must be taken, after which affected samples must be re-analyzed.	5.9.7
Establish Width of Retention Time Windows for Internal Standards (IS)	IS RT windows are established concurrently and whenever target compound RT window widths are established. The plus or minus window widths are valid for the duration when target compound RT windows are valid (although the center of the prediction window varies with each 12-hour calibration).	In each sample, RT shifts (observed minus predicted RTs) must be ≤ ± RT window for each IS	Evaluate in conjunction with IS areas as per SOP. If co-elution caused appearance of RT shift, quantitate sample using external standard method. If actual elution times of IS shifted, then check/correct system performance (recalibrate if adjustments) and re-analyze sample once.	5.9.8

Figure 3

Summary of Quality Control (QC) Requirements

Note: This is a condensed summary. For a complete description of contingencies, etc., see the appropriate section referenced below.

Description of QC Audit Item	Required Frequency of Performance	QC Criteria Limits	Required Action if Limits are Exceeded	Reference Section Number
IS Area Control Limits	Each analytical run must be evaluated to determine if IS areas are within control limits relative to IS areas in continuing calibration standard run before samples.	Percent difference in IS areas in sample versus continuing calibration ≥ - 50 percent and ≤ + 100 percent	Check integration data as per SOP. If co-elution caused appearance of abnormal IS area, quantitate sample using external standard method (if external standard QC criteria can be met) or re-analyze sample on second GC column. If co-elution is not indicated, then check/correct system performance (recalibrate if adjustments) and re-analyze sample. If criteria exceeded for initial and reanalysis of a blank, then a continuing calibration standard is mandatory before further analysis can occur.	5.9.8
Quantitation of Compounds Within Linear Range	For each sample run, concentrations of any site-specific selected target compounds must be less than or equal to the highest initial calibration standard.	Concentration ≤ highest standard	Dilute sample to achieve level above method reporting limit and within calibrated range.	5.10.5.3
Carry-Over Check: Comparison of Sample Instrument Level to Level in Preceding Run	Applicable to any sample or field QC sample found to contain a positive (reportable) quantity of any site-specific selected target compound that is also present in the preceding analysis at a higher level.	Instrument level in sample < 1.7 percent of level in preceding run	If carry-over criteria are exceeded, then the sample must be rerun after the system has been decontaminated and a reagent blank has been acceptably analyzed.	5.2.3 and 5.10.5.4

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Figure 4

Example Page Format for GC Injection Logbook

Inject Date and Time	Operator Initials	Disc File ID	Column	Method	Detector(s)	Project ID/ TDD No.	Sample ID	Injection Weight or Volume	Comments

Naval Surface Warfare Center INDIAN HEAD DIVISION Naval Sea Systems Command	STANDARD OPERATING PROCEDURES	Number SA-1-1	Page 1 of 25
		Effective Date 02/04	Revision 0
		Applicability	
		Prepared	
Subject GROUNDWATER SAMPLE ACQUISITION AND ONSITE WATER QUALITY TESTING		Approved	

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1.0 PURPOSE

The purpose of this procedure is to provide general reference information regarding the sampling of groundwater wells.

2.0 SCOPE

This procedure provides information on proper sampling equipment, onsite water quality testing, 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 modifications to methodology.

3.0 GLOSSARY

Conductivity – Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, their total concentration, mobility, valence, and relative concentrations, and on temperature of measure. Conductivity is highly dependent on temperature and should be reported at a particular temperature, i.e., 20.2 mS/cm at 14°C.

Dissolved Oxygen (DO) – DO levels in natural and wastewater depend on the physical, chemical, and biochemical activities in the water sample.

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.

pH - The negative logarithm (base 10) of the hydrogen ion activity. The hydrogen ion activity is related to the hydrogen ion concentration, and, in a relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is a measure of the hydrogen ion concentration.

pH Paper - Indicator 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's pH.

Salinity – The measurement of dissolved salts in a given mass of solution. Note: most field meters determined salinity automatically from conductivity and temperature. The displayed value will be displayed in either parts per thousand (ppt) or % (e.g., 35 ppt will equal 3.5%).

Turbidity – Turbidity in water is caused by suspended matter, such as clay, silt, fine organic and inorganic matter. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample.

4.0 RESPONSIBILITIES

Project Hydrogeologist - Responsible for selecting and detailing the specific groundwater sampling techniques, onsite water quality testing (type, frequency, and location), and equipment to be used, and providing detailed input in this regard to the project plan documents. The project hydrogeologist is also responsible for properly briefing and overseeing the performance of the site sampling personnel.

Project Geologist/Field Sample Technician - is primarily responsible for the proper acquisition of the groundwater samples. He/she is also responsible for the actual analyses of onsite water quality samples, as well as instrument calibration, care, and maintenance. When appropriate, such responsibilities may be performed by other qualified personnel (e.g., field technicians).

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 analysis 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:

1. All monitoring wells shall be purged prior to obtaining a sample. Evacuation of three to five volumes is recommended prior to sampling. In a high-yielding groundwater formation and where there is no stagnant water in the well above the screened section, extensive evacuation prior to sample withdrawal is not as critical.

2. For wells that can be purged dry, the well shall be evacuated and allowed to recover to 75% full capacity prior to sample acquisition. If the recovery rate is fairly rapid, evacuation of more than one volume of water is required.

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 or the 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 drops. 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 or other approved device may be used to collect the sample for analysis.

   - The intake line of the sampling pump (or the submersible pump itself) unless otherwise directed shall be placed near the center of the screened section, and approximately one casing volume of water shall be pumped from the well at a low purge rate, equal to the well's recovery rate (low flow sampling).

Stratification of contaminants may exist in the aquifer. Concentration gradients as a result of mixing and dispersion processes, layers of variable permeability, and the presence of separate-phase product (i.e.,

floating hydrocarbons) may cause stratification. Excessive pumping or improper sampling methods can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column as it naturally occurs at that point, thus the result is the collection of a non-representative sample.

5.2 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform with the guidelines expressed in SOP SA-6.1.

The following equipment shall be on hand when sampling groundwater wells (reference SOPs SA-6.1 and SA-7.1):

- Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, appropriate sampling containers and filler, ice, labels and chain-of-custody documents.
- Field tools and instrumentation - Multi-parameters water quality meter capable of measuring ORP, pH, temperature, DO, specific conductance, turbidity and salinity or individual meters (as applicable), pH paper, camera and film (if appropriate), appropriate keys (for locked wells), water level indicator.
- Pumps
  - Shallow-well pumps: Centrifugal, bladder, 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 bladder pumps where applicable.
- Other sampling equipment - Bailers and inert line with tripod-pulley assembly (if necessary).
- Pails - Plastic, graduated.
- Decontamination solutions - Deionized water, potable water, laboratory detergents, 10% nitric acid solution (as required), and analytical-grade solvent (e.g., pesticide-grade isopropanol), as required.

Ideally, sample withdrawal equipment shall be completely inert, economical, easily cleaned, cleaned prior to use, reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well purging 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 site logbook or field notebook or on a sample log sheet form (see SOP SA-6.3):

- Obtain all available information on well construction (location, casing, screens, etc.).
- Determine well or inner casing diameter.
- Measure and record static water level (depth below ground level or top of casing reference point).
- Determine depth of well 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).

- Calculate one static well volume in gallons $V = (0.163)(T)(r^2)1$

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.

- Per evacuation volumes discussed above, determine the minimum amount to be evacuated before sampling.

5.4 Evacuation of Static Water (Purging)

5.4.1 General

The amount of purging 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, specific conductance, pH, and turbidity (as applicable), have stabilized. Onsite measurements of these parameters shall be recorded in the site logbook, field notebook, or on standardized data sheets.

5.4.2 Evacuation Devices

The following discussion is limited to those devices commonly used at hazardous waste sites. Attachment A 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.

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.

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.
- 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.

Suction Pumps

There are many different types of inexpensive suction pumps including centrifugal, diaphragm, and peristaltic 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 that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination.

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.

Air-Lift Samplers

This group of pump 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. Air (or 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.

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).

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 can be difficult and time-consuming.

5.5 Onsite Water Quality Testing

This section 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)
- Oxidation-Reduction Potential (ORP)

- Turbidity
- Salinity

This section is applicable for use in an onsite groundwater quality monitoring program to be conducted at a hazardous or nonhazardous site. The procedures and equipment described are applicable to groundwater samples and are not, in general, subject to solution interferences from color, turbidity, and colloidal material or suspended matter.

This section provides general 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. Most meters used to measure field parameters require calibration on a daily basis. Refer to SOP 6.3 for example equipment calibration log.

5.5.1 Measurement of pH

5.5.1.1 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.

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.

5.5.1.2 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or alkalinity of the solution created by the addition of the water sample reacting with the indicator compound on the paper. Various types of pH papers are available, including litmus (for general acidity or alkalinity determination) and specific pH range hydrion paper.

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 (in this instance, 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 the ion concentration is generated and measured.

5.5.1.3 Equipment

The following equipment is needed for taking pH measurements:

- Stand-alone portable pH meter, or combination meter (e.g., Horiba U-10), or combination meters equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).

- 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).
- Buffer solutions, as specified by the manufacturer.
- pH indicator paper, to cover the pH range 2 through 12.
- Manufacturer's operation manual.

5.5.1.4 Measurement Techniques for Field Determination of pH

pH Meter

The following procedure is used for measuring pH with a pH meter (meter standardization is according to manufacturer's instructions):

- Inspect the instrument and batteries prior to initiation of the field effort.
- Check the integrity of the buffer solutions used for field calibration. Buffer solutions need to be changed often as a result of degradation upon exposure to the atmosphere.
- If applicable, 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).
- Calibrate on a daily use basis (or as recommended by manufacturer) following manufacturer's instructions. Record calibration data on an equipment calibration log sheet.
- Immerse the electrode(s) in the sample. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a physical 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.
- Read and record the pH of the sample. pH shall be recorded to the nearest 0.01 pH unit. Also record the sample temperature.
- Rinse the electrode(s) with deionized water.
- Store the electrode(s) in an appropriate manner when not in use.

Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted.

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 and proceed with successively narrower range paper until the sample pH is adequately determined.

5.5.2 Measurement of Specific Conductance

5.5.2.1 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. Most conductivity meters in use today display specific conductance (SC); units of milliSiemens per centimeter, which is the conductivity normalized to temperature @ 25°C. This format (SC) is the required units recorded on the groundwater sample log field form (Attachment B).

5.5.2.2 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 dissociate in aqueous solution, conduct a current very poorly, if at all.

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.

5.5.2.3 Equipment

The following equipment is needed for taking specific conductance (SC) measurements:

- Stand alone portable conductivity meter, or combination meter (e.g., Horiba U-10), or combination meters equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

A variety of conductivity meters are available which may also be used to monitor salinity and temperature. Probe types and cable lengths vary, so equipment must be obtained to meet the specific requirement of the sampling program.

5.5.2.4 Measurement Techniques for Specific Conductance

The steps involved in taking specific conductance measurements are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate instrument before going into the field.
- Calibrate on a daily use basis (or as recommended by manufacturer), according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet. Potassium chloride solutions with a SC closest to the values expected in the field shall be used for calibration.
- 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.
- Read and record the results in a field logbook or sample log sheet.
- Rinse the electrode with deionized water.

If the specific conductance measurements become erratic, recalibrate the instrument and see the manufacturer's instructions for details.

5.5.3 Measurement of Temperature

5.5.3.1 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 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.

5.5.3.2 Equipment

Temperature measurements may be taken with alcohol-toluene, mercury filled, dial-type thermometers or combination meters equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).. 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.

5.5.3.3 Measurement Techniques for Water Temperature

If a thermometer is used to determine the temperature for a water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of cross-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 used, the instrument shall be calibrated according to manufacturer's recommendations.

5.5.4 Measurement of Dissolved Oxygen

5.5.4.1 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 monitoring method 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 is not susceptible to interference caused by color, turbidity, colloidal material or suspended matter.

5.5.4.2 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.

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, while leaving the surface of the solution undisturbed.

Dissolved oxygen probes are relatively unaffected by 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 a 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.

5.5.4.3 Equipment

The following equipment is needed to measure dissolved oxygen concentration:

- Stand alone portable dissolved oxygen meter, or combination meter (e.g., Horiba U-10), or combination meters equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).
- Sufficient cable to allow the probe to contact the sample.
- Manufacturer's operation manual.

5.5.4.4 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 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 according to manufacturer's recommendations or in a freshly air-saturated water sample of known temperature.
- Record all pertinent information on an equipment calibration sheet.
- Rinse the probe with deionized water.
- Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane by stirring the sample. Probes without stirrers placed in wells can be moved up and down.
- Record the dissolved oxygen content and temperature of the sample in a field logbook or sample log sheet.
- Rinse the probe with deionized water.
- 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. This however, may not always be practical.

Special care shall be taken during sample collection to avoid turbulence which can lead to increased oxygen solubilization and positive test interferences.

5.5.5 Measurement of Oxidation-Reduction Potential

5.5.5.1 General

The oxidation-reduction potential (ORP) provides a measure of the tendency of organic or inorganic compounds to exist in an oxidized state. The ORP parameter 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.

5.5.5.2 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 is 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.

5.5.5.3 Equipment

The following equipment is needed for measuring the oxidation-reduction potential of a solution:

- Combination meters with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).
- Reference solution as specified by the manufacturer.
- Manufacturer's operation manual.

5.5.5.4 Measurement Techniques for Oxidation-Reduction Potential

The following procedure is used for measuring oxidation-reduction potential:

- The equipment shall be checked using the manufacturer's recommended reference solution and have its batteries checked before going to the field.

- Thoroughly rinse the electrode with deionized water.

- If the probe does not respond properly to the recommended reference solution, then verify the sensitivity of the electrodes by noting the change in millivolt reading when the pH of a test solution is altered. The ORP will increase when the pH of a test solution decreases, and the ORP will decrease if the test solution pH is increased. Place the sample in a clean container and agitate the sample. Insert the electrodes and note the ORP drops sharply when the caustic is added (i.e., pH is raised) thus indicating 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 or the probe should be replaced.

- Record all pertinent information on an equipment calibration log sheet.

5.5.6 Measurement of Turbidity

5.5.6.1 General

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample. Turbidity in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and microscopic organisms, including plankton.

It is important to obtain a turbidity reading immediately after taking a sample, since irreversible changes in turbidity may occur if the sample is stored too long.

5.5.6.2 Principles of Equipment Operation

Turbidity is measured by the Nephelometric Method. This method is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the scattered light intensity, the higher the turbidity.

Formazin polymer is used as the reference turbidity standard suspension because of its ease of preparation combined with a higher reproducibility of its light-scattering properties than clay or turbid

natural water. The turbidity of a specified concentration of formazin suspension is defined as 40 nephelometric units. This same suspension has an approximate turbidity of 40 Jackson units when measured on the candle turbidmeter. Therefore, nephelometric turbidity units (NTU) based on the formazin preparation will approximate units derived from the candle turbidimeter but will not be identical to them.

5.5.6.3 Equipment

The following equipment is needed for turbidity measurement:

- Light meter (e.g., LaMotte 2020) which calibrates easily using test cells with standards of 0.0 NTUs, and 10 NTUs, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber (e.g., YSI 600 series and Horiba U-22).
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

5.5.6.4 Measurement Techniques for Turbidity

The steps involved in taking turbidity measurements utilizing an electrode (e) or light meter (l) are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate instrument before going into the field.
- Check the expiration date (etc.) of the solutions used for field calibration.
- Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet.
- Rinse the electrode with one or more portions of the sample to be tested or with deionized water (applies to "e").
- Fill the light meters glass test cell with ~5 ml of sample, screw on cap, wipe off glass, place test cell in light meter and close the lid (applies to "l").
- Immerse the electrode in the sample and measure the turbidity (applies to "e").
- The reading must be taken immediately as suspended solids will settle over time resulting in a lower, inaccurate turbidity reading.
- Read and record the results in a field logbook or sample log sheet. Include a physical description of the sample, including color, qualitative estimate of turbidity, etc.
- Rinse the electrode or test cell with deionized water.

5.5.7 Measurement of Salinity

5.5.7.1 General

Salinity is a unitless property of industrial and natural waters. It is the measurement of dissolved salts in a given mass of solution. Note: Most field meters determined salinity automatically from conductivity and

temperature. The displayed value will be displayed in either parts per thousand (ppt) or % (e.g., 35 ppt will equal 3.5%).

5.5.7.2 Principles of Equipment Operation

Salinity is determined automatically from the meter's conductivity and temperature readings according to algorithms (found in *Standard methods for the Examination of Water and Wastewater*). Depending on the meter, the results are displayed in either ppt or %. The salinity measurements are carried out in reference to the conductivity of standard seawater (*corrected to S = 35*).

5.5.7.3 Equipment

The following equipment is needed for Salinity measurements:

- Multi-parameter water quality meter capable of measuring conductive, temperature and converting them to salinity (e.g., Horiba U-10 or YSI 600 series).
- Calibration Solution, as specified by the manufacturer.
- Manufacturer's operation manual.

5.5.7.4 Measurement Techniques for Salinity

The steps involved in taking Salinity measurements are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate before going into the field.
- Check the expiration date (etc.) of the solutions used for field calibration.
- Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet.
- Rinse the cell with the sample to be tested.
- Immerse the multi-probe in the sample and measure the salinity. Read and record the results in a field logbook or sample log sheet.
- Rinse the probes with deionized water.

5.6 Sampling

5.6.1 Sampling Plan

The sampling approach consisting of the following, shall be developed as part of the project plan documents which are approved prior to beginning work in the field:

- 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.

- Work 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.

5.6.2 Sampling Methods

The collection of a groundwater sample consists of the following steps:

1. The site Health & Safety Officer (or designee) will first open the well cap and use volatile organic detection equipment (PID or FID) 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 on a groundwater sampling log sheet (see Attachment B); then calculate the fluid volume in the well pipe (as previously described in this SOP).

3. Calculate well volume to be removed as stated in Section 5.3.

4. Select the appropriate purging equipment (see Attachment A). If an electric submersible pump with packer is chosen, go to Step 10.

5. Lower the 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 (as applicable). Lower the purging device, as required, to maintain submergence.

6. Measure the rate of discharge frequently. A graduated bucket or cylinder and stopwatch are most commonly used.

7. Observe the 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.

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. Purged water shall be collected in a designated container and disposed in an acceptable manner.

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 just below the water surface.

10. (For pump and packer assembly only). Lower the assembly into the well so that the packer is positioned just above the screen or open section. Inflate the packer. 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 or greater), sample collection can be delayed until the following day. If the well has been purged 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 this occurrence in the site logbook.

12. Fill sample containers (preserve and label as described in SOP SA-6.1).

13. Replace the well cap and lock as appropriate. Make sure the well is readily identifiable as the source of the samples.

14. Process sample containers as described in SOP SA-6.1.

15. Decontaminate equipment as described in SOP SA-7.1.

5.7 Low Flow Purging and Sampling

5.7.1 Scope & Application

Low flow purging and sampling techniques are sometimes required for groundwater sampling activities. The purpose of low flow purging and sampling is to collect groundwater samples that contain "representative" amounts of mobile organic and inorganic constituents in the vicinity of the selected open well interval, at or near natural flow conditions. The minimum stress procedure emphasizes negligible water level drawdown and low pumping rates in order to collect samples with minimal alterations in water chemistry. This procedure is designed primarily to be used in wells with a casing diameter of 1 inch or more and a saturated screen, or open interval, length of ten feet or less. Samples obtained are suitable for analyses of common types of groundwater contaminants (volatile and semi-volatile organic compounds, pesticides, PCBs, metals and other inorganic ions [cyanide, chloride, sulfate, etc.]). This procedure is not designed to collect non-aqueous phase liquids samples from wells containing light or dense non-aqueous phase liquids (LNAPLs or DNAPLs), using the low flow pumps.

The procedure is flexible for various well construction types and groundwater yields. The goal of the procedure is to obtain a turbidity level of less than 10 NTU and to achieve a water level drawdown of less than 0.3 feet during purging and sampling. If these goals cannot be achieved, sample collection can take place provided the remaining criteria in this procedure are met.

5.7.2 Equipment

The following equipment is required (as applicable) for low flow purging and sampling:

- Adjustable rate, submersible pump (e.g., centrifugal or bladder pump constructed of stainless steel or Teflon).

- Disposable clear plastic bottom filling bailers may be used to check for and obtain samples of LNAPLs or DNAPLs.

- Tubing - Teflon, Teflon-lined polyethylene, polyethylene, PVC, Tygon, or stainless steel tubing can be used to collect samples for analysis, depending on the analyses to be performed and regulatory requirements.
- Water level measuring device, 0.01 foot accuracy, (electronic devices are preferred for tracking water level drawdown during all pumping operations).
- Interface probe, if needed.
- Flow measurement supplies.
- Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at a safe distance from the well so that the exhaust fumes do not contaminate the samples.
- Indicator parameter monitoring instruments - pH, turbidity, specific conductance, and temperature. Use of a flow-through cell is recommended. Optional Indicators - ORP, salinity, and dissolved oxygen, flow-through cell is required. Standards to perform field calibration of instruments.
- Decontamination supplies.
- Logbook(s), and other forms (see Attachments B and C).
- Sample Bottles.
- Sample preservation supplies (as required by the analytical methods).
- Sample tags and/or labels.
- Well construction data, location map, field data from last sampling event (if available).
- Field Sampling Plan.
- PID or FID instrument for measuring VOCs (volatile organic compounds).

5.7.3 Purging and Sampling Procedure

Open monitoring well, measure head space gases using PID/FID. If there is an indication of off gassing when opening the well, wait 3-5 minutes to permit water level an opportunity to reach equilibrium.

Measure and record the water level immediately prior to placing the pump in the well.

Lower pump or tubing slowly into the well so that the pump intake is located at the center of the saturated screen length of the well. If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of sediment that may be present in the bottom of the well. Collection of turbidity-free water samples may be difficult if there is three feet or less of standing water in the well.

Start with the initial pump rate set at approximately 0.1 liters/minute. Use a graduated cylinder and stopwatch to measure the pumping rate. Adjust pumping rates as necessary to prevent drawdown from exceeding 0.3 feet during purging. If no drawdown is noted, the pump rate may be increased (to a max of 0.4 liters/minute) to expedite the purging and sampling event. The pump rate will be reduced if turbidity is greater than 10 NTUs after all other field parameters have stabilized. If groundwater is drawn down below

the top of the well screen, purging will cease or the well will be pumped to dryness and the well will be allowed to recover before purging continues. Slow recovering wells will be identified and purged at the beginning of the workday. If possible, samples will be colleted from these wells within the same workday and no later than 24 hours after the start of purging.

Measure the well water level using the water level meter every 5 to 10 minutes. Record the well water level on the Low-Flow Purge Data Form (Attachment C).

Record on the Low-Flow Purge Data Form every 5 to 10 minutes the water quality parameters (pH, specific conductance, temperature, turbidity, oxidation-reduction potential, dissolved oxygen and salinity or as specified by the approved site specific work plan) measured by the water quality meter and turbidity meter. If the cell needs to be cleaned during purging operations, continue pumping (allow the pump to discharge into a container) and disconnect the cell. Rinse the cell with distilled/deionized water. After cleaning is completed, reconnect the flow-through cell and continue purging. Document the cell cleaning on the Low-Flow Purge Data Form.

Measure the flow rate using a graduated cylinder. Remeasure the flow rate any time the pump rate is adjusted.

During purging, check for the presence of bubbles in the flow-through cell. The presence of bubbles is an indication that connections are not tight. If bubbles are observed, check for loose connections.

After stabilization is achieved, sampling can begin when a minimum of two saturated screen volumes have been removed and three consecutive readings, taken at 5 to 10 minute intervals, are within the following limits:

- pH ±0.1 standard units
- Specific conductance ±3%
- Temperature ±10%
- Turbidity ±10% or as low as practicable given sampling conditions
- Dissolved oxygen ±10%
- Oxygen Reduction Potential ±10 mV

If, in the professional judgment of the field personnel, the well does not show signs of meeting the above conditions, purging the well may be terminated. In no event will purging be conducted for more than 4 hours. In the event that purging has been terminated prior to establishing stable conditions, consideration will be given to collecting a filtered sample of the groundwater in addition to the unfiltered groundwater sample. Record the final well stabilization parameters from the Low-Flow Purge Data Form onto the Groundwater Sample Log Form.

VOC samples are preferably collected first, directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

If the water column in the pump tubing collapses (water does not completely fill the tubing) before exiting the tubing, use one of the following procedures to collect VOC samples: (1) Collect the non-VOCs samples first, then increase the flow rate incrementally until the water column completely fills the tubing, collect the sample and record the new flow rate; (2) reduce the diameter of the existing tubing until the water column fills the tubing either by adding a connector (Teflon or stainless steel), or clamp which should reduce the flow rate by constricting the end of the tubing; (3) insert a narrow diameter Teflon tube into the pump's tubing so that the end of the tubing is in the water column and the other end of the tubing protrudes beyond the pump's tubing, collect sample from the narrow diameter tubing.

Prepare samples for shipping as per SOP SA-6.1.

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ATTACHMENT A

PURGING EQUIPMENT SELECTION

Diameter Casing		Bailer	Peristaltic Pump	Vacuum Pump	Air-lift	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	X			
	Water Level >25 feet	X			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

ATTACHMENT A

PURGING EQUIPMENT SELECTION

PAGE 2

Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter/Length (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
BarCad Systems, Inc.	BarCad Sampler	Dedicated; gas drive (positive displacement)	1.5/16	PE, brass, nylon, aluminum oxide	0-150 with std. tubing	1 liter for each 10-15 feet of submergence	$220-350	Requires compressed gas; custom sizes and materials available; acts as piezometer.
Cole-Parmer Inst. Co.	Master Flex 7570 Portable Sampling Pump	Portable; peristaltic (suction)	<1.0/NA	(not submersible) Tygon®, silicone Viton®	0-30	670 mL/min with 7015-20 pump head	$500-600	AC/DC; variable speed control available; other models may have different flow rates.
ECO Pump Corp.	SAMPLifier	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 gasoline-driven motors available; must be primed.
Geltek Corp.	Bailer 219-4	Portable; grab (positive displacement)	1.66/38	Teflon®	No limit	1,075 mL	$120-135	Other sizes available.
GeoEngineering, Inc.	GEO-MONITOR	Dedicated; gas drive (positive displacement)	1.5/16	PE, PP, PVC, Viton®	Probably 0-150	Approximately 1 liter for each 10 feet of submergence	$185	Acts as piezometer; requires compressed gas.
Industrial and Environmental Analysts, Inc. (IEA)	Aquarius	Portable; bladder (positive displacement)	1.75/43	SS, Teflon®, Viton®	0-250	0-2,800 mL/min	$1,500-3,000	Requires compressed gas; other models available; AC, DC, manual operation possible.
IEA	Syringe Sampler	Portable; grab (positive displacement)	1.75/43	SS, Teflon®	No limit	850 mL sample volume	$1,100	Requires vacuum and/or pressure from hand pump.
Instrument Specialties Co. (ISCO)	Model 2600 Well Sampler	Portable; bladder (positive displacement)	1.75/50	PC, silicone, Teflon®, PP, PE, Detrin®, acetal	0-150	0-7,500 mL/min	$990	Requires compressed gas (40 psi minimum).
Keck Geophysical Instruments, Inc.	SP-81 Submersible Sampling Pump	Portable; helical rotor (positive displacement)	1.75/25	SS, Teflon®, PP, EPDM, Viton®	0-160	0-4,500 mL/min	$3,500	DC operated.
Leonard Mold and Die Works, Inc.	GeoFilter Small Diameter Well Pump (#0500)	Portable; bladder (positive displacement)	1.75/38	SS, Teflon®, PC, Neoprene®	0-400	0-3,500 mL/min	$1,400-1,500	Requires compressed gas (55 psi minimum); pneumatic or AC/DC control module.
Oil Recovery Systems, Inc.	Surface Sampler	Portable; grab (positive displacement)	1.75/12	acrylic, Detrin®	No limit	Approximately 250 mL	$125-160	Other materials and models available; for measuring thickness of "floating" contaminants.
Q.E.D. Environmental Systems, Inc.	Well Wizard® Monitoring System (P-100)	Dedicated; bladder (positive displacement)	1.66/36	PVC	0-230	0-2,000 mL/min	$300-400	Requires compressed gas; piezometric level indicator; other materials available.

ATTACHMENT A

PURGING EQUIPMENT SELECTION

PAGE 3

Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter/Length (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
Randolph Austin Co.	Model 500 Vari-Flow Pump	Portable; peristaltic (suction)	<0.5/NA	(Not submersible) Rubber, Tygon®, or Neoprene®	0-30	See comments	$1,200-1,300	Flow rate dependent on motor and tubing selected; AC operated; other models available.
Robert Bennett Co.	Model 180	Portable; piston (positive displacement)	1.8/22	SS, Teflon®, Delrin® PP, Viton®, acrylic, PE	0-500	0-1,800 mL/min	$2,600-2,700	Requires compressed gas; water level indicator and flow meter; custom models available.
Slope Indicator Co. (SINCO)	Model 514124 Pneumatic Water Sampler	Portable; gas drive (positive displacement)	1.9/18	PVC, nylon	0-1,100	250 mL/flushing cycle	$250-350	Requires compressed gas; SS available; piezometer model available; dedicated model available.
Solinst Canada Ltd.	5W Water Sampler	Portable; grab (positive displacement)	1.9/27	PVC, brass, nylon, Neoprene®	0-330	500 mL	$1,300-1,800	Requires compressed gas; custom models available.
TIMCO Mfg. Co., Inc.	Std. Bailer	Portable; grab (positive displacement)	1.66/Custom	PVC, PP	No limit	250 mL/ft of bailer	$20-60	Other sizes, materials, models available; optional bottom-emptying device available; no solvents used.
TIMCO	Air or Gas Lift Sampler	Portable; gas drive (positive displacement)	1.66/30	PVC, Tygon®, Teflon®	0-150	350 mL/flushing cycle	$100-200	Requires compressed gas; other sizes, materials, models available; no solvents used.
Tole Devices Co.	Sampling Pump	Portable; bladder (positive displacement)	1.38/48	SS, silicone, Delrin®, Tygon®	0-125	0-4,000 mL/min	$800-1,000	Compressed gas required; DC control module; custom built.

Construction Material 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 groundwater 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.

ATTACHMENT B
GROUNDWATER SAMPLE LOG SHEET

Tetra Tech NUS, Inc.

GROUNDWATER SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[ ] Domestic Well Data
[x] Monitoring Well Data
[ ] Other Well Type: _____
[ ] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____
Type of Sample:
[X] Low Concentration
[ ] High Concentration

SAMPLING DATA:

Date:	Color	pH	S.C.	Temp.	Turbidity	DO	ORP	Other
Time:	Visual	Standard	mS/cm	Degrees C	NTU	mg/l	mV	NA
Method:								

PURGE DATA:

Date:	Volume	pH	S.C.	Temp. (C)	Turbidity	DO	ORP	Other
Method:								
Monitor Reading (ppm):			SEE LOW FLOW PURGE DATA SHEET					
Well Casing Diameter & Material								
Type:								
Total Well Depth (TD):								
Static Water Level (WL):								
One Casing Volume(gal/L):								
Start Purge (hrs):								
End Purge (hrs):								
Total Purge Time (min):								
Total Vol. Purged (gal/L):								

SAMPLE COLLECTION INFORMATION:

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS / NOTES:

Circle if Applicable:		Signature(s):
MS/MSD	Duplicate ID No.:	

ATTACHMENT C
LOW FLOW PURGE DATA SHEET

LOW FLOW PURGE DATA SHEET

PROJECT SITE NAME: _____ WELL ID.: _____
PROJECT NUMBER: _____ DATE: _____

Time (Hrs.)	Water Level (Ft. below TOC)	Flow (mL/Min.)	pH (S.U.)	S. Cond. (mS/cm)	Turb. (NTU)	DO (mg/L)	Temp. (Celcius)	ORP mV	Salinity % or ppt	Comments

SIGNATURE(S): _____ PAGE___OF___

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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 onsite examination and chemical testing, or for subsequent 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 5.5), 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 - a sample containing (or suspected to contain) low-level concentrations of contaminants, which does not require special handling or transport considerations as detailed in SOP SA-6.1.

Hazardous Waste Sample - a sample containing (or suspected to contain) higher concentrations of contaminants thus requiring special handling and/or transport considerations per SOP SA-6.1.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager has the overall responsibility for seeing that all surface water and sediment sampling activities are properly conducted by appropriately trained personnel.

Field Operations Leader - The Field Operations Leader (FOL) is responsible for the supervision of onsite water quality analyses, ensuring proper sample collection, handling, and the completion and accuracy of all field documentation, and making sure that custody of all samples obtained is maintained according to proper procedures.

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 characteristic 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 quality control applied during laboratory analyses and subsequent scrutiny of analytical data packages, reported data are no better than the confidence that can be placed in the representativeness of the samples.

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, physical characteristics of the water body (such as flow and mixing), 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 adsorption/desorption). The hydrogeologist 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 within 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 overland runoff, leachate influx to the waterbody, 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 adsorb onto particulate matter. Nitrogen, phosphorus, and the heavy metals may also be transported by particulates. Samples must be collected with a representative amount of suspended material; transfer from the sampling device shall include transferring a proportionate amount of the suspended material.

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 consideration 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 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 hydrogeologist 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 project plan documents. 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 (i.e., 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 project plans (often monthly or quarterly, and during droughts and floods). Samples of bottom material shall be collected from fresh deposits at least yearly, and preferably seasonally, during both spring and fall.

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

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 multi-point 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 watercourse 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 stream or river transports. The greater the 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, as directed in the project plan documents.

5.3.2 Lakes, Ponds and Reservoirs

Lakes, ponds, and reservoirs have a 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 and on the composite itself. 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 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 multi-parameter 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. Each type of estuarine area is described below:

- 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 to be acquired. The most frequently used samplers are:

- Open tube.
- Dip sampler.
- Weighted bottle.
- Hand pump.
- Kemmerer.
- Depth-Integrating Sampler.

The dip sampler and the weighted bottle sampler are used most often, and detailed discussions for these devices only (and the Kemmerer sampler) are addressed subsequently in this section.

The criteria for selecting a sampler include:

1. Disposability and/or easy decontamination.
2. Inexpensive cost (if the item is to be disposed).
3. Ease of operation.
4. Nonreactive/noncontaminating properties - Teflon-coated, glass, stainless-steel or PVC sample chambers are preferred (in that order).

As specified above, each sample (grab or each aliquot collected for compositing) shall be measured for but not limited to:

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

Sample measurements shall be conducted as soon as the sample is acquired. Measurement techniques described in SOP SA-1.1 shall be followed. All pertinent data and results shall be recorded in a field

notebook or on sample logsheets (see Attachment A). These analyses will provide information on water mixing/stratification and potential contamination.

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.

Weighted Bottle Sampling

A grab sample can also be taken using a weighted holder that allows a bottle 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 with this device 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 stopper line.
- Allow the bottle to fill completely, as evidenced by the absence of air bubbles.
- Raise the sampler and cap the bottle.
- Decontaminate the outside of the bottle. This bottle can be used as the sample container as long as the bottle is an approved container type.

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 (thus allowing free passage of water through the cylinder). A "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 a 0.6 foot 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. This is not applicable when sample containers are provided "pre-preserved."

- For sampling moving water, it is suggested that the farthest downstream sample be obtained first, and that subsequent samples be taken as one works upstream. In general, 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 node is combined into one sample, or several grid nodes are selected at random.

- Care should be taken to avoid excessive agitation of the water, as loss of volatile constituents could result.

- 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 of the septum faces in after the vial is filled and capped. The vial 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. When sample containers are provided "pre-preserved," use a dedicated, clean, un-preserved bottle for sampling and transfer to an appropriately-preserved container.

5.4 Onsite Water Quality Testing

Onsite water quality testing shall be conducted as described in SOP SA-1.1.

5.5 Sediment Sampling

5.5.1 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 sampling location shall be approximately at the center of the water body.

Generally, the coarser grained sediments are deposited near the headwaters of the reservoir. Bed sediments near the center of a water body 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, bathometry (i.e., depth distribution), and water circulation patterns must all be considered when selecting sediment sampling sites. In streams, areas likely to have sediment accumulation (e.g., bends, behind islands or boulders, quiet shallow areas or very deep, low-velocity areas) shall be sampled while areas likely to show net erosion (i.e., 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). Therefore, it is important to minimize the loss of low-density "fines" during any sampling process.

All relevant information pertaining to sediment sampling shall be documented as applicably described in SOP SA-6.3 and Attachment B.

5.5.2 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 onshore or offshore techniques.

The following health and safety provisions apply when working on/over/near water.

Size of Work Team:

1) Never less than 2 persons [who are wearing USCG approved Personal Flotation Devices (PFDs)]

2) A minimum of 3 persons if *any* of the following conditions are anticipated or observed:

- Depth is greater than 3 feet
- Involves a waterway that is turbulent *or* swift
- The underwater walking surface (e.g., stream/river bed) is suspected or observed to involve conditions that increase the potential for a worker to fall into the water. Examples would include large/uneven rocks or boulders, dense mud or sediment that could entrap worker's feet, etc.)
- Waterway is tidal, and conditions such as those listed above could change

The third person in the above condition must be equipped and prepared to render emergency support [e.g., lifeline, tethered PFD (life saver), skiff, means to contact external emergency response support, etc.]

The following samplers may be used to collect bottom materials:

- Scoop sampler.
- Dredge samplers.

Each type of sampler is discussed subsequently.

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, PVC, 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 best 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 the sampler along the bottom in an upstream direction. It is very difficult not to disturb fine-grained materials of the sediment-water interface when using this method.

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 sample 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". Some dredges are heavy and may 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 Peterson 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". 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.

6.0 REFERENCES

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ATTACHMENT A
SURFACE WATER SAMPLE LOG SHEET

Tetra Tech NUS, Inc. **SURFACE WATER SAMPLE LOG SHEET**

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Stream
[] Spring
[] Pond
[] Lake
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

SAMPLING DATA

	Color	pH	S.C.	Temp.	Turbidity	DO	Salinity	Other
Date:	Visual	Standard	mS/cm	Degrees C	NTU	mg/l	%	NA
Time:								
Depth:								
Method:								

SAMPLE COLLECTION INFORMATION

Analysis	Preservative	Container Requirements	Collected

OBSERVATIONS/NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

ATTACHMENT B
SOIL & SEDIMENT SAMPLE LOG SHEET

Tetra Tech NUS, Inc.

SOIL & SEDIMENT SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Surface Soil
[] Subsurface Soil
[] Sediment
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

GRAB SAMPLE DATA:

Date:	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Time:			
Method:			
Monitor Reading (ppm):			

COMPOSITE SAMPLE DATA:

Date:	Time	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Method:				
Monitor Readings (Range in ppm):				

SAMPLE COLLECTION INFORMATION:

Analysis	Container Requirements	Collected	Other

OBSERVATIONS / NOTES:

MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

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1.0 PURPOSE

This procedure discusses the methods used to collect surface, near surface, and subsurface soil samples. Additionally, it describes the method for sampling of test pits and trenches to determine subsurface soil and rock conditions, and recover small-volume or bulk samples.

2.0 SCOPE

This procedure is applicable to the collection of surface, near surface and subsurface soils for laboratory testing, which are exposed through hand digging, hand augering, drilling, or machine excavating at hazardous substance sites.

3.0 GLOSSARY

Composite Sample - A composite sample exists as a combination of more than one sample at various locations and/or depths and times, which is homogenized and treated as one sample. This type of sample is usually collected when determination of an average waste concentration for a specific area is required. Composite samples are not to be collected for volatile organics analysis.

Grab Sample - One sample collected at one location and at one specific time.

Non-Volatile Sample - A non-volatile sample includes all other chemical parameters (e.g., semivolatiles, pesticides/PCBs, metals, etc.) and those engineering parameters that do not require undisturbed soil for their analysis.

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 a Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outside diameter (OD) and from 18 to 54 inches in length.

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-barrel sampler is typically 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-barrel samplers commonly range in size from 2-inch OD to 3-1/2 inch OD. The larger sizes are commonly used when a larger volume of sample material is required.

Test Pit and Trench - Open, shallow excavations, typically rectangular (if a test pit) or longitudinal (if a trench), excavated to determine the shallow subsurface conditions for engineering, geological, and soil chemistry exploration and/or sampling purposes. These pits are excavated manually or by machine (e.g., backhoe, clamshell, trencher excavator, or bulldozer).

Confined Space - As stipulated in 29 CFR 1910.146, a confined space means a space that: 1) is large enough and so configured that an employee can bodily enter and perform assigned work; 2) has limited or restricted means for entry or exit (for example tanks, vessels, silos, storage bins, hoppers, vaults, pits, and excavations); and 3) is not designed for continuous employee occupancy. TtNUS considers all confined space as permit-required confined spaces.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for determining sampling objectives, as well as, the field procedures used in the collection of soil samples. Additionally, in consultation with other project personnel (geologist, hydrogeologist, etc.), the Project Manager establishes the need for test pits or trenches, and determines their approximate locations and dimensions.

Site Safety Officer (SSO) - The SSO (or a qualified designee) is responsible for providing the technical support necessary to implement the project Health and Safety Plan. This will include (but not be limited to) performing air quality monitoring during sampling, boring and excavation activities, and to ensure that workers and offsite (downwind) individuals are not exposed to hazardous levels of airborne contaminants. The SSO/designee may also be required to advise the FOL on other safety-related matters regarding boring, excavation and sampling, such as mitigative measures to address potential hazards from unstable trench walls, puncturing of drums or other hazardous objects, etc.

Field Operations Leader (FOL) - The FOL is responsible for finalizing the location of surface, near surface, and subsurface (hand and machine borings, test pits/trenches) soil samples. He/she is ultimately responsible for the sampling and backfilling of boreholes, test pits and trenches, and for adherence to OSHA regulations during these operations.

Project Geologist/Sampler - The project geologist/sampler is responsible for the proper acquisition of soil samples and the completion of all required paperwork (i.e., sample log sheets, field notebook, boring logs, test pit logs, container labels, custody seals, and chain-of-custody forms).

Competent Person - A Competent Person, as defined in 29 CFR 1929.650 of Subpart P - Excavations, means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

5.0 PROCEDURES

5.1 Overview

Soil sampling is an important adjunct to groundwater monitoring. Sampling of the soil horizons above the groundwater table can detect contaminants before they have migrated into the water table, and can establish the amount of contamination sorbed on aquifer solids that have the potential of contributing to groundwater contamination.

Soil types can vary considerably on a hazardous waste site. These variations, along with vegetation, can affect the rate of contaminant migration through the soil. It is important, therefore, that a detailed record be maintained during the sampling operations, particularly noting the location, depth, and such characteristics as grain size, color, and odor. Subsurface conditions are often stable on a daily basis and may demonstrate only slight seasonal variation especially with respect to temperature, available oxygen and light penetration. Changes in any of these conditions can radically alter the rate of chemical reactions or the associated microbiological community, thus further altering specific site conditions. As a result, samples must be kept at their at-depth temperature or lower, protected from direct light, sealed tightly in approved glass containers, and be analyzed as soon as possible.

The physical properties of the soil, its grain size, cohesiveness, associated moisture, and such factors as depth to bedrock and water table, will limit the depth from which samples can be collected and the method required to collect them. Often this information on soil properties can be obtained from published soil surveys available through the U.S. Geological Surveys and other government or farm agencies. It is the

intent of this procedure to present the most commonly employed soil sampling methods used at hazardous waste sites.

5.2 Soil Sample Collection

5.2.1 Procedure for Collecting Soil Samples for Volatile Organic Compounds

The above described traditional sampling techniques, used for the collection of soil samples for volatile organic analysis, have recently been evaluated by the scientific community and determined to be ineffective in producing accurate results (biased low) due to the loss of volatile organics in the sampling stages and microbial degradation of aromatic volatiles. One of the newly adopted sampling procedures for collecting soil samples includes the field preservation of samples with methanol or sodium bisulfate to minimize volatilization and biodegradation. These preservation methods may be performed either in the field or laboratory, depending on the sampling methodology employed.

Soil samples to be preserved by the laboratory are currently being performed using method SW-846, 5035. Laboratories are currently performing low level analyses (sodium bisulfate preservation) and high level analyses (methanol preservation) depending on the end users needs.

It should be noted that a major disadvantage of the methanol preservation method is that the laboratory reporting limits will be higher than conventional testing. The reporting levels using the new method for most analytes are 0.5 µg/g for GC/MS and 0.05 µg/g for GC methods.

The alternative preservation method for collecting soil samples is with sodium bisulfate. This method is more complex to perform in the field and therefore is not preferred for field crews. It should also be noted that currently, not all laboratories have the capabilities to perform this analysis. The advantage to this method is that the reporting limits (0.001 µg/g for GC/PID or GC/ELCD, or 0.010 for GC/MS) are lower than those described above.

The following procedures outline the necessary steps for collecting soil samples to be preserved at the laboratory, and for collecting soil samples to be preserved in the field with methanol or sodium bisulfate.

5.2.1.1 Soil Samples to be Preserved at the Laboratory

Soil samples collected for volatile organics that are to be preserved at the laboratory will be obtained using a hermetically sealed sample vial such as an EnCore™ sampler. Each sample will be obtained using a reusable sampling handle provided with the EnCore™ sampler. The sample is collected by pushing the EnCore™ sampler directly into the soil, ensuring that the sampler is packed tight with soil, leaving zero headspace. Using this type of sampling device eliminates the need for field preservation and the shipping restrictions associated with preservatives. A complete set of instructions is included with each Encore™ sampler shipment by the manufacturer.

Once the sample is collected, it should be placed on ice immediately and shipped to the laboratory within 48 hours (following the chain-of-custody and documentation procedures outlined in SOP SA-6.1). Samples must be preserved by the laboratory within 48 hours of sample collection.

If the lower detection limits are necessary, an option would be to collect several EnCore™ samplers at a given sample location. Send all samplers to the laboratory and the laboratory can perform the required preservation and analyses.

5.2.1.2 Soil Samples to be Preserved in the Field

Soil samples preserved in the field may be prepared for analyses using both the low-level (sodium bisulfate preservation) method and medium-level (methanol preservation) method.

Methanol Preservation (Medium Level):

Soil samples to be preserved in the field with methanol will utilize 40-60 mL glass vials with septum lids. Each sample bottle will be filled with 25 mL of demonstrated analyte-free purge and trap grade methanol. Bottles may be prespiked with methanol in the laboratory or prepared in the field.

Soil will be collected with the use of a decontaminated (or disposable), small-diameter coring device such as a disposable tube/plunger-type syringe with the tip cut off. The outside diameter of the coring device must be smaller than the inside diameter of the sample bottle neck.

A small electronic balance or manual scale will be necessary for measuring the volume of soil to be added to the methanol preserved sample bottle. Calibration of the scale should be performed prior to use and intermittently throughout the day according to the manufacturers requirements.

The sample should be collected by pulling the plunger back and inserting the syringe into the soil to be sampled. The top several inches of soil should be removed before collecting the sample. Approximately 10 grams $\pm$2g (8-12 grams) of soil should be collected. The sample should be weighed and adjusted until obtaining the required amount of sample. The sample weight should be recorded to the nearest 0.01 gram in the field logbook and/or sample log sheet. The soil should then be extruded into the methanol preserved sample bottle taking care not to contact the sample container with the syringe. The threads of the bottle and cap must be free of soil particles.

After capping the bottle, swirl the sample (do not shake) in the methanol and break up the soil such that all of the soil is covered with methanol. Place the sample on ice immediately and prepare for shipment to the laboratory as described in SOP SA-6.1.

Sodium Bisulfate Preservation (Low Level):

Samples to be preserved using the sodium bisulfate method are to be prepared as follows:

Add 1 gram of sodium bisulfate to 5 mL of laboratory grade deionized water in a 40-60 mL glass vial with septum lid. Bottles may be prespiked in the laboratory or prepared in the field. The soil sample should be collected in a manner as described above and added to the sample container. The sample should be weighed to the nearest 0.01 gram as described above and recorded in the field logbook or sample log sheet.

Care should be taken when adding the soil to the sodium bisulfate solution. A chemical reaction of soils containing carbonates (limestone) may cause the sample to effervesce or the vial to possibly explode.

When preparing samples using the sodium bisulfate preservation method, duplicate samples must be collected using the methanol preservation method on a one for one sample basis. The reason for this is because it is necessary for the laboratory to perform both the low level and medium level analyses. Place the sample on ice immediately and prepare for shipment to the laboratory as described in SOP SA-6.1.

If the lower detection limits are necessary, an option to field preserving with sodium bisulfate would be to collect 3 EnCore™ samplers at a given sample location. Send all samplers to the laboratory and the laboratory can perform the required preservation and analyses.

5.2.2 Procedure for Collecting Non-Volatile Soil Samples

Non-volatile soil samples may be collected as either grab or composite samples. The non-volatile soil sample is thoroughly mixed in a stainless steel or disposable, inert plastic tray, using a stainless steel trowel or other approved tool, then transferred into the appropriate sample container(s). Head space is permitted in a non-volatile soil sample container to allow for sample expansion.

5.2.3 Procedure for Collecting Undisturbed Soil Samples (ASTM D1587-83)

When it is necessary to acquire undisturbed samples of soil for purposes of engineering parameter analysis (e.g., permeability), a thin-walled, seamless tube sampler (Shelby tube) will be employed. The following method will be used:

1. Remove all surface debris (e.g., vegetation, roots, twigs, etc.) from the specific sampling location and drill and clean out the borehole to the sampling depth, being careful to minimize the chance for disturbance of the material to be sampled. In saturated material, withdraw the drill bit slowly to prevent loosening of the soil around the borehole and to maintain the water level in the hole at or above groundwater level.

2. The use of bottom discharge bits or jetting through an open-tube sampler to clean out the borehole shall not be allowed. Use of any side-discharge bits is permitted.

3. 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 into the borehole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.

4. 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're 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 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.

5. Upon removal of the sampling 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. Clean filler must be placed in voids at either end of the tube prior to sealing with wax. Place plastic caps on the ends of the sample tube, tape the caps in place, and dip the ends in wax.

6. Affix label(s) to the tube as required and record sample number, depth, penetration, and recovery length on the label. Mark the "up" direction on the side of the tube with indelible ink, and mark the end of the sample. Complete Chain-of-Custody (see SOP SA-6.3) and other required forms (including Attachment A of this SOP). 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 Dennison 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 need for acquiring an undisturbed sample.

5.3 Surface Soil Sampling

The simplest, most direct method of collecting surface soil samples (most commonly collected to a depth of 6 inches) for subsequent analysis is by use of a stainless steel trowel. Surface soils are considered 0-12 inches bgs.

In general, the following equipment is necessary for obtaining surface soil samples:

- Stainless steel or pre-cleaned disposable trowel.
- Real-time air monitoring instrument (e.g., PID, FID, etc.).
- Latex gloves.
- Required Personal Protective Equipment (PPE).
- Required paperwork (see SOP SA-6.3 and Attachment A of this SOP).
- Required decontamination equipment.
- Required sample container(s).
- Wooden stakes or pin flags.
- Sealable polyethylene bags (i.e., Ziploc® baggies).
- Heavy duty cooler.
- Ice.
- Chain-of-custody records and custody seals.

When acquiring surface soil samples, the following procedure shall be used:

1. Carefully remove vegetation, roots, twigs, litter, etc., to expose an adequate soil surface area to accommodate sample volume requirements.

2. Using a decontaminated stainless steel trowel, follow the procedure cited in Section 5.2.1 for collecting a volatile soil sample. Surface soil samples for volatile organic analysis should be collected from 6-12 inches bgs only.

3. Thoroughly mix (in-situ) a sufficient amount of soil to fill the remaining sample containers and transfer the sample into those containers utilizing the same stainless steel trowel employed above. Cap and securely tighten all sample containers.

4. Affix a sample label to each container. Be sure to fill out each label carefully and clearly, addressing all the categories described in SOP SA-6.3.

5. Proceed with the handling and processing of each sample container as described in SOP SA-6.2.

5.4 Near-Surface Soil Sampling

Collection of samples from near the surface (depth of 6-18 inches) can be accomplished with tools such as shovels and stainless steel or pre-cleaned disposable trowels.

The following equipment is necessary to collect near surface soil samples:

- Clean shovel.
- The equipment listed under Section 5.3 of this procedure.
- Hand auger.

To obtain near-surface soil samples, the following protocol shall be observed:

1. With a clean shovel, make a series of vertical cuts to the depth required in the soil to form a square approximately 1 foot by 1 foot.

2. Lever out the formed plug and scrape the bottom of the freshly dug hole with a decontaminated stainless steel or pre-cleaned disposable trowel to remove any loose soil.

3. Follow steps 2 through 5 listed under Section 5.3 of this procedure.

5.5 Subsurface Soil Sampling With a Hand Auger

A hand augering system generally consists of a variety of all stainless steel bucket bits (i.e., cylinders 6-1/2" long, and 2-3/4", 3-1/4", and 4" in diameter), a series of extension rods (available in 2', 3', 4' and 5' lengths), and a cross handle. A larger diameter bucket bit is commonly used to bore a hole to the desired sampling depth and then withdrawn. In turn, the larger diameter bit is replaced with a smaller diameter bit, lowered down the hole, and slowly turned into the soil at the completion depth (approximately 6 inches). The apparatus is then withdrawn and the soil sample collected.

The hand auger can be used in a wide variety of soil conditions. It can be used to sample soil both from the surface, or to depths in excess of 12 feet. However, the presence of rock layers and the collapse of the borehole normally contribute to its limiting factors.

To accomplish soil sampling using a hand augering system, the following equipment is required:

- Complete hand auger assembly (variety of bucket bit sizes).
- Stainless steel mixing bowls.
- The equipment listed under Section 5.3 of this procedure.

To obtain soil samples using a hand auger, the following procedure shall be followed:

1. Attach a properly decontaminated bucket bit to a clean extension rod and further attach the cross handle to the extension rod.

2. Clear the area to be sampled of any surface debris (vegetation, twigs, rocks, litter, etc.).

3. Begin augering (periodically removing accumulated soils from the bucket bit) and add additional rod extensions as necessary. Also, note (in a field notebook, boring log, and/or on standardized data sheets) any changes in the color, texture or odor of the soil.

4. After reaching the desired depth, slowly and carefully withdraw the apparatus from the borehole.

5. Remove the soiled bucket bit from the rod extension and replace it with another properly decontaminated bucket bit. The bucket bit used for sampling is commonly smaller in diameter than the bucket bit employed to initiate the borehole.

6. Carefully lower the apparatus down the borehole. Care must be taken to avoid scraping the borehole sides.

7. Slowly turn the apparatus until the bucket bit is advanced approximately 6 inches.

8. Discard the top of the core (approximately 1"), which represents any loose material collected by the bucket bit before penetrating the sample material.

9. Fill volatile sample container(s), using a properly decontaminated stainless steel trowel, with sample material directly from the bucket bit. Refer to Section 5.2.1 of this procedure.

10. Utilizing the above trowel, remove the remaining sample material from the bucket bit and place into a properly decontaminated stainless steel mixing bowl and thoroughly homogenize the sample material prior to filling the remaining sample containers. Refer to Section 5.2.2 of this procedure.

11. Follow steps 4 and 5 listed under Section 5.3 of this procedure.

5.6 Subsurface Soil Sampling With a Split-Barrel Sampler (ASTM D1586-84)

Split-barrel (split-spoon) samplers consist of a heavy carbon steel or stainless steel sampling tube that can be split into two equal halves to reveal the soil sample (see Attachment B). A drive head is attached to the upper end of the tube and serves as a point of attachment for the drill rod. A removable tapered nosepiece/drive shoe attaches to the lower end of the tube and facilitates cutting. A basket-like sample retainer can be fitted to the lower end of the split tube to hold loose, dry soil samples in the tube when the sampler is removed from the drill hole. This split-barrel sampler is made to be attached to a drill rod and forced into the ground by means of a 140-lb. or larger casing driver.

Split-barrel samplers are used to collect soil samples from a wide variety of soil types and from depths greater than those attainable with other soil sampling equipment.

The following equipment is used for obtaining split-barrel samples:

- Drilling equipment (provided by subcontractor).
- Split-barrel samplers (O.D. 2 inches, I.D. 1-3/8 inches, either 20 inches or 26 inches long); Larger O.D. samplers are available if a larger volume of sample is needed.
- Drive weight assembly, 140-lb. weight, driving head and guide permitting free fall of 30 inches.
- Stainless steel mixing bowls.
- Equipment listed under Section 5.3 of this procedure.

The following steps shall be followed to obtain split-barrel samples:

1. Remove the drive head and nosepiece, and open the sampler to reveal the soil sample. Immediately scan the sample core with a real-time air monitoring instrument (e.g., FID, PID, etc.). Carefully separate the soil core, with a decontaminated stainless steel knife or trowel, at about 6-inch intervals while scanning the center of the core for elevated readings. Also scan stained soil, soil lenses, and anomalies (if present), and record readings.

2. Collect the volatile sample from the center of the core where elevated readings occurred. If no elevated readings where encountered the sample material should still be collected from the core's

center (this area represents the least disturbed area with minimal atmospheric contact). Refer to Section 5.2.1 of this procedure.

3. Using the same trowel, remove remaining sample material from the split-barrel sampler (except for the small portion of disturbed soil usually found at the top of the core sample) and place the soil into a decontaminated stainless steel mixing bowl. Thoroughly homogenize the sample material prior to filling the remaining sample containers. Refer to Section 5.2.2 of this procedure.

4. Follow steps 4 and 5 listed under Section 5.3 of this procedure.

5.7 Subsurface Sol Sampling Using Direct Push Technology

Subsurface soil samples can be collected to depths of 40+ feet using direct push technology (DPT). DPT equipment, responsibilities, and procedures are described in SOP SA-2.5.

5.8 Excavation and Sampling of Test Pits and Trenches

5.8.1 Applicability

This subsection presents routine test pit or trench excavation techniques and specialized techniques that are applicable under certain conditions.

During the excavation of trenches or pits at hazardous waste sites, several health and safety concerns arise which control the method of excavation. No personnel shall enter any test pit or excavation over 4 feet deep except as a last resort, and then only under direct supervision of a Competent Person (as defined in 29 CFR 1929.650 of Subpart P - Excavations). Whenever possible, all required chemical and lithological samples should be collected using the excavator bucket or other remote sampling apparatus. If entrance is still required, all test pits or excavations must be stabilized by bracing the pit sides using specifically designed wooden or steel support structures. Personnel entering the excavation may be exposed to toxic or explosive gases and oxygen-deficient environments. Any entry may constitute a Confined Space and must be done in conformance with all applicable regulations. In these cases, substantial air monitoring is required before entry, and appropriate respiratory gear and protective clothing is mandatory. There must be at least two persons present at the immediate site before entry by one of the investigators. The reader shall refer to OSHA regulations 29 CFR 1926, 29 CFR 1910.120, 29 CFR 1910.134, and 29 CFR 1910.146.

Excavations are generally not practical where a depth of more than about 15 feet is desired, and they are usually limited to a few feet below the water table. In some cases, a pumping system may be required to control water levels within the pit, providing that pumped water can be adequately stored or disposed. If data on soils at depths greater than 15 feet are required, the data are usually obtained through test borings instead of test pits.

In addition, hazardous wastes may be brought to the surface by excavation equipment. This material, whether removed from the site or returned to the subsurface, must be properly handled according to any and all applicable federal, state, and local regulations.

5.8.2 Test Pit and Trench Excavation

These procedures describe the methods for excavating and logging test pits and trenches excavated to determine subsurface soil and rock conditions. Test pit operations shall be logged and documented (see Attachment C).

Test pits and trenches may be excavated by hand or by power equipment to permit detailed description of the nature and contamination of the in-situ materials. The size of the excavation will depend primarily on the following:

- The purpose and extent of the exploration.
- The space required for efficient excavation.
- The chemicals of concern.
- The economics and efficiency of available equipment.

Test pits normally have a cross section that is 4 to 10 feet square; test trenches are usually 3 to 6 feet wide and may be extended for any length required to reveal conditions along a specific line. The following table, which is based on equipment efficiencies, gives a rough guide for design consideration:

Equipment	Typical Widths, in Feet
Trenching machine	2
Backhoe	2-6
Track dozer	10
Track loader	10
Excavator	10
Scraper	20

The lateral limits of excavation of trenches and the position of test pits shall be carefully marked on area base maps. If precise positioning is required to indicate the location of highly hazardous waste materials, nearby utilities, or dangerous conditions, the limits of the excavation shall be surveyed. Also, if precise determination of the depth of buried materials is needed for design or environmental assessment purposes, the elevation of the ground surface at the test pit or trench location shall also be determined by survey. If the test pit/trench will not be surveyed immediately, it shall be backfilled and its position identified with stakes placed in the ground at the margin of the excavation for later surveying.

The construction of test pits and trenches shall be planned and designed in advance as much as possible. However, field conditions may necessitate revisions to the initial plans. The final depth and construction method shall be determined by the field geologist. The actual layout of each test pit, temporary staging area, and spoils pile will be predicated based on site conditions and wind direction at the time the test pit is made. Prior to excavation, the area can be surveyed by magnetometer or metal detector to identify the presence of underground utilities or drums.

As mentioned previously, no personnel shall enter any test pit or excavation except as a last resort, and then only under direct supervision of a Competent Person. If entrance is still required, Occupational Safety and Health Administration (OSHA) requirements must be met (e.g., walls must be braced with wooden or steel braces, ladders must be in the hole at all times, and a temporary guardrail must be placed along the surface of the hole before entry). It is emphasized that the project data needs should be structured such that required samples can be collected without requiring entrance into the excavation. For example, samples of leachate, groundwater, or sidewall soils can be taken with telescoping poles, etc.

Dewatering may be required to assure the stability of the side walls, to prevent the bottom of the pit from heaving, and to keep the excavation dry. This is an important consideration for excavations in cohesionless material below the groundwater table. Liquids removed as a result of dewatering operations must be handled as potentially contaminated materials. Procedures for the collection and disposal of such materials should be discussed in the site-specific project plans.

5.8.3 Sampling in Test Pits and Trenches

5.8.3.1 General

Test pits and trenches are usually logged as they are excavated. Records of each test pit/trench will be made as presented in Attachment C. These records include plan and profile sketches of the test pit/trench showing materials encountered, their depth and distribution in the pit/trench, and sample locations. These records also include safety and sample screening information.

Entry of test pits by personnel is extremely dangerous, shall be avoided unless absolutely necessary, and can occur only after all applicable Health and Safety and OSHA requirements have been met.

The final depth and type of samples obtained from each test pit will be determined at the time the test pit is excavated. Sufficient samples are usually obtained and analyzed to quantify contaminant distribution as a function of depth for each test pit. Additional samples of each waste phase and any fluids encountered in each test pit may also be collected.

In some cases, samples of soil may be extracted from the test pit for reasons other than waste sampling and chemical analysis, for instance, to obtain geotechnical information. Such information would include soil types, stratigraphy, strength, etc., and could therefore entail the collection of disturbed (grab or bulk) or relatively undisturbed (hand-carved or pushed/driven) samples, which can be tested for geotechnical properties. The purposes of such explorations are very similar to those of shallow exploratory or test borings, but often test pits offer a faster, more cost-effective method of sampling than installing borings.

5.8.3.2 Sampling Equipment

The following equipment is needed for obtaining samples for chemical or geotechnical analysis from test pits and trenches:

- Backhoe or other excavating machinery.
- Shovels, picks, hand augers, and stainless steel trowels/disposable trowels.
- Sample container - bucket with locking lid for large samples; appropriate bottleware for chemical or geotechnical analysis samples.
- Polyethylene bags for enclosing sample containers; buckets.
- Remote sampler consisting of 10-foot sections of steel conduit (1-inch-diameter), hose clamps and right angle adapter for conduit (see Attachment D).

5.8.3.3 Sampling Methods

The methods discussed in this section refer to test pit sampling from grade level. If test pit entry is required, see Section 5.8.3.4.

- Excavate trench or pit in several depth increments. After each increment, the operator will wait while the sampler inspects the test pit from grade level to decide if conditions are appropriate for sampling. (Monitoring of volatiles by the SSO will also be used to evaluate the need for sampling.) Practical depth increments range from 2 to 4 feet.

- The backhoe operator, who will have the best view of the test pit, will immediately cease digging if:

  - Any fluid phase or groundwater seepage is encountered in the test pit.
  - Any drums, other potential waste containers, obstructions or utility lines are encountered.
  - Distinct changes of material are encountered.

This action is necessary to permit proper sampling of the test pit and to prevent a breach of safety protocol. Depending upon the conditions encountered, it may be required to excavate more slowly and carefully with the backhoe.

For obtaining test pit samples from grade level, the following procedure shall be followed:

- Remove loose material to the greatest extent possible with backhoe.

- Secure walls of pit if necessary. (There is seldom any need to enter a pit or trench which would justify the expense of shoring the walls. All observations and samples should be taken from the ground surface.)

- Samples of the test pit material are to be obtained either directly from the backhoe bucket or from the material once it has been deposited on the ground. The sampler or Field Operations Leader directs the backhoe operator to remove material from the selected depth or location within the test pit/trench. The bucket is brought to the surface and moved away from the pit. The sampler and/or SSO then approaches the bucket and monitors its contents with a photoionization or flame ionization detector. The sample is collected from the center of the bucket or pile and placed in sample containers using a decontaminated stainless steel trowel or disposable spatula.

- If a composite sample is desired, several depths or locations within the pit/trench are selected and a bucket is filled from each area. It is preferable to send individual sample bottles filled from each bucket to the laboratory for compositing under the more controlled laboratory conditions. However, if compositing in the field is required, each sample container shall be filled from materials that have been transferred into a mixing bucket and homogenized. Note that homogenization/compositing is not applicable for samples to be subjected to volatile organic analysis.

- Using the remote sampler shown in Attachment D, samples can be taken at the desired depth from the side wall or bottom of the pit. The face of the pit/trench shall first be scraped (using a long-handled shovel or hoe) to remove the smeared zone that has contacted the backhoe bucket. The sample shall then be collected directly into the sample jar, by scraping with the jar edge, eliminating the need to utilize samplers and minimizing the likelihood of cross-contamination. The sample jar is then capped, removed from the assembly, and packaged for shipment.

- Complete documentation as described in SOP SA-6.3 and Attachment C of this SOP.

5.8.3.4 <u>In-Pit Sampling</u>

Under rare conditions, personnel may be required to enter the test pit/trench. This is necessary only when soil conditions preclude obtaining suitable samples from the backhoe bucket (e.g., excessive mixing of soils or wastes within the test pit/trench) or when samples from relatively small discrete zones within the test pit are required. This approach may also be necessary to sample any seepage occurring at discrete levels or zones in the test pit that are not accessible with remote samplers.

In general, personnel shall sample and log pits and trenches from the ground surface, except as provided for by the following criteria:

- There is no practical alternative means of obtaining such data.
- The Site Safety Officer and Competent Person determines that such action can be accomplished without breaching site safety protocol. This determination will be based on actual monitoring of the pit/trench after it is dug (including, at a minimum, measurements of volatile organics, explosive gases and available oxygen).
- A Company-designated Competent Person determines that the pit/trench is stable or is made stable (by grading the sidewalls or using shoring) prior to entrance of any personnel. OSHA requirements must be strictly observed.

If these conditions are satisfied, one person will enter the pit/trench. On potentially hazardous waste sites, this individual will be dressed in safety gear as required by the conditions in the pit. He/she will be affixed to a safety rope and continuously monitored while in the pit.

A second individual will be fully dressed in protective clothing including a self-contained breathing device and on standby during all pit entry operations. The individual entering the pit will remain therein for as brief a period as practical, commensurate with performance of his/her work. After removing the smeared zone, samples shall be obtained with a decontaminated trowel or spoon. As an added precaution, it is advisable to keep the backhoe bucket in the test pit when personnel are working below grade. Such personnel can either stand in or near the bucket while performing sample operations. In the event of a cave-in they can either be lifted clear in the bucket, or at least climb up on the backhoe arm to reach safety.

5.8.3.5 Geotechnical Sampling

In addition to the equipment described in Section 5.8.3.2, the following equipment is needed for geotechnical sampling:

- Soil sampling equipment, similar to that used in shallow drilled boring (i.e., open tube samplers), which can be pushed or driven into the floor of the test pit.
- Suitable driving (i.e., a sledge hammer) or pushing (i.e., the backhoe bucket) equipment which is used to advance the sampler into the soil.
- Knives, spatulas, and other suitable devices for trimming hand-carved samples.
- Suitable containers (bags, jars, tubes, boxes, etc.), labels, wax, etc. for holding and safely transporting collected soil samples.
- Geotechnical equipment (pocket penetrometer, torvane, etc.) for field testing collected soil samples for classification and strength properties.

Disturbed grab or bulk geotechnical soil samples may be collected for most soils in the same manner as comparable soil samples for chemical analysis. These collected samples may be stored in jars or plastic-lined sacks (larger samples), which will preserve their moisture content. Smaller samples of this type are usually tested for their index properties to aid in soil identification and classification, while larger bulk samples are usually required to perform compaction tests.

Relatively undisturbed samples are usually extracted in cohesive soils using open tube samplers, and such samples are then tested in a geotechnical laboratory for their strength, permeability and/or compressibility. The techniques for extracting and preserving such samples are similar to those used in performing Shelby tube sampling in borings, except that the sampler is advanced by hand or backhoe,

rather than by a drill rig. Also, the sampler may be extracted from the test pit by excavation around the sampler when it is difficult to pull it out of the ground. If this excavation requires entry of the test pit, the requirements described in Section 5.8.3.4 of this procedure must be followed. The open tube sampler shall be pushed or driven vertically into the floor or steps excavated in the test pit at the desired sampling elevations. Extracting tube samples horizontally from the walls of the test pit is not appropriate, because the sample will not have the correct orientation.

A sledge hammer or the backhoe may be used to drive or push the sampler or tube into the ground. Place a piece of wood over the top of the sampler or sampling tube to prevent damage during driving/pushing of the sample. Pushing the sampler with a constant thrust is always preferable to driving it with repeated blows, thus minimizing disturbance to the sample. If the sample cannot be extracted by rotating it at least two revolutions (to shear off the sample at the bottom), hand-excavate to remove the soil from around the sides of the sampler. If hand-excavation requires entry of the test pit, the requirements in Section 5.8.3.4 of this procedure must be followed. Prepare, label, pack and transport the sample in the required manner, as described in SOP SA-6.3 and SA-6.1.

5.8.4 Backfilling of Trenches and Test Pits

All test pits and excavations must be either backfilled, covered, or otherwise protected at the end of each day. No excavations shall remain open during non-working hours unless adequately covered or otherwise protected.

Before backfilling, the onsite crew shall photograph all significant features exposed by the test pit and trench and shall include in the photograph a scale to show dimensions. Photographs of test pits shall be marked to include site number, test pit number, depth, description of feature, and date of photograph. In addition, a geologic description of each photograph shall be entered in the site logbook. All photographs shall be indexed and maintained as part of the project file for future reference.

After inspection, backfill material shall be returned to the pit under the direction of the FOL.

If a low permeability layer is penetrated (resulting in groundwater flow from an upper contaminated flow zone into a lower uncontaminated flow zone), backfill material must represent original conditions or be impermeable. Backfill could consist of a soil-bentonite mix prepared in a proportion specified by the FOL (representing a permeability equal to or less than original conditions). Backfill can be covered by "clean" soil and graded to the original land contour. Revegetation of the disturbed area may also be required.

5.9 Records

The appropriate sample log sheet (see Attachment A of this SOP) must be completed by the site geologist/sampler. All soil sampling locations should be documented by tying in the location of two or more nearby permanent landmarks (building, telephone pole, fence, etc.) or obtaining GPS coordinates; and shall be noted on the appropriate sample log sheet, site map, or field notebook. Surveying may also be necessary, depending on the project requirements.

Test pit logs (see Attachment C of this SOP) shall contain a sketch of pit conditions. In addition, at least one photograph with a scale for comparison shall be taken of each pit. Included in the photograph shall be a card showing the test pit number. Boreholes, test pits and trenches shall be logged by the field geologist in accordance with SOP GH-1.5.

Other data to be recorded in the field logbook include the following:

- Name and location of job.
- Date of boring and excavation.

- Approximate surface elevation.
- Total depth of boring and excavation.
- Dimensions of pit.
- Method of sample acquisition.
- Type and size of samples.
- Soil and rock descriptions.
- Photographs.
- Groundwater levels.
- Organic gas or methane levels.
- Other pertinent information, such as waste material encountered.

6.0 REFERENCES

American Society for Testing and Materials, 1987. ASTM Standards D1587-83 and D1586-84. ASTM Annual Book of Standards. ASTM. Philadelphia, Pennsylvania. Volume 4.08.

NUS Corporation, 1986. Hazardous Material Handling Training Manual.

NUS Corporation and CH2M Hill, August, 1987. Compendium of Field Operation Methods. Prepared for the U.S. EPA.

OSHA, Excavation, Trenching and Shoring 29 CFR 1926.650-653.

OSHA, Confined Space Entry 29 CFR 1910.146.

ATTACHMENT A
SOIL & SEDIMENT SAMPLE LOG SHEET

Tetra Tech NUS, Inc.

SOIL & SEDIMENT SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Surface Soil
[] Subsurface Soil
[] Sediment
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

GRAB SAMPLE DATA:

Date:	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Time:			
Method:			
Monitor Reading (ppm):			

COMPOSITE SAMPLE DATA:

Date:	Time	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Method:				
Monitor Readings (Range in ppm):				

SAMPLE COLLECTION INFORMATION:

Analysis	Container Requirements	Collected	Other

OBSERVATIONS / NOTES:

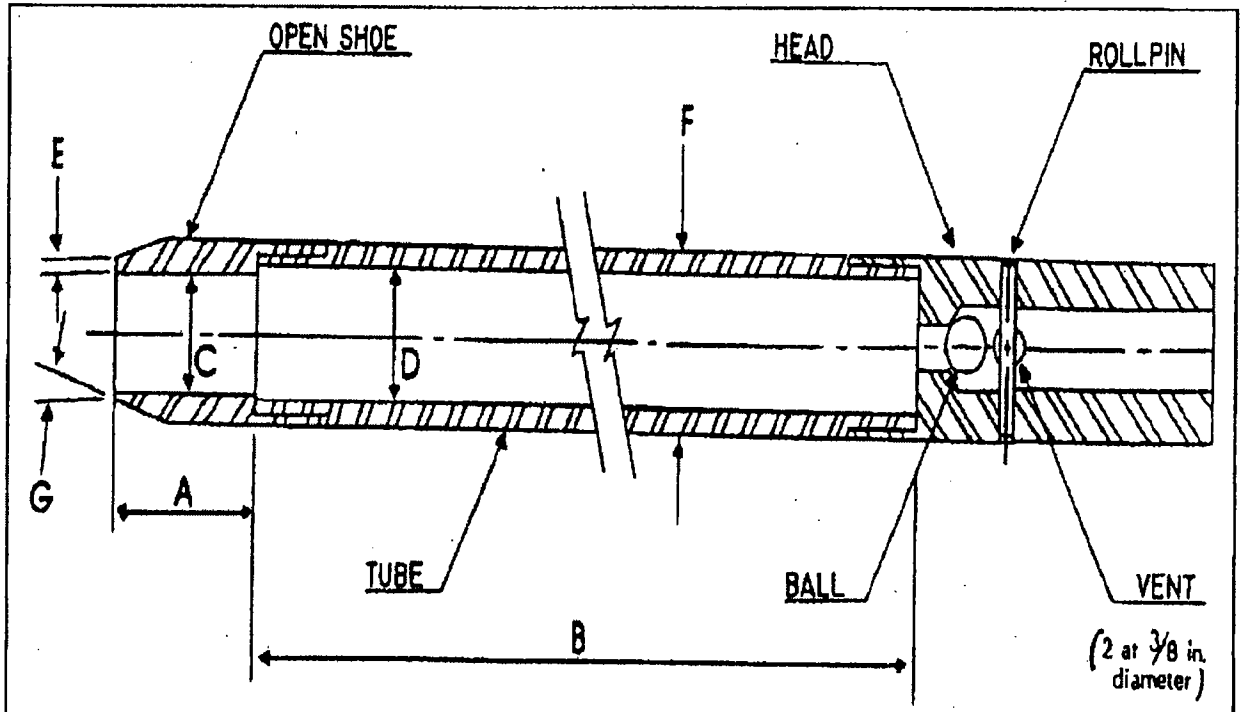
MAP:

Circle if Applicable:

MS/MSD	Duplicate ID No.:

Signature(s):

ATTACHMENT B
SPLIT-SPOON SAMPLER



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 – 0.00 in. (38.1 ± 1.3 – 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 – 0.00 in. (50.8 ± 1.3 – 0.0 mm)
G = 18.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

ATTACHMENT C
TEST PIT LOG

Tetra Tech NUS, Inc.

TEST PIT LOG

Page ___ of ___

PROJECT NAME: _____ TEST PIT No.: _____
PROJECT NUMBER: _____ DATE: _____
LOCATION: _____ GEOLOGIST: _____

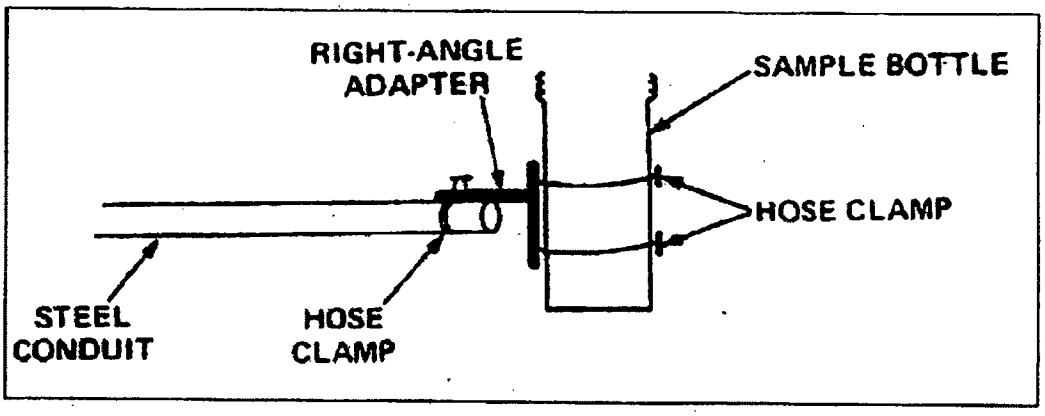
Depth (Ft.)	Lithology Change (Depth/Ft.)	MATERIAL DESCRIPTION: Soil/Waste Characteristics (lithology, density, color, etc.)	USCS	Remarks	PID/FID READING: Source (ppm)	PID/FID READING: BZ (ppm)

TEST PIT CROSS SECTION AND / OR PLAN VIEW

REMARKS: _____

PHOTO LOG: _____

ATTACHMENT D
REMOTE SAMPLE HOLDER FOR TEST PIT/TRENCH SAMPLING



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1.0 PURPOSE

The purpose of this procedure is to provide general reference information on Direct Push Technology (DPT). DPT is designed to collect soil, groundwater, and soil gas samples without using conventional drilling techniques. The advantage of using DPT over conventional drilling includes the generation of little or no drill cuttings, sampling in locations with difficult accessibility, reduced overhead clearance requirements, no fluid introduction during probing, and typical lower costs per sample than with conventional techniques. Disadvantages include a maximum penetration depth of approximately 15 to 40 feet in dense soils (although it may be as much as 60 to 80 feet in certain types of geological environments), reduced capability of obtaining accurate water-level measurements, and the inability to install permanent groundwater monitoring wells. The methods and equipment described herein are for collection of surface and subsurface soil samples and groundwater samples. Soil gas sampling is discussed in SOP SA-2.4.

2.0 SCOPE

This procedure provides information on proper sampling equipment and techniques for DPT. 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

Direct Push Technology (DPT) - DPT refers to sampling tools and sensors that are driven directly into the ground without the use of conventional drilling equipment. DPT typically utilizes hydraulic pressure and/or percussion hammers to advance the sampling tools. A primary advantage of DPT over conventional drilling techniques is that DPT results in the generation of little or no investigation derived waste.

Geoprobe® - Geoprobe® is a manufacturer of a hydraulically-powered, percussion/probing machines utilizing DPT to collect subsurface environmental samples. Geoprobe® relies on a relatively small amount of static weight (vehicle) combined with percussion as the energy for advancement of a tool string. The Geoprobe® equipment can be mounted in a multitude of vehicles for access to all types of environmental sites.

HydroPunch™ - HydroPunch™ is a manufacturer of stainless steel and Teflon® sampling tools that are capable of collecting representative groundwater and/or soil samples without requiring the installation of a groundwater monitoring well or conventional soil boring. HydroPunch™ is an example of DPT sampling equipment.

Flame Ionization Detector (FID) - A portable instrument for the measurement of many combustible organic compounds and a few inorganic compounds in air at parts-per million levels. The basis for the detection is the ionization of gaseous species utilizing a flame as the energizing source.

Photo Ionization Detector (PID) - A portable instrument for the measurement of many combustible organic compounds and a few inorganic compounds in air at parts-per million levels. The basis for the detection is the ionization of gaseous species utilizing ultraviolet radiation as the energizing source.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for selecting and/or reviewing the appropriate DPT drilling procedure required to support the project objectives.

Field Operations Leader (FOL)- The FOL is primarily responsible for performing the DPT in accordance with the project-specific plan.

5.0 SOIL SAMPLING PROCEDURES

5.1 General

The common methodology for the investigation of the vadose zone is soil boring drilling and soil sampling. However, drilling soil borings can be very expensive. Generally the advantage of DPT for subsurface soil sampling is the reduced cost of disposal of drilling cuttings and shorter sampling times.

5.2 Sampling Equipment

Equipment needed for conducting DPT drilling for subsurface soil sampling includes, but is not limited to, the following:

- Geoprobe® Sampling Kit
- Cut-resistant gloves
- 4-foot x 1.5-inch diameter macrocore sampler
- Probe sampling adapters
- Roto-hammer with 1.5-inch bit
- Disposable acetate liners for soil macrocore sampler
- Cast aluminum or steel drive points
- Geoprobe® AT-660 Series Large Bore Soil Sampler, or equivalent
- Standard decontamination equipment and solutions

For health and safety equipment and procedures, follow the direction provided in the Safe Work Permit in Attachment 1, or the more detailed directions provided in the project's Health and Safety Plan.

5.3 DPT Sampling Methodology

There are several methods for the collection of soil samples using DPT drilling. The most common method is discussed in the following section. Variations of the following method may be conducted upon approval of the Project Manager in accordance with the project-specific plan.

- Macrocore samplers fitted with detachable aluminum or steel drive points are driven into the ground using hydraulic pressure. If there is concrete or pavement over a sampling location, a Roto-hammer is used to drill a minimum 1.5-inch diameter hole through the surface material. A Roto-hammer may also be used if very dense soils are encountered.

- The sampler is advanced continuously in 4-foot intervals or less if desired. No soil cuttings are generated because the soil which is not collected in the sampler is displaced within the formation.

- The sampler is retracted from the hole, and the 4-foot continuous sample is removed from the outer coring tube. The sample is contained within an inner acetate liner.

- Attach the metal trough from the Geoprobe® Sampling Kit firmly to the tail gate of a vehicle. If a vehicle with a tail gate is not available, secure the trough on another suitable surface.

- Place the acetate liner containing the soils in the trough.

- While wearing cut-resistant gloves (constructed of leather or other suitable material), cut the acetate liner through its entire length using the double-bladed knife that accompanies the Geoprobe® Sampling Kit. Then remove the strip of acetate from the trough to gain access to the collected soils. Do not attempt to cut the acetate liner while holding it in your hand.

- Field screen the sample with an FID or PID, and observe/examine the sample (according to SOP GH-1.3). If appropriate, transfer the sample to sample bottles for laboratory analysis. If additional volume is required, push an additional boring adjacent to the first and composite/mix the same interval. Field compositing is usually not acceptable for sample requiring volatile organics analysis.

- Once sampling has been completed, the hole is backfilled with bentonite chips or bentonite cement grout, depending upon project requirements. Asphalt or concrete patch is used to cap holes through paved or concrete areas. All holes should be finished smooth to existing grade.

- In the event the direct push van/truck cannot be driven to a remote location or a sampling location with difficult accessibility, sampling probes may be advanced and sampled manually or with air/electric operated equipment (e.g., jack hammer).

- Sampling equipment is decontaminated prior to collecting the next sample.

6.0 GROUNDWATER SAMPLING PROCEDURES

6.1 General

The most common methodology for the investigation of groundwater is the installation and sampling of permanent monitoring wells. If only groundwater screening is required, the installation and sampling of temporary well points may be performed. The advantage of temporary well point installation using DPT is reduced cost due to no or minimal disposal of drilling cuttings and well construction materials, and shorter installation/times sampling.

Two disadvantages of DPT drilling for well point installation are:

- In aquifers with low yields, well points may have to be sampled without purging or development.
- If volume requirements are high, this method can be time consuming for low yield aquifers.

6.2 Sampling Equipment

Equipment needed for temporary well installation and sampling using DPT includes, but is not limited, to the following:

- 2-foot x 1-inch diameter mill-slotted (0.005 to 0.02-inch) well point
- Connecting rods
- Roto-hammer with 1.5-inch bit
- Mechanical jack
- 1/4-inch OD polyethylene tubing
- 3/8-inch OD polyethylene tubing
- Peristaltic pump
- Standard decontamination equipment and solutions

6.3 DPT Temporary Well Point Installation and Sampling Methodology

There are several methods for the installation and sampling of temporary well points using DPT. The most common methodology is discussed below. Variations of the following method may be conducted upon approval of the Project Manager in accordance with the project specific plan.

- A 2-foot x 1-inch diameter mill-slotted (0.005 to 0.02-inch) well point attached to connecting rods is driven into the ground to the desired depth using a rotary electric hammer or other direct push drill rig. If there is concrete or pavement over a sampling location, a Roto-hammer or electric coring machine is used to drill a hole through the surface material.

- The well point will be allowed to equilibrate for at least 15 minutes, after which a measurement of the static water level will be taken. The initial measurement of the water level will be used to assess the amount of water which is present in the well point and to determine the amount of silt and sand infiltration that may have occurred.

- The well point will be developed using a peristaltic pump and polyethylene tubing to remove silt and sand which may have entered the well point. The well point is developed by inserting polyethylene tubing to the bottom of the well point and lifting and lowering the tubing slightly while the pump is operating. The pump will be operated at a maximum rate of approximately 2 liters per minute. After removal of sediment from the bottom of the well point, the well point will be vigorously pumped at maximum capacity until discharge water is visibly clear and no further sediments are being generated. Measurements of pH, specific conductance, temperature, and turbidity shall be recorded every 5 to 10 minutes during the purging process. After two consistent readings of pH, specific conductance, temperature and turbidity (±10 percent), the well may be sampled.

- A sample will be collected using the peristaltic pump set at the same or reduced speed as during well development. Samples (with the exception of the samples to be analyzed for volatile organic compounds, VOCs) will be collected directly from the pump discharge. Sample containers for VOCs will be filled by (first shutting off the pump) crimping the discharge end of the sample tubing when filled, removing the inlet end of the sample tubing from the well, suspending the inlet tubing above the vial, and allowing water to fill each vial by gravity flow.

- Once the groundwater sample has been collected, the connecting rods and well point will be removed from the hole with the direct push rig hydraulics. The hole will be backfilled with bentonite chips or bentonite cement grout, depending upon project requirements. Asphalt or concrete patch will be used to cap holes through paved or concrete areas. All holes will be finished smooth to existing grade.

- In the event the direct push van/truck cannot be driven to a remote location or sampling location with difficult accessibility, sampling probes may be advanced and sampled manually or with air/electric-operated equipment (e.g., jack hammer).

- Decontaminate the equipment before moving to the next location.

7.0 RECORDS

A record of all field procedures, tests, and observations must be recorded in the field logbook, boring logs, and sample log sheets, as needed. Entries should include all pertinent data regarding the investigation. The use of sketches and field landmarks will help to supplement the investigation and evaluation.

ATTACHMENT 1
SAFE WORK PERMIT FOR DPT OPERATIONS

Permit No. _____ Date: _____ Time: From _____ to _____

SECTION I: General Job Scope

I. Work limited to the following (description, area, equipment used): **Monitoring well drilling and installation through direct push technology**

II. Required Monitoring Instruments: _____

III. Field Crew: _____

IV. On-site Inspection conducted ☐ Yes ☐ No Initials of Inspector _____ _____
TtNUS

SECTION II: General Safety Requirements (To be filled in by permit issuer)

V. Protective equipment required
Level D ☒ Level B ☐
Level C ☐ Level A ☐
Detailed on Reverse

Respiratory equipment required
Full face APR ☐ Escape Pack ☐
Half face APR ☐ SCBA ☐
SKA-PAC SAR ☐ Bottle Trailer ☐
Skid Rig ☐ None ☒

Level D Minimum Requirements: Sleeved shirt and long pants, safety footwear, and work gloves. Safety glasses, hard hats, and hearing protection will be worn when working near or sampling in the vicinity of the DPT rig.

Modifications/Exceptions.

VI. Chemicals of Concern _____ Action Level(s) _____ Response Measures _____

VII. Additional Safety Equipment/Procedures

Hard-hat	☒ Yes	☐ No	Hearing Protection (Plugs/Muffs)	☒ Yes	☐ No
Safety Glasses	☒ Yes	☐ No	Safety belt/harness	☐ Yes	☒ No
Chemical/splash goggles	☐ Yes	☒ No	Radio	☐ Yes	☒ No
Splash Shield	☐ Yes	☒ No	Barricades	☒ Yes	☐ No
Splash suits/coveralls	☐ Yes	☐ No	Gloves (Type - _____)	☐ Yes	☐ No
Steel toe Work shoes or boots	☒ Yes	☐ No	Work/warming regimen	☐ Yes	☐ No

Modifications/Exceptions: Reflective vests for high traffic areas.

VIII. Procedure review with permit acceptors

	Yes	NA		Yes	NA
Safety shower/eyewash (Location & Use)	☐	☒	Emergency alarms	☐	☐
Daily tail gate meetings	☒	☐	Evacuation routes	☐	☐
Contractor tools/equipment/PPE inspected	☐	☐	Assembly points	☐	☐

IX. Site Preparation

Utility Clearances obtained for areas of subsurface investigation	☐ Yes	☐ No
Physical hazards removed or blockaded	☐ Yes	☐ No
Site control boundaries demarcated/signage	☐ Yes	☐ No

X. Equipment Preparation

	Yes	NA
Equipment drained/depressurized	☐	☒
Equipment purged/cleaned	☐	☒
Isolation checklist completed	☐	☒
Electrical lockout required/field switch tested	☐	☒
Blinds/misalignments/blocks & bleeds in place	☐	☒
Hazardous materials on walls/behind liners considered	☐	☒

XI. Additional Permits required (Hot work, confined space entry) ☐ Yes ☐ No
If yes, complete permit required or contact Health Sciences, Pittsburgh Office

XII. Special instructions, precautions:
_____

Permit Issued by: _____ Permit Accepted by: _____

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1.0 PURPOSE

The objective of this Standard Operating Procedure is to specify the proper approach and methodologies to identify and quantify airborne chemical contamination levels through the use of direct reading instrumentation and air sample collection. The results of these activities provide vital information for site characterization and risk assessment considerations.

2.0 SCOPE

Applies to all Tetra Tech NUS site activities where the potential for personnel exposures to respiratory health hazards exists.

3.0 GLOSSARY

Direct Reading Instruments (DRIs) - Instrumentation operating on various detection principles such as flame ionization or photoionization providing real time readings of ambient contaminants in air.

Personal/Area Air Sampling - Personal/area air sampling is conducted utilizing an air sampling pump and a specific collection media to quantify airborne contaminants.

Meteorological Considerations - Meteorological information must be collected on site to properly determine air sampling results, as well as aid in the characterization of contaminant potential plume migration and intensity. This information will also be used to support the selection of sampling locations and determine which samples should be analyzed. The meteorological information will be used to estimate downwind concentration levels based on short-term field levels encountered at the source.

4.0 RESPONSIBILITIES

Project Manager (PM) - Responsible for all aspects of project implementation and direction. The project manager is responsible for providing the necessary resources in support of all air monitoring and sampling applications.

Field Operations Leader (FOL) - Responsible for implementing the air monitoring program as detailed in approved project plans for the specific site. Air monitoring requirements will be included in both the Field Sampling and Analysis Plan (FSAP) and the site-specific Health and Safety Plan (HASP).

Health and Safety Officer (HSO) - The health and safety officer provides technical assistance to the FOL concerning air monitoring and sampling applications, collection methodologies, data interpretations, and establishes action items based on results. This information is further used to assess atmospheric migration of airborne chemical contaminants.

5.0 PROCEDURES

5.1 Introduction

Air monitoring is used to help establish criteria for worker safety, document potential exposures, and determine protective measures for the site personnel and the surrounding public. To accomplish this, it is necessary for an effective air surveillance program to be tailored to meet the conditions found at each work site.

During site operations, data are collected concerning air contaminants representative for site operations. Monitoring for vapors, gases, and particulates is performed using DRIs, air sampling systems, and

meteorological considerations. DRIs can be used to detect many organics as well as a few inorganics and can provide approximate total concentrations through applications of relative response ratios of contaminants to reference standards. If specific chemicals (organics and inorganics) have been identified, then properly calibrated DRIs can be used for more accurate onsite assessments.

The most accurate method for evaluating any air contaminant is to collect samples and analyze them at a qualified laboratory. Although accurate, this method presents two disadvantages: (1) cost and (2) the time required to obtain results. Analyzing large numbers of laboratory samples can be expensive, especially if results are needed quickly. Onsite laboratories tend to reduce the turnaround time, but unless they can analyze other types of samples, they may also be costly. In emergencies, time is often not available for laboratory analysis of samples either on site or off site.

To obtain air monitoring data rapidly at the site, DRI utilizing flame ionization detectors (FIDs), photoionization detectors (PIDs), and other detection methodology can be used. Some of these may be used as survey instruments or operated as gas chromatographs. As gas chromatographs, these instruments can provide real-time, qualitative/quantitative data when calibrated with standards of known air contaminants. Combined with selective laboratory analysis of samples, they provide a tool for evaluating airborne organic hazards on a real-time basis and at a lower cost than analyzing samples in a laboratory.

5.2 Air Sampling

For more complete information about air contaminants, measurements obtained with DRIs can be supplemented by collecting and analyzing air samples. To assess air contaminants more thoroughly, air sampling devices equipped with appropriate collection media may be placed at various locations throughout the area and on persons with at-risk occupations. These samples provide air quality information for the period of time they are taken, and can indicate contaminant types and concentrations over the sampling period. As a result, careful selection of sampling types, numbers, and locations, by a qualified health and safety professional is essential to obtain representative information. As data is obtained (from the analysis of samples, DRIs, knowledge about materials involved, site operations, and the potential for airborne toxic hazards), adjustments can be in the types of samples, number of samples collected, frequency of sampling, and analysis required. In addition to air samplers, area monitoring stations may also include DRIs equipped with data logging capabilities and operated as continuous air monitors.

Area air sampling locations may be located in various places as required by project and site needs. Area air sampling stations may include, but are not limited to:

- Upwind - Industrial operations, vehicle traffic, spills and other contributing sources may cause or otherwise result in the generation of air pollutants. Upwind samples establish background levels

- Support Zone (SZ) - Samples may be taken near the command post or other support facilities to ensure that they are, in fact, located in an unaffected area, and that the area remains clean throughout operations at the site.

- Contamination Reduction Zone (CRZ) - Air samples may be collected along the decontamination line to ensure that decontamination workers are properly protected and that onsite workers are not removing their respiratory protective gear in a contaminated area.

- Exclusion Zone (EZ) - The Exclusion Zone presents the greatest risk of release/generation of contaminants and requires the highest concern for air sampling. The location of sampling stations shall be based upon factors such as hot-spots detected by DRIs, types of substances present, and potential for airborne contaminants. The data from these stations, in conjunction with intermittent

walk-around surveys with DRIs, are used to verify the selection of proper levels of worker protection and EZ boundaries as well as to provide a continual record of air contaminants.

- Downwind - One or more sampling stations may be located downwind from the site to indicate if any air contaminants are leaving the site. If there are indications of airborne hazards in populated areas, appropriate response action must be taken and additional samplers should be placed downwind. Downwind locations are further determined based on meteorological considerations concerning generation, air plume migration, and intensity.

5.3 Media for Collecting Air Samples

Hazardous material incidents and abandoned waste sites can involve thousands of potentially dangerous substances, such as gases, vapors, and particulates that could become airborne. A variety of media are used to collect these substances. Sampling systems typically include a calibrated air sampling pump, which draws air into selected collection media. It is essential that appropriate, approved air sampling methodologies (such as those published by NIOSH, OSHA, and EPA) be followed for the collection of each specific analyte. Some of the most common types of samples and the collection media used for them are described in the following information:

One of the most common types of collection media is activated carbon which is an excellent adsorbent for most organic vapors. However, other solid adsorbents (such as Tenax, silica gel, and Florisil) are routinely used to sample specific organic compounds or classes of compounds that do not adsorb or desorb well onto activated carbon. To avoid stocking a large number of sorbents for collecting samples for various chemicals, a smaller number is generally chosen for collecting the widest range of materials or for chemicals known to be present. The vapors are collected using an industrial hygiene personal sampling pump with either one sampling port or a manifold capable of simultaneously collecting samples on several sorbent tubes (provided that sampling parameters such as flow rates and sample volumes are satisfied). For example, in a manifold with four sorbent tubes (or on individual pumps with varying flow rates), the tubes might contain:

- Activated carbon to collect vapors of materials with a boiling point above zero degrees Centigrade. Common materials collected on activated carbon include organic vapors such as solvents, BTEX, and ketones.

- A porous polymer, such as Tenax or Chromosorb, to collect substances (such as high-molecular-weight hydrocarbons, organophosphorus compounds, and the vapors of certain pesticides) that adsorb poorly onto activated carbon. Some of these porous polymers also absorb organic materials at low ambient temperatures more efficiently than carbon.

- A polar sorbent, such as silica gel, to collect organic vapors (aromatic amines, for example) that exhibit a relatively high dipole moment.

- Another specialty absorbent selected for the specific site. For example, a Florisil tube could be used if polychlorinated biphenyls are expected.

- Liquid impingers - aldehydes, ketones, phosgene, phenols.

- Glass fiber filters, membrane filters, Teflon filters - Inorganics and other semivolatile compounds.

- Airborne particulates can be either solid or liquid. Examples of common particulate analytes include some metals, fibers such as asbestos, and condensed particulates such as welding fumes. Dusts, fumes, smoke, and fibers are dispersed solids; mists and fogs are dispersed liquids. For air sampling, most particulates are collected using glass fiber, mixed cellulose ester, or polyvinyl chloride filters,

depending on the filter's ability to collect the subject material and its suitability for laboratory analysis. A cyclone is used to collect particles of respirable size. Atomic Absorption Spectrophotometry, Emission Spectroscopy, Phase Contrast Microscopy, and other techniques are used to analyze various types of particulates. Direct-reading monitors are also used to quantify particulate concentrations, and are usually based on the light-scattering properties of the particulate matter.

5.3.1 Other Methods

Colorimetric detector tubes can also be used with a sampling pump when monitoring for some specific compounds. A detector tube is a vial that contains a chemical preparation that reacts with the measured substance by changing color. Most detector tubes are scale tubes that permit a comparison of the length of the stain to an indicated concentration. Passive organic vapor monitors can be substituted for the active monitoring if they are available for the types of materials suspected to be present at a given site.

5.3.2 NIOSH Methods

The National Institute for Occupational Safety and Health's (NIOSH) Manual of Analytical Methods, 4th ed., contains acceptable methods for collecting and analyzing air samples for a variety of chemical substances. Consult these volumes for specific procedures.

5.4 Collection and Analysis

Collection and analysis of air samples is a multi-faceted task, and is part of the overall air surveillance program. The program is structured to cover the following air pathway analyses:

5.4.1 Selecting Monitoring Constituents

Applications within this program are accomplished using two considerations:

- Air surveillance for specific constituents is based on quantity of the pollutant and the likelihood for vapor release or generation.

- Controlling toxicity - These substances, even when represented in limited quantities, present the greatest threat to the public or worker safety, and influence environmental impact.

5.4.2 Specifying Meteorological Considerations

The following factors will influence sample collection:

- Wind direction and speed
- Sigma theta (atmospheric stability)
- Temperature
- Barometric pressure
- Humidity

These factors will provide information essential to properly arrive at accurate air sampling concentration results. This information is also used to identify how airborne chemical contaminants will react for modeling and for monitoring purposes. The results will provide indicators of plume movement, intensity, and dilution.

5.4.3 Design of Monitoring Network

The air surveillance network is structured to consider:

- Source characteristics (physical state; vapor release and/or generation; emission rates; and disturbance of the source impacting these aspects)
- Receptor sites (receptor sites are monitored and tracked based on priority)
- Meteorological consideration
- Air modeling input
- Data quality objectives

5.4.4 Air Monitoring Documentation/Data Reduction

5.4.4.1 Air Monitoring Documentation

Elements of the air surveillance program are used to provide documentation valuable to safely performing/containing site activities.

Air monitoring results from DRIs must be recorded, such as on instrument results reporting forms, or in the field logbook. This information, where applicable, will be correlated to air sampling information if/when collected.

Air sampling results for personnel and area measurement efforts must be validated, prior to notifying affected individuals. Personal air sampling results notification is accomplished through verbal or written communications.

Results of air monitoring/sampling activities can be identified on site maps. This information is used to structure operational zones and identify levels of protection.

5.4.4.2 Data Reduction

Data reduction combines and correlates the DRI results, air sampling results, and meteorological information to determine area and source airborne contaminant levels and movement.

All air sampling surveillance efforts must incorporate appropriate and approved NIOSH, OSHA, or EPA analytical methods. These procedures identify specific sample collection media, sampling methodologies, and analytical procedures. Sample analysis for health and safety considerations must be further supported by using American Industrial Hygiene Association accredited laboratories.

5.5 Personnel Monitoring

In addition to area atmospheric sampling, personnel monitoring -- both active and passive -- can be used to sample for air contaminants. Representative workers must be identified, and equipped with appropriate personal sampling systems to determine contaminants at specific locations or for specific work being performed. When sampling devices are placed on workers (generally within 1 foot of the mouth and nose) the results are used to indicate worker exposures.

5.6 Calibration

As a rule, the entire air sampling system shall be calibrated. Proper pre-and post-calibration activities are essential for correct operation and for accurate data. In some instances, additional calibration during the sampling period may be required. The overall frequency of calibration will depend upon the particular sampling event, including the general handling and use of a given sampling system. Pump mechanisms shall be calibrated after repair, when newly purchased, and following suspected abuse. All DRIs will be calibrated according to manufacturers instructions. All calibration activities for both air monitoring and sampling equipment must be properly documented, such as through the use of a calibration form. This form will be kept on site throughout the life of the project. The calibration log will be submitted as documentation that instrument calibration was performed on a regular basis.

5.7 Meteorological Considerations

Meteorological information is an integral part of an air surveillance program. Data concerning wind speed and direction, temperature, barometric pressure, and humidity (singularly or in combination) are needed for:

- Selecting air sampling locations
- Calculating accurate air sampling results
- Calculating air dispersion
- Calibrating instruments
- Determining population at risk or environmental exposure from airborne contaminants

Knowledge of wind speed and direction is necessary to effectively place air samplers. In source-oriented ambient air sampling, samplers need to be located downwind (at different distances) of the source and others need to be placed to collect background samples. Shifts in wind direction must be known. Consequently, the samplers must be relocated or corrections made for these shifts. In addition, atmospheric simulation models for predicting contaminant dispersion and concentration need windspeed and direction as inputs for predictive calculations. Information may be needed concerning the frequency and intensity that winds blow from certain directions (windrose data). Consequently, the wind direction must be continually monitored when use of this type of data is contemplated.

Air sampling systems need to be calibrated before use. This must include corrections in the calibration curves for actual temperatures and pressures during the sampling event. After sampling, collected air volumes are also mathematically corrected for temperature and pressure conditions.

Air sampling is sometimes designed to assess population exposure (and frequently potential worker exposure). Air samplers are generally located in population centers, irrespective of wind direction. Even in these instances, however, meteorological data is needed for air dispersion modeling. Models are then used to predict or verify population-oriented sampling results.

Proper data is collected by having meteorological stations on site or by obtaining the information from one or more of several government or private organizations, which routinely collect this data. The choice of how information is obtained depends on the availability of reliable data at the location desired, resources needed to obtain meteorological equipment, accuracy of information needed, and use of information.

The collection, handling, and analysis of air samples is an intricate, involved process. Appropriate methodologies, media, and equipment must be used to collect accurate data. Furthermore, selection of appropriate numbers, types, and locations of samples is essential if the data collected are to be used for personnel exposure criteria. For these reasons, air sampling activities must be coordinated and conducted by properly qualified and experienced industrial hygiene professionals. Air monitoring activities also need to be established and monitored carefully. However, as the proper use of these instruments is

not as complicated as air sampling, it is commonly acceptable to cross-train capable environmental professionals to use DRIs, with adequate technical support provided by health and safety professionals.

6.0 REFERENCES

Standard Operating Safety Guides, EPA, November 1984.
NIOSH Manual of Analytical Methods, 4th Edition.

7.0 ATTACHMENTS

None.

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1.0 PURPOSE

The purpose of this procedure is to provide general reference information on soil gas sampling. Soil gas investigations measure the general extent of volatile organic compound (VOC) contamination, such as chlorinated solvents and petroleum products, given off by subsurface soil and groundwater. The methods and equipment described are for collection of soil gas from the unsaturated zone of the subsurface soil.

2.0 SCOPE

This procedure provides information on proper sampling equipment and techniques for soil gas 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

Sampling Grid - Typically consists of a series of equal-distant sampling points set along parallel survey lines. The sample point spacing and number of parallel grid lines will depend upon the site specific conditions and project objectives.

Transect Line - A sampling network used to find the source area of contamination. Sampling points are placed along a transect line between the area of impact and a suspected source area. This can significantly decrease the number of points compared to a typical sampling grid.

Biased Location - Sample points are either placed near a suspected source area or in an anticipated clean area to refine the location of "hot spots" for further delineation or remediation.

Random Location - Random networks use a grid with numbers designating the nodes or areas within the grid. The sample points are then selected by a random number generator to designate which nodes or areas are targeted for sampling. This type of network is used in areas where little information is known or no contamination is suspected.

Combined Locations - This type of network is the most common used, and includes a combination of any of the four previous sampling networks mentioned.

Head Space Analysis - The screening or analysis of volatile organic vapors that have accumulated in the air space within a soil or groundwater sample container.

Flame Ionization Detector (FID) - A portable instrument for the measurement of many combustible organic compounds and a few inorganic compounds in air at parts-per million (ppm) levels. The basis for the detection is the ionization of gaseous species utilizing a flame as the energizing source.

Photo Ionization Detector (PID) - A portable instrument for the measurement of many combustible organic compounds and a few inorganic compounds in air at ppm levels. A PID will not detect methane gas. The basis for the detection is the ionization of gaseous species utilizing ultraviolet radiation as the energizing source.

Direct Push Technology (DPT) - DPT refers to sampling tools and sensors that are driven directly into the ground without the use of conventional drilling equipment. DPT typically utilizes hydraulic pressure and/or percussion hammers to advance the sampling tools. A primary advantage of DPT over conventional drilling techniques is that DPT results in the generation of little or no investigation derived waste (soil cuttings, purge water, etc.).

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for selecting and/or reviewing the appropriate soil gas sampling procedure required to support the project objectives.

Field Operations Leader (FOL)-The FOL is primarily responsible for performing the soil gas sampling technique in accordance with the project-specific plan.

5.0 PROCEDURES

5.1 General

Soil gas methods are performed to delineate VOC contamination in subsurface soil and groundwater. Soil gas surveys are not intended to be a substitute for conventional subsurface methodologies (e.g., monitoring well installation and groundwater sampling) but rather are to be used as a screening technique to focus subsequent investigations to areas of potential concern. The advantages of using soil gas methodologies to define VOC contamination include:

1. Minimizing the number of subsequent test borings and monitoring wells required to characterize the nature and extent of the contamination.
2. Optimizing the placement of subsequent monitoring wells and test borings.
3. Allowing the collection of large amounts of data in a short time period relative to conventional methods.
4. Generating little or no investigative derived waste.

To assess the effectiveness of a soil gas survey, consider the following items:

1. The near surface geology.
2. The type of contamination present.
3. The anticipated concentration of contamination present.
4. The anticipated depth to the zone of contamination.

Common soil gas methods are most effective in geological settings that contain coarse textured soils (e.g., silty sands, sands and gravels) and are least effective in areas of fine textured soils (e.g., silty clays and clays). Soil gas methods may be effective at mapping areas of dense non-aqueous phase liquid VOC contamination that are present beneath the water table. Areas with deep water tables or low concentrations of VOC contamination may require the use of specialized soil gas techniques. These techniques could require the use of more expensive passive sorbent samplers left in place for a relatively long time period.

5.2 Soil Gas Sampling Grids

The first stage of a soil gas survey is to establish a sampling grid or network. The grid should be designed to obtain all necessary information with a minimal expenditure of time and resources. The development of the grid should be based on background information regarding chemical properties of the contaminant, properties of the vadose zone, and hydrogeologic conditions of the area. All of this information should be used to design a sampling protocol specific to the conditions at the site. Some of the designs used include grids, transect lines, and biased, random or combined methodologies.

The size of the grid spacing is determined on a site specific basis. Locations should be marked with pin flags or wooden stakes and numbered sequentially at each site. The grid should be referenced to permanent site features and the stakes left in place to assist with future subsurface investigations. The location of any nearby surface or subsurface features which may affect the results of the survey (sewer

line, fuel farm, etc.) shall be noted in the field notebook. Detailed notes and a sketch of each site, including station locations and station numbers will be documented in the field logbook. After the grid has been laid-out a dig permit must be applied for and approved prior to the start of sampling.

5.3 Sampling Methodologies

There are several methods for the collection of soil gas samples. The most common types will be discussed in the following sections. Variations of the following methods may be conducted if approved by the Project Manager.

5.3.1 Head Space Screening

Head space screening is a method of obtaining rapid information concerning the presence of VOC contamination in the subsurface. Head space screening is usually applicable to soil samples but can also be modified to include groundwater samples. Although head space screening is not a direct measurement of insitu soil vapors, the procedure is included in this SOP because soil vapors are the actual media being screened or analyzed during headspace screening.

Upon sample retrieval from the subsurface, a small quantity of undisturbed soil (approximately 6 oz.) is removed from the sampler (e.g., hand auger, split-spoon sampler, Shelby tube, etc.) and immediately placed in a sealing (Ziploc®-type) plastic bag. Once sealed in the bag, the sample is gently massaged to break apart any large soil clumps. The bag is then warmed for 15 minutes in order to volatilize the potential contaminants from the soil sample into the head-space of the bag. For consistent readings at a particular site, it is important to warm each sample for the same time period and to approximately the same temperature. For this reason, placing the sample in the passenger compartment of a warm vehicle will provide a consistent ambient temperature for the procedure. Other methods of gently warming the sample can be used as long as the resulting temperature is consistent and the procedure is documented in the field log book. After 15 minutes, the tip of the PID or FID is carefully pushed directly through the plastic bag and a direct reading is obtained of the maximum detection. The PID or FID should be capable of storing the maximum detection value for a given reading. All head-space readings (maximum detection per sample) will be noted on the appropriate soil boring log and/or sample log form.

5.3.2 Pipe Probes

Pipe probes involve the use of a hollow steel tube to collect the soil gas sample. The probes can be passively placed into a predrilled hole or driven to the required depth. The predrilled hole can be made using a slide hammer, bucket auger, electric hammer, or DPT drill rig. The following three soil gas procedures using pipe probes are commonly used for preliminary screening in the field.
The first method described is the simplest and will provide immediate results that may help in the location of subsequent test pits, soil borings, etc. The steps are as described below:

- Drive a 3/4-inch steel pipe into the ground using a slide hammer, electric hammer or equivalent to the desired depth. Generally this will not exceed five feet due to the difficulty in retrieving the pipe.

- Remove the steel pipe from the ground by hand or jack.

- Place a hollow 3/4-inch diameter by 1 foot long steel pipe into the previously created hole and seal off the outside of the pipe with bentonite clay so that no soil gas can escape. Allow 5 minutes for vapors in the hole to reach equilibrium conditions.

- Attach the tip of the PID/FID to the hollow pipe using silicon tubing and collect instrument readings for a minimum of 1 minute, or until the readings peak and begin to decline. Record the highest value in the field notebook along with the time, date, and sample location.

- Decontaminate the steel pipes before moving to the next location to minimize the potential for cross-borehole contamination.

  Note: Any ancillary observations made such as soil type, soil color, depth to water table, etc., should be recorded in the field logbook.

The next method is a variation of the first, but provides a more depth specific sample and uses a Tedlar® bag for the collection of the soil gas.

- Drive an expandable steel drive point (3/4-inches diameter) attached to a 5 foot connecting rod into the ground using a slide or electric hammer or DPT drill rig.
- Retract the rod a sufficient distance to leave a space for the soil gas to enter the drive point (approximately 6 inches). Allow 5 minutes for vapors in the hole to reach equilibrium conditions.
- After the drive point and connecting rod have been retracted, assemble the sampling apparatus by attaching 1/4-inch I.D. polyethylene tubing to the top of the connecting rod.
- Place the tubing to the inlet side of a peristaltic pump and connect the discharge side of the pump to a 1-liter Tedlar® bag.
- Fill the Tedlar® bag twice to adequately purge the sample equipment and ambient air that exists in the bag.
- Collect the soil gas sample in a separate Tedlar® bag as above and then connect it directly to the inlet of a PID/FID.
- Obtain the maximum reading from the PID/FID in ppm and record the data in the field notebook or sample log form.
- Decontaminate the equipment before moving to the next location.

The third procedure is similar to the above, except that the soil gas collected in the Tedlar® bag is analyzed in the field using either a portable or onsite lab gas chromatograph (GC). This procedure can identify specific contaminant(s) of concern. These instruments, though more expensive, can be very sensitive and selective to the contaminant(s) of concern.

5.3.3 Passive Sorbent Samplers

The most common type of sorbent sampler used is known as a Petrex® tube, which consists of activated charcoal chemically fused to the tip of a Curie-point ferromagnetic wire and inserted into a glass tube. The collector is then buried at a depth of 2 to 4 feet in an inverted position with the glass tube acting as a flux chamber for an optimal period of time as determined by the manufacturers recommendations. Sample analysis is by thermal desorption onto a mass spectrometer (MS) or GC.

This method is recommended when the contaminants are unknown and concentrations are expected to be low. Specialized sorbent samplers may require the use of a soil gas subcontractor.

5.3.4 Well Points

Well points can be installed to obtain data on subsurface gas concentrations at depths or areas inaccessible by other monitoring techniques. Single or multiple probes may be installed in a single

borehole. Well points are recommended for projects if more than one soil gas sampling event is to occur to monitor contaminant migration versus time. The construction of the well points may vary and may require the use of a conventional drill rig, DPT drill rig, power auger, or hand auger. The need for this type of soil gas survey shall be determined by the Project Manager and site specific conditions. The installation of a soil gas well point is described below:

- Drill the borehole to the desired depth.
- Set the screened well point at the desired depth and backfill with a clean silica sand to approximately 1 foot above the screened length.
- Place soil cuttings or bentonite pellets on top of the sand pack.
- Place 1 to 2 feet of a cement/bentonite grout on top of the bentonite plug.
- If necessary, install a steel protective casing over the well point to prevent damage.
- Place sample outlets inside the protective casing for sampling.

6.0 REFERENCES

New Jersey Department of Environmental Protection and Energy, Field Sampling Procedures Manual, May, 1992.

7.0 RECORDS

A record of all field procedures, tests, and observations must be recorded in the field logbook. Entries should include all pertinent data regarding the soil gas survey. The use of sketches, photographs, and field landmarks will help to supplement the investigation and evaluation.

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1.0 PURPOSE

The purpose of this procedure is to provide general reference information for use in planning for and implementing sampling programs involving one or a combination of the following specialized media: sampling containers of unknown contents, tank sampling, lagoon sampling, waste pile sampling, or dioxin sampling.

2.0 SCOPE

2.1 Container Sampling

This procedure is applicable to opening and sampling of containers (e.g., 55-gallon drums, cylinders, packaged laboratory waste, etc.) when the characteristics and hazards associated with the contents have not been determined.

2.2 Tank Sampling

This procedure covers tank inspection and sampling techniques for use in assessing the condition and contents of tanks. This guideline does not address actual entry for internal inspection or sampling which requires strict Health and Safety protocols during this potentially hazardous activity.

2.3 Lagoon Sampling

This procedure describes requirements and methods for collecting samples of liquid, sludges, sediments and bottom soils from lagoons containing hazardous materials. Factors which affect access to appropriate sampling locations and methods of obtaining samples at these locations are discussed herein. In this guideline, however, strong emphasis is given to the stringent health and safety requirements related to lagoon sampling. Since many lagoons contain highly concentrated wastes and present direct physical hazards via inhalation or contact, extreme care must be taken with all lagoon sampling programs.

2.4 Waste Pile Sampling

This procedure describes methods for collecting solid waste samples from homogeneous and heterogeneous waste piles.

2.5 Dioxin Sampling

The areas addressed in this procedure include sample collection and handling, documentation, packaging and shipping, and decontamination for aqueous, soil/sediment and wipe samples to be analyzed for TCDD. As personnel protection and sampling are dependent upon site conditions (the extent of contamination, the medium to be sampled, etc.) they are better discussed in the Health and Safety Plan and will not be covered here. It should be noted that the techniques presented in this guideline are subject to revision and modification. The user will follow the most up-to-date revisions or site-specific modifications of this guideline.

3.0 GLOSSARY

Air Reactive Wastes - Some chemicals, such as white phosphorus or barium oxide, react with oxygen in the air, while others, such as sodium, cesium or various metal hydrides, react with the moisture or water vapor in the air. Many of these compounds are explosive when they come in contact with air or water.

Caisson - A large diameter circular tube or pipe from which lagoon or impoundment liquid can be removed to allow collection of a "dry" sample of bottom solids.

Container - Any drum, bottle, can, bag, etc., with a capacity of 120 gallons (450 liters) or less.

Core Sample - A sediment sample from taken in such a way as to preserve the horizontal and vertical integrity of the sample for subsequent physical and/or chemical characterization of specific vertical intervals.

Glass Thief - A glass tube, usually 4 feet long and 3/4 inches in diameter, used for taking samples from drums. The tube is usually broken and disposed of in the drum following sampling.

Lagoon - Any onsite impoundment, depression, excavation, or diked area containing liquids where waste materials have been deposited.

TCDD - Abbreviation for the compound 2,3,7,8-tetrachloro-dibenzo-p-diozin (also called dioxin). TCDD will be used throughout this guideline.

4.0 RESPONSIBILITIES

Project Manager (PM) - responsible to assure that the need for specialized media sampling is justified and that the sampling techniques chosen are adequate to obtain a representative sample and prevent spills and/or atmospheric releases.

Field Operations Leader (FOL) - responsible for implementing the sampling plan and for overseeing the sampling effort in the field.

Health and Safety Officer (HSO) - responsible for developing the safety-related procedures for specialized media sampling and for assuring their correct implementation in the field.

5.0 PROCEDURES

5.1 Container Sampling

5.1.1 General Principles

In general, a container opening and sampling program will have one of the following objectives:

- To determine the presence of waste and/or hazardous materials on the site. Such a program involves a very limited number of containers, perhaps as few as one.
- To characterize the range of materials present at a site. Containers would be chosen for sampling by means of systematic selection criteria.
- To characterize container contents for such purposes as segregation or bulking for storage and/or disposal. This program may involve opening and sampling every container on a site, and performing onsite compatibility testing.

The guidance presented is based on field experience in working with containers on hazardous substance sites. It will be evident that in many cases pre-established procedures cannot be given, and professional judgment is required because of the number of variables involved. For example, one can never be certain of any assessment of the potential contents of a container, or the accuracy of labels. Only educated

guesses can be made by a thorough review of all available background data, such as potential sources of the wastes.

Three basic risks are involved in moving and opening closed containers: (1) exposure of personnel to toxic materials, (2) fire, and (3) explosion. The first risk can be reasonably eliminated through the use of proper skin and respiratory protection equipment. The use of Level A protection acceptably reduces the risk of a worker being injured by toxic vapors, mists, or splashes. In the same way, standard fire prevention procedures can be used to reduce the fire hazard through the use of detector instruments and proper equipment. These include the use of non-sparking tools and intrinsically safe radios, pumps, and other equipment, as well as the staging of fire fighting equipment and the elimination of other possible ignition sources.

The explosive risk, however, is not as easily handled, and thus is the primary consideration in any container-opening operation. Even if no solid evidence of the presence of explosives is found during the preliminary data collection, one can never be certain that explosive material have not been disposed of at the site. In order to provide the same reasonable level of protection against this risk as against toxic exposure and fire, a very cautious approach, such as the one recommended in this procedure, should be used.

5.1.2 Background Review

This section details the elements of a site background review necessary to prepare a Sampling Plan for drum opening. The decision of whether or not to conduct the operations depends on the assessment of the site history. Therefore, it is important that the following tasks are completed thoroughly.

5.1.2.1 Preliminary Assessment and Site Inspection

Any existing data should be consulted in planning for a container-opening operation. Of special importance are items that can be used to characterize the types of hazardous materials present at the site (e.g., generator records, manifests, inventories, personal interviews, monitoring data). The review of all such data should search for the possible presence of shock-sensitive explosives and/or reactive chemicals.

5.1.2.2 Explosive Product Survey

If the site is a waste disposal or storage operations, a survey of commercial producers or users of explosives within the area served by the facility must be conducted. The determination of the area covered in this survey is a judgment that should be based on locations of known waste generators that used the facility and geographic locations of the site. Agencies that could assist in identifying explosive producers or users are local and state police units, state transportation departments, the U.S. Department of Transportation (DOT), and EPA or state hazardous waste permit offices. Standard Industrial Classification (SIC) codes can be used to locate producers of explosives from lists of manufacturers available from state commerce agencies, local chamber of commerce, planning agencies, etc.

5.1.2.3 Site Visit

A site visit is required prior to planning a drum opening operation. Information on the following should be gathered during the site visit:

- Site boundaries - fences, roads, natural boundaries, etc.
- Access points and travel routes on the site.

- Topographic features
- Adjacent land uses - residential, agricultural, public use areas, commercial establishments, schools, natural areas, etc.
- Power lines, railroad, and public roads close to the site.
- Container storage areas - provide observational details; describe if drums are jumbled, stacked, piled, arranged in rows, etc. General condition of drums indicates if containers can be grouped according to contents, or any other classification method. Note damaged drums (e.g., bulging, dented, punctured, rusty, etc.) and determine if overpack drums are necessary.
- Buildings and other site structures, as well as any other disposal areas such as lagoons, surface piles, etc.
- Location of water sources.
- Location of potential staging areas.

During the site visit, local officials should be contacted to arrange for fire protection and police support during the operation. Interviews should also be conducted with site workers, local officials, and any other people familiar with the site's history.

The central purpose of the background review is to evaluate the risk presented to personnel engaged in drum-opening operations. Assessment of drum contents is most important because it identifies specific risks. However, other site features also affect the hazard potential. Leaking and corroded drums, crowded and poorly organized conditions, and drums of unknown and apparently diverse origins are conditions that require careful planning.

There are no accurate quantitative methods available to evaluate the total risk. Assessment of the danger is subjective and should be done by personnel experienced in field operations at hazardous sites. Good professional judgment is required, and project management must feel that adequate information is available to support a decision to conduct the drum-opening operations. Any positive indication of shock-sensitive materials that might react or explode requires special consideration. Unlabelled drums and containers shall be considered to contain hazardous substances and handled accordingly until the contents are positively identified and the drum is labeled.

5.1.3 Container Selection Considerations

The containers selected for opening and sampling will depend on the purpose of the operations and on considerations of safety--that is, a container that may detonate is to be avoided. Even though drums are found at disposal sites where the contents are unknown, it is worthwhile to consider drum markings and types as well as drum groupings.

When considering sampling, the first choice of drums would be those marked with known hazardous materials (trade name, chemical name, empirical formula), or hazard labeling. Next would be those isolated by themselves, of uncommon shape or banding, or material contained in an exotic metal container (e.g., aluminum, nickel, monel, stainless steel). Then consideration should be given to the unmarked drum piles or stacks.

When sampling for site characterization purposes, a concerted effort should be made to distinguish drum lots and to get an accurate drum count among the lots.

On most sites, there is some organization or pattern to the way the material was placed on the site. The pattern is occasionally as detailed as finding the flammable solvents in one area, acids in another, cyanide in another, recoverable metals in a fourth, and so on. Some disposal facilities stencil control numbers on drums to indicate specific lots. Often, the only indication that a group of drums is related will be their color, size, or type.

Approach isolated groups of containers with care, but do try to determine why they were segregated. Occasionally a group of drums is found marked 'DFW' (roughly translates as "Don't Fool With") because of their extreme hazard or because the people handling them have had an accident or other unusual experience with them.

An attempt should be made to avoid drums that are structurally damaged or if their movement or sampling would endanger a team member. Samples of drums in stacks or piles should not be taken if at all possible.

Before sampling drums of unknown content, an external radioactivity scan must be conducted with the results recorded in the field notebook. On a site where many different types of containers are present, they should be sampled in the following order, based on what they can be expected to contain and in increasing order of hazard:

- Paper, plastic, cloth, and burlap bags.
- Glass carboys and jugs (except chemical reagent or laboratory-packed bottles).
- Fiberboard drums.
- Plastic and polyethylene carboys and containers.
- Plastic-lined steel drums.
- Steel drums.
- Exotic metal drums.
- Odd containers (distended, isolated, marked "DFW," etc.).

Attachment A contains information on the types, sizes, DOT designation, openings, and recommended opening techniques for the various kinds of containers. Any drum without a DOT designation should be avoided, as it may have military origins. The DOT designation, which is usually found on the bottom of a drum, can be useful in determining the material of the drum.

5.1.4 Container Handling and Staging

NOTE: A Drum/Container Management Plan will be developed for each site in which drums/containers will be handled, sampled, or staged. The Plan will be prepared consistent with the requirements of Paragraph (j) of 29 CFR 1910.120 (OSHA's Hazardous Waste and Emergency Response Standard, or HAZWOPER). This Plan will discuss site-specific issues related to drum/container management, and will be included as part of the Health and Safety Plan. The following text discusses, in a general fashion, the minimum practices and procedures to be followed. Where provided, the guidance of the site-specific Drum/Container Management Plan shall be followed to supplement this SOP. In the case of overlapping requirements, the more stringent requirement shall take precedence.

When practical, drums and containers shall be inspected and their integrity shall be assured prior to being moved. Drums or containers that cannot be inspected before being moved because of storage conditions shall be moved to an accessible location and inspected prior to further handling.

Personnel involved in handling and transporting containerized waste shall work in teams containing no fewer than two people. Visual contact shall be maintained between members of the working team at all

times. All team members shall be able to communicate between themselves and with the Site Health and Safety Officer by a safe two-way radio at all times on the work site. In addition, employees shall be warned of the potential hazards associated with the contents of the drums or containers.

Prior to physically handling a drum or other container, the following preliminary classifications checklist must be reviewed and each response noted in a field notebook:

- Is the drum radioactive?
- Does the drum exhibit leakage or deterioration, i.e., is it unsound?
- Does the drum exhibit apparent internal pressure?
- Is the drum empty?
- Does the drum contain markings which would indicate that the contents are potentially explosive?

The results of the preliminary classification checklist dictate which specific procedures shall be followed in handling, opening, and sampling the drum.

The handling, movement, and transport of drums and other containers should be by use of mechanical equipment only; equipment may consist of a grappler equipped backhoe, front-end loader, or drum dollie. Drum transportation may be with front-end loaders or fork lifts with modified carrying platforms. When necessary, portions of equipment that contact drums or canisters should be constructed of non-ferrous metals or contact portions should be coated or lined to preclude spark generation. Handling and transport equipment must be equipped with full frontal and side splash and explosion shields. Class ABC fire extinguishers shall be fitted to the body of each piece of equipment.

When possible, drums or other containers to be sampled should be opened and sampled in place to minimize handling. However, when drums are stacked or are close together, they may have to be moved to prevent sympathetic detonation of, or chemical reaction with, other drums around the one being opened. The main criterion is distance to other drums--a reasonable distance should be maintained to keep the drum to be opened segregated from others.

Drums or containers exhibiting the following characteristics require special treatment in handling and sampling:

- Leaking or deteriorated drums
- Bulging drums
- Drums containing explosive or shock-sensitive waste
- Drums containing radioactive waste
- Lab packs
- Gas cylinders

When drums are moved, they should be taken to a staging and sampling area that is diked or bermed to control spillage. Again, this area should be far enough away from other drums on the site to prevent a chain reaction. Only one container at a time should be placed in the staging area and opened. One crew can be moving and setting up the remote-opening equipment on the next container while another crew is sampling, labeling, and resealing the first container.

Containers that are inside warehouses, basements, or other buildings must be moved outside before they can be opened. If this is not possible, the Project Manager must be contacted for special assistance in developing the opening plan. Adequate ventilation is critical for container-opening operations.

5.1.5 Remote Opening

Because of the possibility of encountering a drum containing a shock-sensitive material, any drum to be moved and/or sampled should be remotely shaken. One way of doing this is to carefully tie a rope around the drum and shake it from behind a barrier at a safe distance.

The required method of opening drums is by remote means (except as noted in Attachment A). Three types of remote-opening equipment are available: the bung spinner, the remote-controlled drill, and the drum piercer.

The bung spinner consists of:

- Air impact wrench with non-sparking adapter.
- Drum-mounting bracket.
- Two-stage regulator.
- Compressed-air cylinder with 100 feet of air hose and control valve.

The impact wrench is mounted over the bung on top of the drum by means of the steel-mounting bracket. The air tank, regulator, and control valve can be placed up to 100 feet away from the drum in a well-protected location.

A remote-controlled, air-operated, self-feeding, and self-retracting drill can also be used. This tool consists of:

- Self-feeding and self-retracting drill.
- Drum-mounting bracket.
- 100 feet of air and control hoses.
- Two-stage high-pressure regulator.
- Compressed air cylinder.
- Filter/regulator/lubricator unit.

As with the bung spinner, the air tank, regulator, and control valves can be placed up to 100 feet away from the drum in a well-protected location. There are two controls on this piece of equipment--a start valve and an emergency retract valve.

The drum piercer consists of:

- Hydraulic ram with hand pump.
- 100 feet of hydraulic hose.
- Drum-mounting bracket (top or side).
- Piercing nail.

This unit uses the same bracket as the drum drill. The hydraulic ram slowly forces the steel piercer through the drum surface as the hand pump is operated. When the 1/2-inch-diameter hole is complete, opening a relief valve on the pump allows the spring to retract the piercer from the hole.

When any of these pieces of equipment are used, the control lines are to be extended to their maximum, and drum-opening personnel are to operate the controls from behind sandbags, a concrete or brick structure, or other solid barriers. Remember, the opening surfaces of the drill or bung spinner should be decontaminated after each use.

The following guidelines are offered for other types of containers:

- Ring-closed, open-top drums - Loosen the ring and then remove it remotely by means of a rope. If it is necessary to cut the ring, do so near the bolt or clamp/lever so that there will be a place to attach the rope.

- Glass carboys or jugs with lapped/ground-glass stopper or plastic cap - Slowly release any retaining wire and vent any pressure. Remove the stopper or cap by hand only.

- Fiberpacks or corrugated cardboard containers - Release the locking ring and remove the ring and lid by hand.

- Plastic or polyethylene carboys and plastic-lined drums (when necessary) - Use a non-sparking aluminum, brass, or beryllium bung wrench of the proper size. Do not use a bung wrench on any distended drums of this type; remote methods will be applied.

- Plastic Kraft paper, burlap, or cloth bags - Use a trowel or sampling trier. The bags should be resealed or placed in an overpack.

5.1.6 Problem Containers

Special handling techniques are required for containers which may expose personnel to particularly hazardous conditions. These techniques are described in general below, although site-specific conditions may require the development of specialized methods in the Sampling Plan.

5.1.6.1 Leaking or Deteriorated Drums

- The contents of drums that exhibit leakage or apparent deterioration must immediately be transferred to a repack drum. Equipment, including transfer pumps used in the repack operation, must be of explosion-proof construction or otherwise be classified for the material being transferred.

- Leaking drums containing sludges or semi-solids, drums that are structurally sound but which are open and contain liquid or solid waste, and drums which are deteriorated but can be moved without rupture, must be immediately placed in overpack containers.

5.1.6.2 Bulging Drums

- Drums which potentially may be under internal pressure, as evidenced by bulging, must be sampled in place. Extreme care shall be exercised when working with and adjacent to potentially pressurized drums.

- Should movement of a pressurized drum be unavoidable, handle only with a grappler unit constructed for explosive containment. The bulging drum should be moved only as far as necessary to allow seating on firm ground or it should be carefully overpacked.

- Openings into pressurized drums shall be plugged and the bung holes fitted with pressure venting caps set at 5 psi release.

5.1.6.3 Drums Containing Explosive or Shock Sensitive Waste

- If drums containing wastes that have been identified by sampling, or are suspected by visual examination to be explosive in nature are found, the Project Manager and HSO must be notified immediately, before the drums are handled in any way.

- If the Project Manager and HSO approve handling of these drums, they shall be handled with extreme caution. Initial handling shall be by a grappler unit constructed for explosive containment. Drums shall be palletized prior to transport to a high hazard interim storage and disposal area.

- If at any time during site activities, an explosive, pursuant to provisions of Title 18, U.S. Code, Chapter 40 (Importation, Manufacture, Distribution, and Storage of Explosive Materials, 1975 Explosives List) is identified, it should be secured and the appropriate personnel and/or agencies notified.

- Identification of an explosive substance during the course of site activities is usually based on the experience of the onsite personnel. Potentially explosive materials usually may be identified by their physical characteristics--texture, color, density, etc., as well as the way they are packaged or labeled. Most explosives are solids. In some cases they are packaged in water-tight containers to exclude water, while in other cases they are packaged wet to preclude explosion.

- Prior to handling or transporting drums containing explosive wastes, personnel working in the area shall be removed to a safe distance (as determined by the HSO). Continuous contact with the command post shall be maintained until handling or transporting operations are complete. An audible siren signal system, similar to that employed in conventional blasting operations, shall be used to signify the commencement and completion of explosive waste handling or transporting activities.

5.1.6.4 Drums Containing Radioactive Waste

- Drums containing radioactive wastes shall not be handled until radiation levels have been determined by an initial field survey which is recorded in a field notebook. The survey shall include background levels, direct gamma readings and laboratory analysis of drum surface wipe samples.

- Depending on the level of radiation encountered, handling and transport may require special shielding devices to protect personnel. Following handling and transport, equipment used shall be surveyed by the HSO and decontaminated to background levels prior to recommencing work. Surveys shall also be made of the ground surface in the vicinity of original drum storage to identify potential soil contamination by spilled or leaked radioactive waste. Prior to recommencing work in the area, radioactive soil areas shall be isolated to prevent tracking of radioactive contaminants about the site, and workers who entered the area should have their gloves and boots surveyed for radiation.

5.1.6.5 Packaged Laboratory Wastes (Lab Packs)

- If drums known or suspected of containing discarded laboratory chemicals, reagents or other potentially dangerous materials in small volume, or individual containers are found, the Project Manager is to be notified immediately, before the drums or containers are moved or opened.

- If the Project Manager and HSO approve the handling of these containers, they shall be handled with extreme caution. Until otherwise categorized, they shall be considered explosive or shock sensitive wastes. Initial handling shall be by a grappler unit constructed for explosive containment. Drums shall be palletized and overpacked, if required, prior to transport to the Lab pack staging area for sorting, identification, repacking and/or stabilization.

- Prior to handling or transporting Lab Packs from the existing drum area, personnel working in the immediate area shall be removed to a safe distance. Continuous contact with the command post shall be maintained until handling or transporting operations are complete. An audible siren signal system, similar to that employed in conventional blasting operations will be used to signify the commencement and cessation of Lab Pack handling or transporting activities.

5.1.6.6 Air Reactive Wastes

- If the presence of an air reactive substance is verified or suspected, the material should be immediately segregated and transported to a separate high-hazard interim storage and/or disposal area.

- Air reactive wastes may be discovered during opening or sampling operations. Air reactive substances normally require special packaging. They may be stored under water or some other liquid to minimize air contact. They may also be found in sealed ampoules, corrugated drums, stainless steel canisters, or specially lined drums.

5.1.6.7 Gas Cylinders

- Gas cylinders, when encountered, should be stored and disposed of on a special case basis depending on the integrity of the cylinders and type of substance they are expected to contain.

5.1.7 Container Sampling

5.1.7.1 Equipment

- Personal protection equipment.

- One or two 500 mL, wide-mouth amber glass bottle with Teflon cap liner unless the medium reacts with silica.

- Uniquely numbered sample identification labels filled out and affixed to sample containers before sampling commences.

- 4-foot x 3/4-inch ID glass sampling thief/glass tube for aqueous media.

- Plastic or teflon coated trowel for solid media (trowel must be HSO approved).

- Remotely operated opening device.

- One gallon covered cans half-filled with absorbent material (for offsite shipment only).

5.1.7.2 Sampling Procedures

NOTE: Employees not actually involved in opening drums or containers shall be kept a safe distance from the drums or containers being opened.

All drums and mechanical equipment should be grounded prior to the commencement of sampling. If the bung or container lid can be removed, sample contained liquids using a glass thief, which shall then be broken and discarded within the barrel. A barrel that has a badly rusted bung, or that cannot be sampled as above, shall be safely entered with a hydraulic penetrating device operated remotely. All openings shall be plugged except during sampling operation.

The steps to be followed in sampling are as follows:

- Record any markings, special drum conditions, and type of opening in the field notebook, on the sample log sheet, and, later, on the Chain-of-Custody form and locate the general area on a sketch of the site.

- Stencil an identifying number on the drums and record in logbook. Consult the sampling plan for identifications.
- Make certain that the drum/container is set on a firm base, preferably in a fully upright position. Never stand upon or work from drums or containers.
- Open the drum/container as described in Section 5.1.5 and Attachment A.
- Insert glass tubing almost to the bottom of the drum or until a solid layer is encountered. A little over 1 foot of the 4-foot glass sampling thief/glass tube should extend above the drum.
- Allow the waste in the drum to reach its natural level in the glass tube. Then cap the top of the sampling tube with a tapered stopper, ensuring liquid does not come into contact with stopper.
- Carefully remove the capped tube from the drum and insert the uncapped end in the sample container. Do not spill liquid on the outside of the sample container. Release the stopper and allow the glass thief to drain completely into the sample container.
- Deliver 100 to 250 mL of the sample (the sampling plan will specify the amount) to a clean, wide-mouth, 500-mL (1-pint) glass sample jar. If the sample is not free flowing and is taken through a bung opening, repeated sampling may be necessary.
- Place the used sampling tube, along with paper towels or waste rags used to wipe up any spills, into an empty metal barrel for subsequent disposal. If glass tubing has been used, it may be broken and left inside the drum being sampled.
- Cap the sample container tightly and place pre-labeled sample container in a carrier.
- Replace the bung or lids or place plastic over the drum/container.
- Measure the sample for radioactivity and record results in a field notebook. If the meter readings exceed 10 mR/hr, notify the HSO and FOL immediately; they in turn will notify the Project Manager.
- Fill out a Chain-of-Custody Record and carefully pack samples. The finished package will be custody-sealed for shipment to the laboratory. The preferred procedure includes the use of a custody seal across filament tape that is wrapped around the package at least three times. The custody seal (paper, plastic, or metal) is then folded over and stuck to itself so that the only access to the samples is by cutting the filament tape or breaking the seal to unwrap the tape. The seal is signed before the package is shipped.
- Complete the appropriate traffic report. Drum samples are always considered to be high-hazard samples.

5.1.7.3 <u>Sample Preservation and Packing Procedures for Drummed Waste Samples</u>

- No preservatives shall be used.
- Unless the contents of the drum can be positively identified, the sample(s) collected must be shipped as high-hazard samples (see SA-6.2; Sample Handling and Attachment B).
- Arrange for the appropriate transportation mode consistent with the type of hazardous waste involved.

5.1.8 Resealing and Siting Containers

All containers opened for sampling need to be resealed to prevent the escape of vapors and possible reactions from rainwater, air and so on. The resealing methods will depend on the opening methods used and include the following.

- Replacing the bung, screw cap, etc.
- Replacing the lid and retaining ring.
- Placing the drum in an overpack (larger drum) when it cannot be resealed by any other method.
- If a hole is drilled, use of a special rubber or plastic plug. A drum bonnet should be used to ensure that rainwater does not seep around the plug.

It is important to note that these resealing methods are for the purpose of preventing leakage from the container while it is in storage on the site. If the container is to be moved off the site, DOT regulations regarding transportation of drums must be complied with. These will generally require more rigorous sealing procedures.

Once the drum is sampled and resealed, it should be properly identified and left where it cannot react with other containers on the site. For a small number of drums, the storage areas may be the staging and opening area. In any event, the sampled drums should be placed in an area away from other groups of containers on the site. The reason is that slowly progressing chemical reactions can start when a container is opened and the contents exposed to air or the disturbance caused by handling the drum. Such a reaction could take hours or even days to occur.

5.2 Tank Sampling

5.2.1 Access for Sampling

If possible, tanks will be opened and sampled from the top. The physical size, shape, construction material and location of access will determine the best methods of opening and sampling. In some cases, (for example, if the tank is being sampled from a valve at the bottom of the tank) it may be necessary to have spill response personnel on site in case of an accidental release.

When liquids are contained in sealed vessels, gas vapor pressures build up, sludges settle out, and density layering develops. The potential for explosive reactions or the release of noxious gases when containers are opened require considerable safeguards. The vessels should be opened with extreme caution. Preliminary sampling of any headspace gases is typically warranted. As a minimum, a preliminary check with an explosimeter or an organic vapor analyzer will determine levels of personnel protection and may be of aid in selecting a sampling method.

5.2.2 Tank Sampling

At least two persons must always perform tank sampling: one should collect the actual samples and the other should stand back, usually at the head of the access stairway and observe, ready to assist or call for help. If the walls or roof of the tank are corroded, the samplers should not attempt to climb up the outside of a tank, but instead an aerial lift should be used to gain access to the sampling point.

The sampling of tanks is similar to the sampling of drums. The techniques for sampling are the same, except sampling equipment may need to be longer to give a representative sample of deep tanks. Steps to be followed in tanks sampling include the following:

- Record the tank's condition, markings, openings or valve types, and approximate size in gallons in the site logbook and on the sample log sheet. Note the tank location on the site sketch.

- Attach an identification number to the tank using a stencil or weatherproof tag. Number succeeding tanks consecutively. Record the numbers in the site logbook.

- Determine whether the tank contents are stratified by inserting a long plastic or glass tube sampler, withdrawing it, and examining the tube contents. Samples of stratified contents can be taken using a bomb sampler, weighted bottle, or a Kemmerer sampler. For a description of these methods, see Attachment C of this Guideline. If a composite sample is desired, take one sample each for the upper, middle, and lower sections of the tank or for each identified layer, and composite them in one container.

  NOTE: If a reaction is observed when the glass tube is inserted (violent agitation, fumes, light, etc.) the investigators should leave the area immediately. If the glass tube becomes cloudy or smokey after insertion into the tank, the presence of hydrofluoric acid is indicated and a comparable length of rigid plastic tubing should be used.

- If contents of the tank are homogenous, a sample may be taken using glass tubes. See Attachment D for details of this procedure.

- After collecting the sample in the appropriate pre-labeled container(s), tighten the lid, and fill out the appropriate sample log sheets and Chain-of-Custody Record.

5.2.3 Sample Packaging and Shipping

Many samples collected from storage tanks will be shipped as high-hazard samples (see SA-6.2; Sample Handling and Attachment B).

5.3 Lagoon Sampling

5.3.1 Methods of Obtaining Access to Sampling Locations

Because the collected samples must be representative of conditions throughout a lagoon, sampling directly from the shore is usually only appropriate for sampling of very small lagoons or impoundments (less than 10,000 square feet). Samples can also be collected from a platform suspended from shore-based machinery such as a "cherry picker." These platforms may extend to a maximum of 20-25 feet from the shore, depending on the available support on the lagoon bank. Platforms can be outfitted with suitable protective guardrails to provide a relatively safe working environment. However, space is limited and it is often difficult for more than two people to work effectively.

In situations where samples must be collected from the interior sections of a lagoon, a flotation device is often required. Safety is the overriding factor in such an operation and special care must be exercised to insure that a stable work platform is provided.

In many cases, commercially available vessels are not appropriate for lagoon sampling and must be modified to increase stability, facilitate sampling operations over the side or through the hull and allow enough room for personnel, sampling equipment and personal protection equipment. Provisions must also be made to decontaminate or dispose of the vessel after use. Custom designed and built vessels and equipment may also be appropriate, depending on the situation.

A flat-bottomed boat may be used for lagoon sampling but this may still represent a dangerously unstable condition. To overcome instability, a sampling platform can be constructed from two flat-bottomed boats outfitted with a frame, guardrails, stabilizing legs at each corner and an opening in the center.

This opening can be used for caisson placement, hand coring, or liquid sample collection. Other designs and configurations are also possible.

Independent of final design, platforms may be moved over the lagoon by means of ropes, oars or attached outboard motors. The use of ropes is favored for all but the largest lagoons because the ropes will also keep the platform in position. Where movement of the sampling platform is hindered by viscous surface deposits or other impediments, winches or motor vehicles may be required to move the platform.

5.3.2 Methods of Sample Collection

When collecting liquid samples from the shore, the sampling container can be filled directly (as for the collection of surface water samples) or a sampling bucket can be thrown into the lagoon interior to collect samples before transfer to the sampling container. In the latter case, care must be taken to insure that the sample bucket construction materials are inert to the lagoon materials and will not cause potential interferences (contamination) with the analyses of interest. Also, the bucket should not be allowed to drag along the bottom and thus contaminate the liquid sample with sediment.

Samples of sludges and sediments can be collected directly from the shore in a manner similar to the collection of liquid samples. However, substantial mixing with overlying liquid is likely. For compacted or cemented bottom materials, samples may be collected directly from the shore using a trowel or a drive sampler (e.g., split barrel).

In collecting liquid samples from suspended or floating platforms, various surface water and tank sampling devices (such as the Bacon Bomb Sampler or a weighted bottled sampler) may be used. Direct methods used for shore sampling may also be applied. Use of these specialized samplers is essential if samples from discrete depths are required. Except for very shallow lagoons, sampling from the surface is not recommended because of the likelihood that non-representative samples will be obtained.

Sediment coring samples can be obtained from floating or suspended platforms. Sediment coring may be required to examine the extent of contaminant migration below the lagoon floor. Special considerations in this instance include breaching of the lagoon liner, degree of consolidation of lagoon bottom sediments or sludges, depth of the lagoon, and the desired depth of the sample. Generally, sediment core samples can be obtained using an open ended pipe (hand corer) which is driven by hand into the sediments. A sledge hammer is usually adequate for driving the sampler. The sampler should be equipped with a suitable check-valve assembly so that an interior vacuum can be maintained to hold the material in the sampler. The core materials can then be extracted and examined and sampled, or the pipe capped with the sample still within and the entire assembly sent to the lab for analysis. This method will probably not work well with highly liquid samples. In this case, a vacuum pump, weighted bottle sampler, or modified Kemmerer/Van Dorn Sampler may suffice.

In cases where collection of subsurface soil or sediment samples is hindered by the presence of overlying liquid, the liquid will either have to be removed or impounded away from the sampling location prior to sample collection with a hand auger or drive sampler. Application of the former method requires adequate pumping capacity and temporary liquid storage facilities which are often not available or expensive.

If samples are taken from a bottom layer which has served as a seal for the lagoon contents, resealing with a bentonite or equivalent "plug" will be required. This can only be done when dry samples are taken. There is no way to adequately seal the bottom after sample removal by the hand coring method unless the overlying water is removed.

As an alternative to evacuating the lagoon, the liquid may be impounded away from the bottom sampling location by means of implanting a caisson in the lagoon bottom. This caisson may consist of a large diameter pipe which is forced into the lagoon bottom so that liquid can be removed, seepage subsequently controlled and a "dry" lagoon bottom sample obtained via a hand auger or driven sampler. In some cases, a double caisson arrangement may be needed with seepage constantly removed from the outer casing. Caissons are normally driven in place by hand although heavy machinery (backhoes, cherry pickers) may be used if installation is close to shore.

Caisson installation can be a difficult and time-consuming task. It should only be used when alternate methods for collection of bottom sludges or soil samples are not available and when there is a danger of breaching the liner.

5.3.3 Sample Packaging and Shipping

Many samples collected from lagoons will be shipped as high-hazard samples (see SA-6.1; Non-Radiological Sample Handling and Attachment B).

5.4 Waste Pile Sampling

5.4.1 Methods of Sample Collection

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/core 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 pre-labeled sample container. Record all the required information in the field logbook and on the sample log sheet and other required forms.

5.4.2 Sample Packaging and Shipping

Many samples collected from waste piles will be shipped as high-hazard samples (see SA-6.1; Sample Handling and Attachment B).

5.5 Dioxin Sampling

5.5.1 Sample Collection and Handling

5.5.1.1 Aqueous Samples

Samples collected for TCDD analysis may be taken using the appropriate methods for collecting other aqueous samples. It is important to use amber glass and to protect samples from light, as the concentration of TCDD is affected by exposure to light.

5.5.1.2 Soil/Sediment Samples

Soil and sediment samples are collected using conventional sampling techniques and equipment. In areas where a highly compacted material such as asphalt covers the soil to be sampled, the overburden is

to be broken and removed, using picks and shovels, until a 1-foot-square area is cleared. All holes are backfilled after sample collection with clean appropriate material(s).

Before the sample is placed in its container, it is homogenized using a stainless steel spoon and mixing bowl. Prior to filling, each sample jar is placed inside a clean plastic baggie held secure with a rubber band. Stainless steel scoops or spoons are used to transfer the homogenized sample to the jar. After filling and capping, the baggie and rubber band are removed, if visual contamination is present, 1,1,1-trichloroethane, allowed to dry, and then placed in a clean baggie. Samples are stored away from light.

5.5.1.3 Wipe Samples

Wipe samples are often collected to determine the extent of surface contamination. The following procedures will be implemented when collecting wipe samples for TCDD analysis (OSHA, 1984):

- Using clean gloves, pre-load vials with appropriate filters. The type of filter will depend on the type of analysis to be performed. Glass fiber filters are to be used with HPLC or GC analysis; paper filters are used with any other analysis.
- Prepare a rough drawing of each of the locations to be sampled.
- Withdraw filter from vial. Solvents such as hexane, methanol and isopropyl alcohol are often used to wet the filter before wiping. These also depend on the analysis to be performed. In some cases, distilled, deionized water is used.
- Wipe a 4-square-inch (100-square-centimeter) area.
- Fold the filter with the exposed area in, fold again, place in vial and cap the vial. It is especially important that the sampler change gloves between samples.
- Include at least one blank filter treated in the same manner, excluding wiping, for each sampled area.

5.5.2 Sample Documentation

In order to track each sample through shipping and analysis, the following documents will be prepared:

- Sample Labels (One per sample bottle).
- Chain-of-Custody Records and Seals.
- Airbills (One for each shipment to an individual laboratory).

In addition, a field log book will be kept by the sampling team leader. The log book will include daily entries describing all site and sampling activities.

5.5.3 Sample Packaging and Shipping

In many cases, samples collected for TCDD analysis may be shipped as high-hazard samples. See Procedure SA-6.1 and Attachment B for proper high-hazard packaging and shipping procedures.

5.5.4 Decontamination

All sampling equipment is to be decontaminated as follows:

- Alconox and potable water wash
- Potable water rinse
- Alcohol rinse
- 1,1,1-Trichloroethane rinse
- Air dry

A sample of the 1,1,1-trichloroethane must be submitted as a rinsate sample. A volume of 6 ounces is to be collected in an 8-ounce glass jar.

All wastes are to be containerized and properly labeled.

6.0 REFERENCES

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ATTACHMENT A
TECHNIQUES FOR OPENING CONTAINERS

Types	Size	DOT Designation	Type of Opening	Recommended Opening Technique
Steel drum, open-head, unlined and lined	5-110G	DOT 5 - DOT 6 - DOT 17 - DOT 37 - DOT 42 -	Detachable steel lid with a clamp or lever-locking ring, or a ring with forged lugs and secured by a bolt.	Remove bolt. If possible, relieve pressure on clamp or lever-locking ring remotely (i.e., lanyard); remove ring with lanyard. Remove lid by hand.
Steel drum, closed-head, lined	5-110G	DOT 5 - DOT 6 - DOT 17 - DOT 37 - DOT 42 -	Plastic bung opening not larger than 2.3 inches.	Preferred method is to remotely open bung. Manually open otherwise.
Steel drum, closed-head, unlined (steel, monel, stainless, nickel, and aluminum)	5-110G	DOT 5 - DOT 6 - DOT 17 - DOT 37 - DOT 42 -	Steel or other metal bung not over 2.3 inches.	Remote method.
Burlap bag, double Kraft paper bag, cloth bag, plastic bag	Various	DOT 36 - DOT 44 - DOT 45 -	Various.	Open with sharp implement; reseal bag or overpack in fiberpack.
Glass carboys and jugs	6-20G	Usually DOT 1 - branded into the wooden outer sheathing; often sheathing is no longer present.	Lapped or ground glass stopper; occasionally a plastic screw cap will be encountered.	Manually.
Laboratory reagent bottles (amber bottles), small reagent cans	Various	None	Screw top or press lid.	Usually encountered in lab packs. Not to be handled or sampled. Replace drum lid carefully. Contact ZPMO for action.
Polyethylene and other plastic drums or barrels	5-110G	DOT 2 -	Usually bung opening not over 2.7 inches in diameter.	Manually.
Gas cylinders	Various	DOT 3 - DOT 4 - DOT 8 - DOT 39 -	Valve, threaded fitting, quick-connect or puncture-type fittings.	Not to be handled or sampled. Contact ZPMO for action.
Fiberpack or corrugated	5-110G	DOT 12 - DOT 21 - DOT 23 -	Usually a detachable plastic lid with a clamp or lever-locking ring.	Manually remove locking ring and lid.

ATTACHMENT B
PROCEDURES FOR PACKAGING AND SHIPPING HIGH-HAZARD SAMPLES

The U.S. Department of Transportation and other regulatory agencies have specific requirements addressing the packaging, labeling and shipping of hazardous materials (including high-hazard samples). These requirements may or may not apply to Tetra Tech NUS depending upon the chemical and physical properties of samples to be shipped. Given that these requirements can vary considerably, and it is illegal to ship hazardous materials that are not properly packaged and labeled, specific procedures for hazardous materials cannot be identified within the scope of this SOP. Should site activities generate a potentially hazardous material in the form of a collected sample, the following actions must be taken:

- As soon as possible after collecting a high-hazard sample (or as early as possible in anticipation of collecting a high-hazard sample), the FOL must contact Health Sciences in Pittsburgh (412/921/7090). This notification must include the volume of the sample collected, the likely composition of the sample, and any observed properties (color, odor, etc.) of interest in characterizing the sample. Do not wait until you are about to package the sample to contact Health Sciences, as this may delay shipping your sample on-time.

- In concert with Health Sciences, the Proper Shipping Name will be identified for the sample to be shipped. Health Sciences will also identify how the sample needs to be packaged and labeled, and will coordinate securing the proper package and label(s) for shipment if necessary.

- Only employees who have participated in the TtNUS course "Shipping Hazardous Materials" (or similar pre-approved DOT shipping course) are permitted to offer a hazardous material for shipment. If you have not received this training, but anticipate you will need to ship a hazardous material, you should contact Health Sciences or your local Safety Representative to arrange to receive this training.

Questions regarding application of this guidance for high-hazard samples or any other hazardous material should be directed to Health Sciences in Pittsburgh.

ATTACHMENT C
METHODS OF SAMPLING STRATIFIED CONTENTS OF TANKS

1. Sampling Using the Bacon Bomb Sampler

Discussion

The Bacon Bomb (Figure C-1) is designed for the withdrawal of samples by the "thief" method from various levels within a storage tank. It consists of a cylindrical body with an internal tapered plunger that acts as a valve to admit the sample. A line attached to the top of the plunger is used to open and close the valve. A removable top cover provides a point of attachment for the sample and has a locking mechanism to keep the plunger closed after sampling. The Bacon Bomb is usually constructed of chrome-plated brass and bronze with a rubber O-ring acting as the plunger sealing surface. Stainless steel versions are also available. The volumetric capacity is 8, 16, or 32 ounces (236, 473, or 946 milliliters).

Uses

The Bacon Bomb is a heavy sampler for viscous materials held in large storage tanks or in lagoons. If a more non-reactive sampler is needed, the stainless steel version should be used or the samplers could be coated with Teflon.

Sampling Method

1. Attach the sample line and the plunger line to the sampler.
2. Measure and then mark the sampling line at the desired depth for sampling.
3. Gradually lower the sampler by the sample line until the desired level is reached.
4. When the desired level is reached, pull up on the plunger line and allow the sampler to fill before releasing the plunger line to seal off the sampler.
5. Retrieve the sampler by the sample line, being careful not to pull up on the plunger line and thereby prevent accidental opening of the bottom valve.
6. Rinse or wipe off the exterior of the sampler body.
7. Position the sampler over the sample container and release its contents by pulling up on the plunger line.
8. Thoroughly decontaminate the sampler prior to next use.

ATTACHMENT C
METHODS OF SAMPLING STRATIFIED CONTENTS OF TANKS
PAGE TWO

2. Sampling using the Weighted Bottle Sampler

Discussion

The weighted bottle sampler consists of a glass bottle, a weight sinker, a bottle stopper, and a line for opening the bottle and lowering and raising the sampler during sampling (Figure C-2). There are variations of this sampler, as illustrated in the American Society of Testing and Materials (ASTM) Methods D0270 and E-300. This sampler can be either fabricated or purchased commercially.

Uses

Weighted bottle samplers are used to sample liquids at a particular depth. These samplers are difficult to use in very viscous liquids. In addition, the outside of the bottle is exposed to the waste. This is undesirable if the bottle is used as the sample container. An alternative to the weighted bottle sampler is the Kemmerer bottle.

Sampling Method

1. Gently lower the sampler into the liquid to the desired depth so as not to remove the stopper prematurely.

2. Pull out the stopper with a sharp jerk of the sampler line.

3. Allow the bottle to fill completely, as evidenced by the cessation of air bubbles.

4. Raise the sampler and cap the bottle.

5. The bottle can be used as the sample container, but it must be thoroughly decontaminated.

ATTACHMENT C
METHODS OF SAMPLING STRATIFIED CONTENTS OF TANKS
PAGE THREE

3. Collection of Samples from Depth with a Kemmerer Bottle

Discussion

The Kemmerer bottle is a messenger-activated sampling device (see Figure C-3). In the open position, liquid flows easily through the device. Once lowered to the desired depth, a messenger is dropped down the sample line, tripping the release mechanism and closing the bottle. In the closed position, the bottle is sealed, both on top and bottom, from any additional contact with the liquid column and the sample can be retrieved. Most commercially-available Kemmerer bottles are of brass or plastic construction.

Uses

The Kemmerer bottle is currently the most practical method of collecting discrete, at-depth samples from vessels. The application is limited, however, by the incompatibility of various construction materials with some analytical techniques. Proper selection, i.e., all metal assemblies for organic analysis, or all plastic assemblies for trace element analysis, will overcome this deficiency.

Sampling Method

1. Inspect Kemmerer bottle for thorough cleaning and ensure that sample drain valve is closed (if bottle is so equipped).

2. Measure and then mark sample line at desired sampling length.

3. Open bottle by lifting top stopper-trip head assembly.

4. Gradually lower bottle until desired level is reached (predesignated mark from Step 2).

5. Place messenger on sample line and release.

6. Retrieve sampler; hold sampler by center stem to prevent accidental opening of bottle stopper.

7. Rinse or wipe off exterior of sampler body (wear proper gloves and protective clothing).

8. Recover sample by grasping lower stopper and sampler body with one hand (gloved), and transfer sample by either (a) lifting top stopper with other hand and carefully pouring contents into sample bottles, or (b) holding drain valve (if present) over sample bottle and opening valve.

9. Thoroughly decontaminate the sampler prior to next use.

FIGURE C-1
BACON BOMB SAMPLER

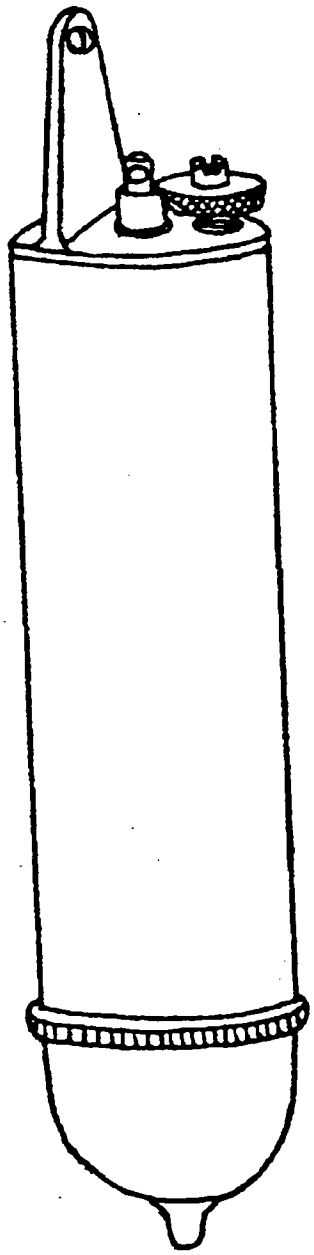
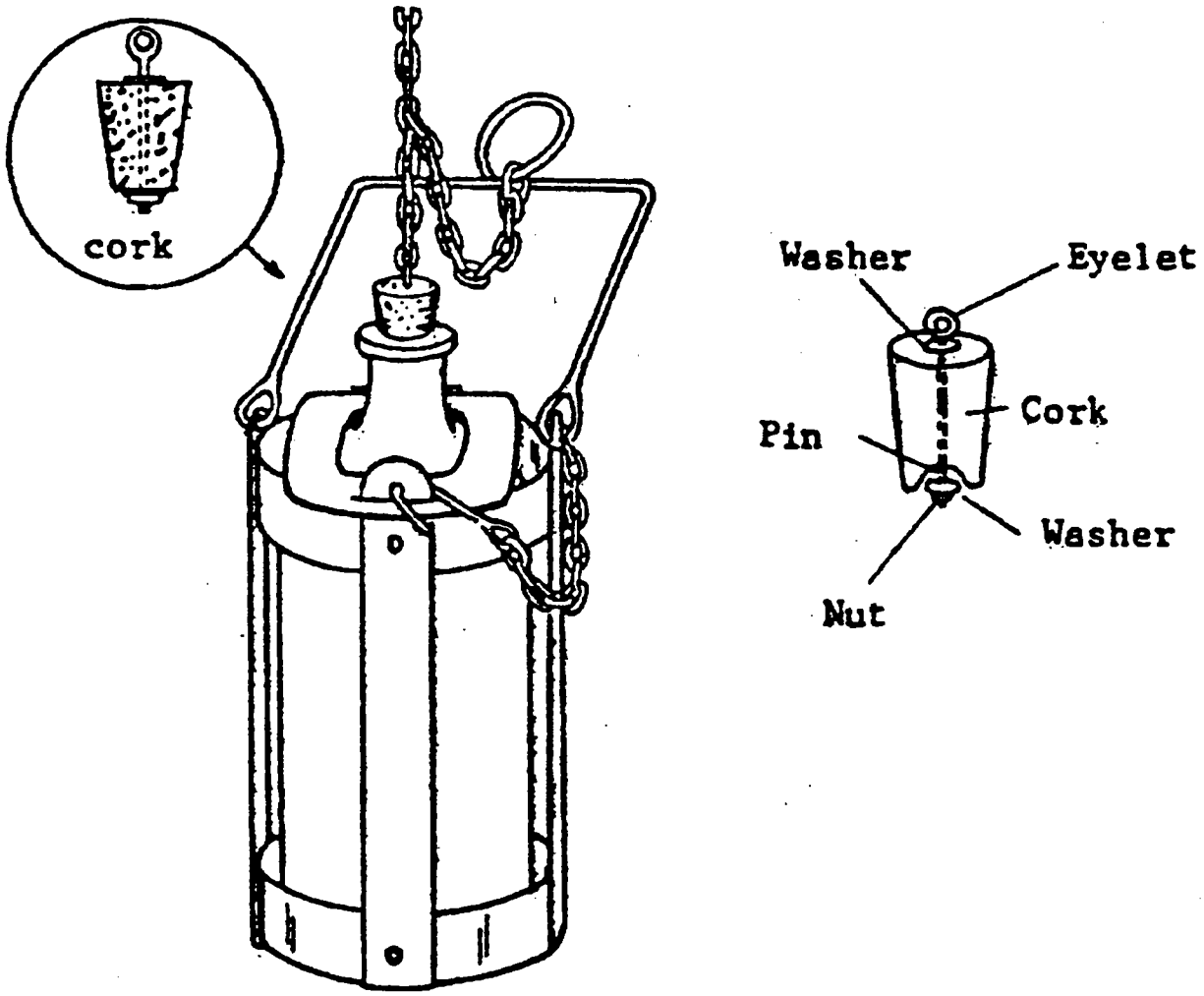
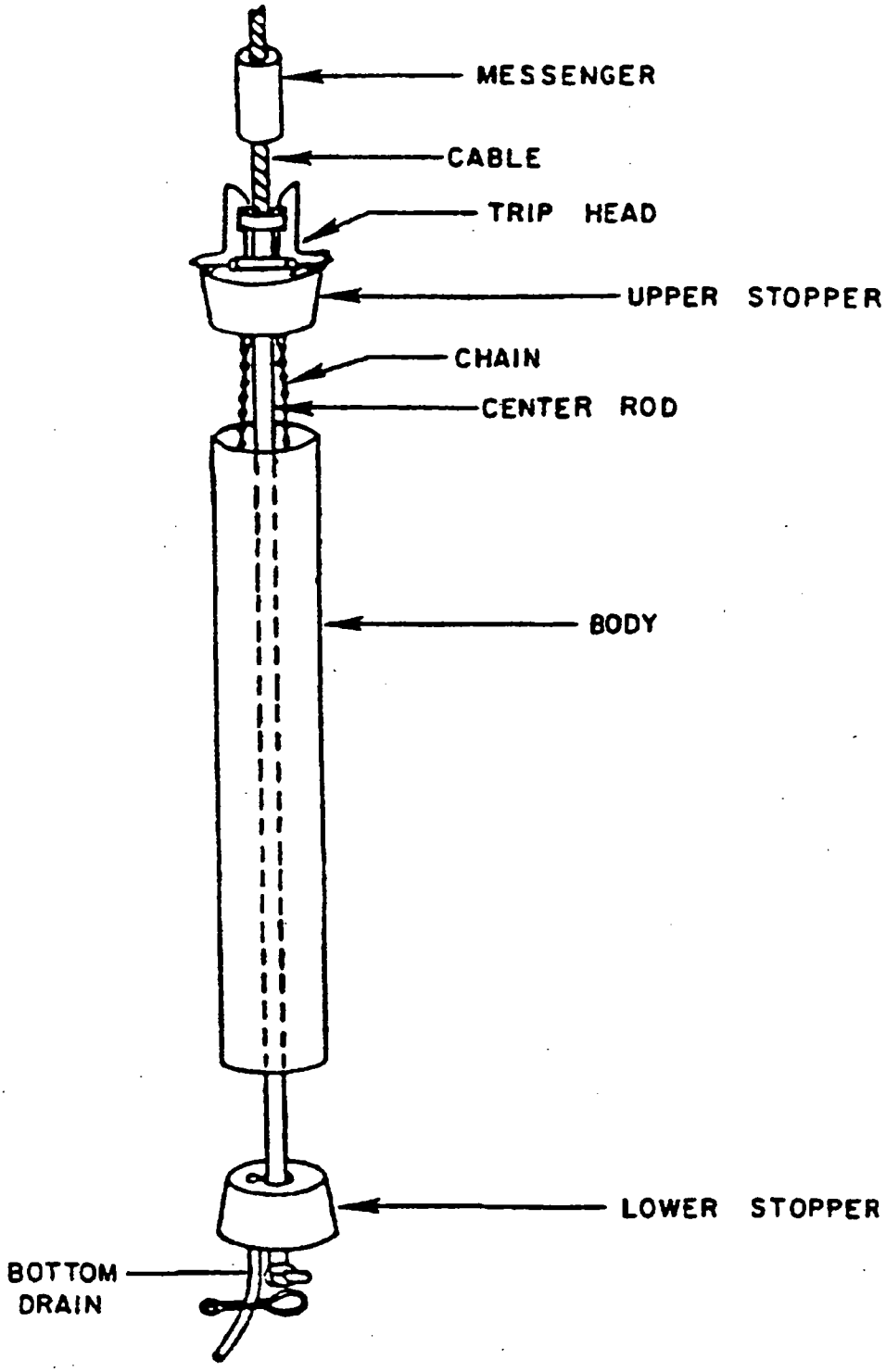


FIGURE C-2
WEIGHTED BOTTLE SAMPLER



1000-ml (1-quart) weighted bottle catcher

FIGURE C-3
MODIFIED KEMMERER SAMPLER



ATTACHMENT D
COLLECTION OF LIQUID CONTAINERIZED WASTES USING GLASS TUBES

Description

Liquid samples from opened containers are collected using lengths of glass tubing. The glass tubes are normally 122 centimeters in length and 6 to 16 millimeters inside diameters. Longer tubes may be used but larger diameter tubing is not effective. The tubing allows inspection of the tank contents for stratification. This method should not be attempted with less than a two-person sampling team.

Uses

This method provides a quick, relatively inexpensive means of collecting containerized wastes. The major disadvantage is from potential sample loss, which is especially prevalent when sampling low viscosity fluids. Splashing can also be a problem, and proper protective clothing should always be worn.

Sampling Method

1. Remove cover from sample container opening.
2. Insert glass tubing almost to the bottom of the container. Try to keep at least 30 centimeters of tubing above the top of the container.
3. Allow the waste in the tank to reach its natural level in the tube, then cap the top of the tube with a rubber stopper or cover tightly with gloved thumb.
4. Carefully remove the capped tube from the tank and insert the uncapped end in the sample container.
5. Release the thumb or stopper on the tube and allow the sample container to fill to approximately 90 percent of its capacity.
6. Repeat Steps 2 through 6 if more volume is needed to fill the sample container.

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1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to provide information on sample preservation, packaging, and shipping procedures to be used in handling environmental samples submitted for chemical constituent, biological, or geotechnical analysis. Sample chain-of-custody procedures and other aspects of field documentation are addressed in SOP SA-6.3. Sample identification is addressed in SOP CT-04.

2.0 SCOPE

This procedure 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 off site for chemical analysis.

3.0 GLOSSARY

Hazardous Material - A substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated. Under 49 CFR, the term includes hazardous substances, hazardous wastes, marine pollutants, and elevated temperature materials, as well as materials designated as hazardous under the provisions of §172.101 and §172.102 and materials that meet the defining criteria for hazard classes and divisions in Part 173. With slight modifications, IATA has adopted DOT "hazardous materials" as IATA "Dangerous Goods."

Hazardous Waste - Any substance listed in 40 CFR, Subpart D (~~y~~261.30 et seq.), or otherwise characterized as ignitable, corrosive, reactive, or toxic (as defined by Toxicity Characteristic Leaching Procedure, TCLP, analysis) as specified under 40 CFR, Subpart C (~~y~~261.20 et seq.), that would be subject to manifest requirements specified in 40 CFR 262. Such substances are defined and regulated by EPA.

Marking - A descriptive name, identification number, instructions, cautions, weight, specification or UN marks, or combination thereof required on outer packaging of hazardous materials.

n.o.i - Not otherwise indicated (may be used interchangeably with n.o.s.).

n.o.s. - Not otherwise specified.

Packaging - A receptacle and any other components or materials necessary for compliance with the minimum packaging requirements of 49 CFR 174, including containers (other than freight containers or overpacks), portable tanks, cargo tanks, tank cars, and multi-unit tank-car tanks to perform a containment function in conformance with the minimum packaging requirements of 49 CFR 173.24(a) & (b).

Placard - Color-coded, pictorial sign which depicts the hazard class symbol and name and which is placed on the side of a vehicle transporting certain hazardous materials.

Common Preservatives:

- Hydrochloric Acid - HCl
- Sulfuric Acid - H_2SO_4
- Nitric Acid - HNO_3
- Sodium Hydroxide - NaOH

Other Preservatives

- Zinc Acetate
- Sodium Thiosulfate - $Na_2S_2O_3$

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.

Reportable Quantity (RQ) - For the purposes of this SOP, means the quantity specified in column 3 of the Appendix to DOT 49 CFR §172.101 for any material identified in column 1 of the appendix. A spill greater than the amount specified must be reported to the National Response Center.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the location and time of collection.

4.0 RESPONSIBILITIES

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

Field Samplers - Responsible for initiating the Chain-of-Custody Record (per SOP SA-6.3), implementing the packaging and shipping requirements, and maintaining custody of samples until they are relinquished to another custodian or to the shipper.

5.0 PROCEDURES

Sample identification, labeling, documentation, and chain-of-custody are addressed by SOP SA-6.3.

5.1 Sample Containers

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, whereas many organic chemicals may dissolve various types of plastic containers. Attachments A and B show proper containers (as well as other information) per 40 CFR 136. In general, the sample container shall allow approximately 5-10 percent air space ("ullage") to allow for expansion/vaporization if the sample warms during transport. However, for collection of volatile organic compounds, head space shall be omitted. The analytical laboratory will generally provide certified-clean containers for samples to be analyzed for chemical constituents. Shelby tubes or other sample containers are generally provided by the driller for samples requiring geotechnical analysis. Sufficient lead time shall be allowed for a delivery of sample container orders. Therefore, it is critical to use the correct container to maintain the integrity of the sample prior to analysis.

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 a missing Teflon liner (if required for the container), shall be discarded.

5.2 Sample Preservation

Many water and soil samples are unstable and therefore require preservation to prevent changes in either the concentration or the physical condition of the constituent(s) requiring analysis. Although complete and 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 (certain biological samples only).

5.2.1 Overview

The preservation techniques to be used for various analytes are listed in Attachments A and B. Reagents required for sample preservation will either be added to the sample containers by the laboratory prior to their shipment to the field or be added in the field (in a clean environment). Only high purity reagents shall be used for preservation. 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, high-hazard organic samples, and some gas samples are typically not preserved. Low-concentration aqueous samples for metals are acidified with HNO_3, whereas medium-concentration and high-hazard aqueous metal samples are not preserved. Low- or medium-concentration soil samples for metals are cooled to 4°C, whereas high-hazard samples are not cooled.

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

The FOL is responsible for ensuring that an accurate Chemical Inventory is created and maintained for all hazardous chemicals brought to the work site (see Section 5 of the TtNUS Health and Safety Guidance Manual). Furthermore, the FOL must ensure that a corresponding Material Safety Data Sheet (MSDS) is collected for every substance entered on the site Chemical Inventory, and that all persons using/handling/ disposing of these substances review the appropriate MSDS for substances they will work with. The Chemical Inventory and the MSDSs must be maintained at each work site in a location and manner where they are readily-accessible to all personnel.

5.2.2 Preparation and Addition of Reagents

Addition of the following acids or bases may be specified for sample preservation; these reagents shall be analytical reagent (AR) grade or purer and shall be diluted to the required concentration with deionized water before field sampling commences. To avoid uncontrolled reactions, be sure to Add Acid to water (not vice versa). A dilutions guide is provided below.

Acid/Base	Dilution	Concentration	Estimated Amount Required for Preservation
Hydrochloric Acid (HCl)	1 part concentrated HCl: 1 part double-distilled, deionized water	6N	5-10 mL
Sulfuric Acid (H_2SO_4)	1 part concentrated H_2SO_4: 1 part double-distilled, deionized water	18N	2 - 5 mL
Nitric Acid (HNO_3)	Undiluted concentrated HNO_3	16N	2 - 5 mL
Sodium Hydroxide (NaOH)	400 grams solid NaOH dissolved in 870 mL double-distilled, deionized water; yields 1 liter of solution	10N	2 mL

The amounts required for preservation shown in the above table assumes proper preparation of the preservative and addition of the preservative to one liter of aqueous sample. This assumes that the sample is initially at pH 7, is poorly buffered, and does not contain particulate matter; as these conditions vary, more preservative may be required. Consequently, the final sample pH must be checked using narrow-range pH paper, as described in the generalized procedure detailed below:

- Pour off 5-10 mL of sample into a dedicated, clean container. Use some of this sample to check the initial sample pH using wide range (0-14) pH paper. Never dip the pH paper into the sample; always apply a drop of sample to the pH paper using a clean stirring rod or pipette.

- Add about one-half of the estimated preservative required to the original sample bottle. Cap and invert gently several times to mix. Check pH (as described above) using medium range pH paper (pH 0-6 or pH 7.5-14, as applicable).

- Cap sample bottle and seal securely.

Additional considerations are discussed below:

- To test if ascorbic acid must be used to remove oxidizing agents present in the sample before it can be properly preserved, place a drop of sample on KI-starch paper. A blue color indicates the need for ascorbic acid addition.

  If required, add a few crystals of ascorbic acid to the sample and retest with the KI-starch paper. Repeat until a drop of sample produces no color on the KI-starch paper. Then add an additional 0.6 grams of ascorbic acid per each liter of sample volume.

  Continue with proper base preservation of the sample as described above.

- Samples for sulfide analysis must be treated by the addition of 4 drops (0.2 mL) of 2N zinc acetate solution per 100 ml of sample.

  The 2N zinc acetate solution is made by dissolving 220 grams of zinc acetate in 870 mL of double-distilled, deionized water to make 1 liter of solution.

  The sample pH is then raised to 9 using the NaOH preservative.

- Sodium thiosulfate must be added to remove residual chlorine from a sample. To test the sample for residual chlorine use a field test kit specially made for this purpose.

  If residual chlorine is present, add 0.08 grams of sodium thiosulfate per liter of sample to remove the residual chlorine.

  Continue with proper acidification of the sample as described above.

For biological samples, 10% buffered formalin or isopropanol may also be required for preservation. Questions regarding preservation requirements should be resolved through communication with the laboratory before sampling begins.

5.3 Field Filtration

At times, field-filtration may be required to provide for the analysis of dissolved chemical constituents. Field-filtration must be performed prior to the preservation of samples as described above. General procedures for field filtration are described below:

- The sample shall be filtered through a non-metallic, 0.45-micron membrane filter, immediately after collection. The filtration system shall consist of dedicated filter canister, dedicated tubing, and a peristaltic pump with pressure or vacuum pumping squeeze action (since the sample is filtered by mechanical peristalsis, the sample travels only through the tubing).

- To perform filtration, thread the tubing through the peristaltic pump head. Attach the filter canister to the discharge end of the silicon tubing (note flow direction arrow); attach the aqueous sample container to the intake end of the silicon tubing. Turn the peristaltic pump on and perform filtration. Run approximately 100 ml of sample through the filter and discard prior to sample collection.

- Continue by preserving the filtrate (contained in the filter canister), as applicable and generally described above.

5.4 Sample Packaging and Shipping

Only employees who have successfully completed the TtNUS "Shipping Hazardous Materials" training course are authorized to package and ship hazardous substances. These trained individuals are responsible for performing shipping duties in accordance with this training.

Samples collected for shipment from a site shall be classified as either environmental or hazardous material samples. Samples from drums containing materials other than Investigative Derived Waste (IDW) and samples obtained from waste piles or bulk storage tanks are generally shipped as hazardous materials. 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.)

Detailed procedures for packaging environmental samples are outlined in the remainder of this section.

5.4.1 Environmental Samples

Environmental samples are packaged as follows:

- Place properly identified sample container, with lid securely fastened, in a plastic bag (e.g. Ziploc baggie), and seal the bag.

- Place sample in a cooler constructed of sturdy material which has been lined with a large, plastic bag (e.g. "garbage" bag). Drain plugs on coolers must be taped shut.

- Pack with enough cushioning materials such as bubble wrap (shoulders of bottles must be iced if required) to minimize the possibility of the container breaking.

- If cooling is required (see Attachments A and B), place ice around sample container shoulders, and on top of packing material (minimum of 8 pounds of ice for a medium-size cooler).

- Seal (i.e., tape or tie top in knot) large liner bag.

- The original (top, signed copy) of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the cooler containing the vials for VOC analysis. The COC form should then state how many coolers are included with that shipment.

- Close and seal outside of cooler as described in SOP SA-6.3. Signed custody seals must be used.

Coolers must be marked as containing "Environmental Samples." The appropriate side of the container must be marked "This End Up" and arrows placed appropriately. No DOT marking or labeling is required; there are no DOT restrictions on mode of transportation.

6.0 REFERENCES

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

International Air Transport Association (latest issue). Dangerous Goods Regulations, Montreal, Quebec, Canada.

U.S. Department of Transportation (latest issue). 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.

ATTACHMENT A

GENERAL SAMPLE CONTAINER AND PRESERVATION REQUIREMENTS

Sample Type and Concentration			Container[1]	Sample Size	Preservation[2]	Holding Time[2]
WATER						
Organics (GC&GC/MS)	VOC	Low	Borosilicate glass	2 x 40 mL	Cool to 4°C HCl to ≤ 2	14 days[9]
	Extractables SVOCs and pesticide/PCBs)	(Low	Amber glass	2x2 L or 4x1 L	Cool to 4°C	7 days to extraction; 40 days after extraction
	Extractables SVOCs and pesticide/PCBs)	(Medium	Amber glass	2x2 L or 4x1 L	None	7 days to extraction; 40 days after extraction
Inorganics	Metals	Low	High-density polyethylene	1 L	HNO_3 to pH ≤2	6 months (Hg-28 days)
		Medium	Wide-mouth glass	16 oz.	None	6 months
	Cyanide	Low	High-density polyethylene	1 L	NaOH to pH>12	14 days
	Cyanide	Medium	Wide-mouth glass	16 oz.	None	14 days
Organic/ Inorganic	High Hazard		Wide-mouth glass	8 oz.	None	14 days
SOIL						
Organics (GC&GC/MS)	VOC		EnCore Sampler	(3) 5 g Samplers	Cool to 4°C	48 hours to lab preservation
	Extractables SVOCs and pesticides/PCBs)	(Low	Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
	Extractables SVOCs and pesticides/PCBs)	(Medium	Wide-mouth glass	8 oz.	Cool to 4°C	14 days to extraction; 40 days after extraction
Inorganics	Low/Medium		Wide-mouth glass	8 oz.	Cool to 4°C	6 months (Hg - 28 days) Cyanide (14 days)
Organic/Inorganic	High Hazard		Wide-mouth glass	8 oz.	None	NA
Dioxin/Furan	All		Wide-mouth glass	4 oz.	None	35 days until extraction; 40 days after extraction
TCLP	All		Wide-mouth glass	8 oz.	None	7 days until preparation; analysis as per fraction
AIR						
Volatile Organics	Low/Medium		Charcoal tube -- 7 cm long, 6 mm OD, 4 mm ID	100 L air	Cool to 4°C	5 days recommended

1 All glass containers should have Teflon cap liners or septa.
2 See Attachment E. Preservation and maximum holding time allowances per 40 CFR 136.

ATTACHMENT B

ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter Number/Name	Container[1]	Preservation[2][3]	Maximum Holding Time[4]
INORGANIC TESTS:			
Acidity	P, G	Cool, 4°C	14 days
Alkalinity	P, G	Cool, 4°C	14 days
Ammonia - Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Biochemical Oxygen Demand (BOD)	P, G	Cool, 4°C	48 hours
Bromide	P, G	None required	28 days
Chemical Oxygen Demand (COD)	P, G	Cool, 4°C; H_2SO_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_2SO_4 to pH 2	6 months
Total Kjeldahl and Organic Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Nitrate - Nitrogen	P, G	None required	48 hours
Nitrate-Nitrite - Nitrogen	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Nitrite - Nitrogen	P, G	Cool, 4°C	48 hours
Oil & Grease	G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Total Organic Carbon (TOC)	P, G	Cool, 4°C; HCl or H_2SO_4 to pH 2	28 days
Orthophosphate	P, G	Filter immediately; Cool, 4°C	48 hours
Oxygen, Dissolved-Probe	G Bottle & top	None required	Analyze immediately
Oxygen, Dissolved-Winkler	G Bottle & top	Fix on site and store in dark	8 hours
Phenols	G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Phosphorus, Total	P, G	Cool, 4°C; H_2SO_4 to pH 2	28 days
Residue, Total	P, G	Cool, 4°C	7 days
Residue, Filterable (TDS)	P, G	Cool, 4°C	7 days
Residue, Nonfilterable (TSS)	P, G	Cool, 4°C	7 days
Residue, Settleable	P, G	Cool, 4°C	48 hours
Residue, Volatile (Ash Content)	P, G	Cool, 4°C	7 days
Silica	P	Cool, 4°C	28 days
Specific Conductance	P, G	Cool, 4°C	28 days
Sulfate	P, G	Cool, 4°C	28 days

ATTACHMENT B
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
PAGE TWO

Parameter Number/Name	Container[1]	Preservation[2][3]	Maximum Holding Time[4]
INORGANIC TESTS (Cont'd):			
Sulfide	P, G	Cool, 4°C; add zinc acetate plus sodium hydroxide to pH 9	7 days
Sulfite	P, G	None required	Analyze immediately
Turbidity	P, G	Cool, 4°C	48 hours
METALS:[7]			
Chromium VI (Hexachrome)	P, G	Cool, 4°C	24 hours
Mercury (Hg)	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% $Na_2S_2O_3$[5]	14 days
Purgeable Aromatic Hydrocarbons	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$[5] HCl to pH 2 [9]	14 days
Acrolein and Acrylonitrile	G, Teflon-lined septum	Cool, 4°C; 0.008% $Na_2S_2O_3$[5] adjust pH to 4-5 [10]	14 days
Phenols[11]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction
Benzidines[11], [12]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[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[11], [14]	G, Teflon-lined cap	Cool, 4°C; store in dark; 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction
PCBs[11]	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% $Na_2S_2O_3$[5]; store in dark	7 days until extraction; 40 days after extraction
Polynuclear Aromatic Hydrocarbons (PAHs)[11],[14]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]; store in dark	7 days until extraction; 40 days after extraction
Haloethers[11]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction
Dioxin/Furan (TCDD/TCDF)[11]	G, Teflon-lined cap	Cool, 4°C; 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction

ATTACHMENT B
ADDITIONAL REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES
PAGE THREE

(1) Polyethylene (P): generally 500 ml or Glass (G): generally 1L.
(2) Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.
(3) When any sample is to be shipped by common carrier or sent through the United States Mail, 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 and 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 periods, 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 are made 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-diphenylthydrazine 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% $Na_2S_2O_3$ 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% $Na_2S_2O_3$.

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1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to identify and designate the field data record forms, logs and reports generally initiated and maintained for documenting field activities.

2.0 SCOPE

Documents presented within this procedure (or equivalents) shall be used for all contractor field activities, as applicable. Other or additional documents may be required by specific client contracts or project planning documents.

3.0 GLOSSARY

None

4.0 RESPONSIBILITIES

Project Manager (PM) - The Project Manager is responsible for obtaining hardbound, controlled-distribution logbooks (from the appropriate source), as needed. In addition, the Project Manager is responsible for placing all field documentation used in site activities (i.e., records, field reports, sample data sheets, field notebooks, and the site logbook) in the project's central file upon the completion of field work.

Field Operations Leader (FOL) - The Field Operations Leader is responsible for ensuring that the site logbook, notebooks, and all appropriate and current forms and field reports illustrated in this guideline (and any additional forms required by the contract) 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 hard-bound, paginated, controlled-distribution record book in which all major onsite activities are documented. At a minimum, the following activities/events shall be recorded or referenced (daily) in the site logbook:

- All field personnel present
- Arrival/departure of site visitors
- Time and date of H&S training
- Arrival/departure of equipment
- Time and date of equipment calibration
- Start and/or completion of borehole, trench, monitoring well installation, etc.
- Daily onsite activities performed each day
- Sample pickup information
- Health and Safety issues (level of protection observed, etc.)
- Weather conditions

A site logbook shall be maintained for each project. The site logbook shall be initiated at the start of the first onsite activity (e.g., site visit or initial reconnaissance survey). Entries are to be made for every day

that onsite activities take place which involve contractor or subcontractor personnel. Upon completion of the fieldwork, the site logbook must become part of the project's central file.

The following information must be recorded on the cover of each site logbook:

- Project name
- Contractor project number
- Sequential book number
- Start date
- End date

Information recorded daily in the site logbook need not be duplicated in other field notebooks (see Section 5.2), but must summarize the contents of these other notebooks and refer to specific page locations in these notebooks for detailed information (where applicable). An example of a typical site logbook entry is shown in Attachment A.

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 field notebook in which the measurements are recorded (see Attachment A).

All logbook, notebook, and log sheet entries shall be made in indelible ink (black pen is preferred). No erasures are permitted. If an incorrect entry is made, the entry shall be crossed out with a single strike mark, and initialed and dated. At the completion of entries by any individual, the logbook pages used must be signed and dated. The site logbook must also be signed by the Field Operations 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 must be numbered sequentially to correspond to logbook/notebook entries. The name of the photographer, date, time, site location, site description, and weather conditions must be entered in the logbook/notebook 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/notebook. If possible, such techniques shall be avoided, since they can adversely affect the accuracy of photographs. Chain-of-custody procedures depend upon the subject matter, type of camera (digital or film), and the processing it requires. Film used for aerial photography, confidential information, or criminal investigation require chain-of-custody procedures. Once processed, the slides of photographic prints shall be consecutively numbered and labeled according to the logbook/notebook descriptions. The site photographs and associated negatives and/or digitally saved images to compact disks must be docketed into the project's central file.

5.2 Field Notebooks

Key field team personnel may maintain a separate dedicated field notebook to document the pertinent field activities conducted directly under their supervision. For example, on large projects with multiple investigative sites and varying operating conditions, the Health and Safety Officer may elect to maintain a separate field notebook. Where several drill rigs are in operation simultaneously, each site geologist assigned to oversee a rig must maintain a field notebook.

5.3 Field Forms

Example field forms are listed in Section 6.0 of this SOP. Forms may be altered or revised for project-specific needs contingent upon client approval. Care must be taken to ensure that all essential information can be documented. Guidelines for completing these forms can be found in the related sampling SOP.

5.3.1 Sample Collection, Labeling, Shipment, Request for Analysis, and Field Test Results

5.3.1.1 Sample Log Sheet

Sample Log Sheets are used to record specified types of data while sampling. The data recorded on these sheets are useful in describing the sample as well as pointing out any problems, difficulties, or irregularities encountered during sampling. A log sheet must be completed for each sample obtained, including field quality control (QC) samples.

5.3.1.2 Sample Label

A typical sample label is illustrated in Attachment B. Adhesive labels must be completed and applied to every sample container. Sample labels can usually be obtained from the appropriate Program source electronically generated in-house, or are supplied from the laboratory subcontractor.

5.3.1.3 Chain-of-Custody Record Form

The Chain-of-Custody (COC) Record is a multi-part form that is initiated as samples are acquired and accompanies a sample (or group of samples) as they are transferred from person to person. This form must be used for any samples collected for chemical or geotechnical analysis whether the analyses are performed on site or off site. One carbonless copy of the completed COC form is retained by the field crew, one copy is sent to the Project Manager (or designee), while the original is sent to the laboratory. The original (top, signed copy) of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the cooler containing vials for VOC analysis or the cooler with the air bill attached. The air bill should then state how many coolers are included with that shipment. An example of a Chain-of-Custody Record form is provided as Attachment C. Once the samples are received at the laboratory, the sample cooler and contents are checked and any problems are noted on the enclosed COC form (any discrepancies between the sample labels and COC form and any other problems that are noted are resolved through communication between the laboratory point-of-contact and the contractor Project Manager). The COC form is signed and copied. The laboratory will retain the copy while the original becomes part of the samples' corresponding analytical data package.

5.3.1.4 Chain-of-Custody Seal

Attachment D is an example of a custody seal. The Custody seal is an 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 and sealed in coolers for transport to the laboratory. The COC seals are signed and dated by the sampler(s) and affixed across the lid and body of each cooler (front and back) containing environmental samples (see SOP SA-6.1). COC seals may be available from the laboratory; these seals may also be purchased from a supplier.

5.3.1.5 Geochemical Parameters Log Sheets

Field Analytical Log Sheets are used to record geochemical and/or natural attenuation field test results.

5.3.2 Hydrogeological and Geotechnical Forms

5.3.2.1 Groundwater Level Measurement Sheet

A Groundwater Level Measurement Sheet must be filled out for each round of water level measurements made at a site.

5.3.2.2 Data Sheet for Pumping Test

During the performance of a pumping test (or an in-situ hydraulic conductivity test), a large amount of data must be recorded, often within a short time period. The Pumping Test Data Sheet facilitates this task by standardizing the data collection format for the pumping well and observation wells, and allowing the time interval for collection to be laid out in advance.

5.3.2.3 Packer Test Report Form

A Packer Test Report Form must be completed for each well upon which a packer test is conducted.

5.3.2.4 Boring Log

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, or Boring Log is used for this purpose and must be completed for each soil boring performed. In addition, if volatile organics are monitored on cores, samples, cuttings from the borehole, or breathing zone, (using a PID or FID), these readings must be entered on the boring log at the appropriate depth. The "Remarks" column can be used to subsequently enter the laboratory sample number, the concentration of key analytical results, or other pertinent information. This feature allows direct comparison of contaminant concentrations with soil characteristics.

5.3.2.5 Monitoring Well Construction Details Form

A Monitoring Well Construction Details Form must be completed for every monitoring well, piezometer, or temporary well point installed. This form contains specific information on length and type of well riser pipe and screen, backfill, filter pack, annular seal 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, stick-up or flush mount), different forms are used.

5.3.2.6 Test Pit Log

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

5.3.2.7 Miscellaneous Monitoring Well Forms

Monitoring Well Materials Certificate of Conformance should be used as the project directs to document all materials utilized during each monitoring well installation.

The Monitoring Well Development Record should be used as the project directs to document all well development activities.

5.3.2.8 Miscellaneous Field Forms - QA and Checklists

Container Sample and Inspection Sheet may be used as the project directs each time a container (drum, tank, etc.) is sampled and/or inspected.

QA Sample Log Sheet may be used at the project directs each time a QA sample is colleted, such as Rinsate Blank, Source Blank, etc.

Field Task Modification Request (FTMR) will be prepared for all deviations from the project planning documents. The FOL is responsible for initiating the FTMRs. Copies of all FTMRs will be maintained with the onsite planning documents and originals will be placed in the final evidence file.

The Field Project Daily Activities Check List and Field Project Pre-Mobilization Checklist may be used during both the planning and field effort to assure that all necessary tasks are planned for and completed. These two forms are not a requirement but a useful tool for most field work.

5.3.3 Equipment Calibration and Maintenance Form

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, others infrequent. Some are calibrated by the manufacturer, others by the user.

Each instrument requiring calibration has its own Equipment Calibration Log which documents that the manufacturer's instructions were followed for calibration of the equipment, including frequency and type of standard or calibration device. An Equipment Calibration Log must be maintained for each electronic measuring device used in the field; entries must be made for each day the equipment is used or in accordance with the manufacturer's recommendations.

5.4 Field Reports

The primary means of recording onsite activities is the site logbook. Other field notebooks may also be maintained. These logbooks and notebooks (and supporting forms) contain detailed information required for data interpretation or documentation, but are not easily useful for tracking and reporting of progress. Furthermore, the field logbook/notebooks remain onsite for extended periods of time and are thus not accessible for timely review by project management.

5.4.1 Daily Activities Report

To provide timely oversight of onsite contractors, Daily Activities Reports are completed and submitted as described below.

5.4.1.1 Description

The Daily Activities Report (DAR) documents the activities and progress for each day's field work. This report must be 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. An example DAR form can be found in Appendix E.

5.4.1.2 Responsibilities

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

5.4.1.3 Submittal and Approval

At the end of the shift, the rig geologist must submit 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 DAR reports are retained by the FOL for use in preparing the site logbook and in preparing weekly status reports for submission to the Project Manager.

5.4.2 Weekly Status Reports

To facilitate timely review by project management, photocopies of logbook/notebook entries may be made for internal use.

It should be noted that in addition to summaries described herein, other summary reports may also be contractually required.

Example field forms can be found in Attachment E to this SOP.
6.0 the following is a list of the example Field Forms found in Appendix E.
Groundwater Sample Log Sheet
Surface Water Sample Log Sheet
Soil/Sediment Sample Log Sheet
Groundwater Level Measurement Sheet
Pumping Test Data Sheet
Packer Test Report Form
Boring Log
Monitoring Well Construction Bedrock Flush Mount
Monitoring Well Construction Bedrock Open Hole
Monitoring Well Construction Bedrock Stick Up
Monitoring Well Construction Confining Layer
Monitoring Well Construction Overburden Flush Mount
Monitoring Well Construction Overburden Stick Up
Test Pit Log
Monitoring Well Development Record
Daily Activities Record
Field Task Modification Request
Hydraulic Conductivity Test Data Sheet
Low Flow Purge Data Sheet
Equipment Calibration Log

ATTACHMENT A
TYPICAL SITE LOGBOOK ENTRY

START TIME: _____ DATE: _____

SITE LEADER: _____

PERSONNEL:

CONTRACTOR	DRILLER	SITE VISITORS
_____	_____	_____
_____	_____	_____
_____	_____	_____

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

ACTIVITIES:

1. Steam jenney 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-S4 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 off site, gate locked.

_____

Field Operations Leader

ATTACHMENT B

Tetra Tech NUS, Inc. 661 Andersen Drive Pittsburgh, 15220 (412)921-7090	Project: Site: Location:		
Sample No:			Matrix:
Date:	Time:	Preserve:	
Analysis:			
Sampled by:	Laboratory:		

ATTACHMENT C

TETRA TECH NUS, INC. CHAIN OF CUSTODY | NUMBER 3413 | PAGE ____ OF _____

PROJECT NO:	FACILITY:	PROJECT MANAGER	PHONE NUMBER	LABORATORY NAME AND CONTACT:
SAMPLERS (SIGNATURE)		FIELD OPERATIONS LEADER	PHONE NUMBER	ADDRESS
		CARRIER/WAYBILL NUMBER		CITY, STATE

STANDARD TAT ☐
RUSH TAT ☐
☐ 24 hr. ☐ 48 hr. ☐ 72 hr. ☐ 7 day ☐ 14 day

CONTAINER TYPE PLASTIC (P) or GLASS (G)
PRESERVATIVE USED
TYPE OF ANALYSIS

DATE YEAR ____	TIME	SAMPLE ID	LOCATION ID	TOP DEPTH (FT)	BOTTOM DEPTH (FT)	MATRIX (GW, SO, SW, SD, QC, ETC.)	COLLECTION METHOD GRAP (G) COMP (C)	No. OF CONTAINERS									COMMENTS

1. RELINQUISHED BY	DATE	TIME	1. RECEIVED BY	DATE	TIME
2. RELINQUISHED BY	DATE	TIME	2. RECEIVED BY	DATE	TIME
3. RELINQUISHED BY	DATE	TIME	3. RECEIVED BY	DATE	TIME
COMMENTS					

DISTRIBUTION: WHITE (ACCOMPANIES SAMPLE) YELLOW (FIELD COPY) PINK (FILE COPY)

4/02R
FORM NO. TtNUS-001

ATTACHMENT D

CHAIN-OF-CUSTODY SEAL

CUSTODY SEAL	**Signature**
Date	**Date**
Signature	**CUSTODY SEAL**

ATTACHMENT E

The following pages consist of examples of field forms as listed in Section 6 of this SOP.

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1.0 PURPOSE

Decontamination is the process of removing and/or neutralizing site contaminants that have contacted and/or accumulated on equipment. The objective/purpose of this SOP is intended to protect site personnel, general public, and the sample integrity through the prevention of cross contamination onto unaffected persons or areas. It is further intended through this procedure to provide guidelines regarding the appropriate procedures to be followed when decontaminating drilling equipment, monitoring well materials, chemical sampling equipment and field analytical equipment.

2.0 SCOPE

This procedure applies to all equipment including drilling equipment, heavy equipment, monitoring well materials, as well as chemical sampling and field analytical equipment decontamination that may be used to provide access/acquire environmental samples. Where technologically and economically feasible, single use sealed disposable equipment will be employed to minimize the potential for cross contamination. This procedure also provides general reference information on the control of contaminated materials.

3.0 GLOSSARY

Acid - For decontamination of equipment when sampling for trace levels of inorganics, a 10% solution of nitric acid in deionized water should be used. Due to the leaching ability of nitric acid, it should not be used on stainless steel.

Decontamination Solution - Is a solution selected/identified within the Health and Safety Plan or Project-Specific Quality Assurance Plan. The solution is selected and employed as directed by the project chemist/health and safety professional.

Deionized Water (DI) - Deionized water is tap water that has been treated by passing through a standard deionizing resin column. This water may also pass through additional filtering media to attain various levels of analyte-free status. The DI water should meet CAP and NCCLS specifications for reagent grade, Type I water.

Potable Water - Tap water used from any municipal water treatment system. Use of an untreated potable water supply is not an acceptable substitute for tap water.

Pressure Washing - Employs high pressure pumps and nozzle configuration to create a high pressure spray of potable water. High pressure spray is employed to remove solids.

Solvent - The solvent of choice is pesticide-grade Isopropanol. Use of other solvents (methanol, acetone, pesticide-grade hexane, or petroleum ether) may be required for particular projects or for a particular purpose (e.g. for the removal of concentrated waste) and must be justified in the project planning documents. As an example, it may be necessary to use hexane when analyzing for trace levels of pesticides, PCBs, or fuels. In addition, because many of these solvents are not miscible in water, the equipment should be air dried prior to use. Solvents should not be used on PVC equipment or well construction materials.

Steam Pressure Washing - This method employs a high pressure spray of heated potable water. This method through the application of heat provides for the removal of various organic/inorganic compounds.

4.0 RESPONSIBILITIES

Project Manager - Responsible for ensuring that all field activities are conducted in accordance with approved project plan(s) requirements.

Field Operations Leader (FOL) - Responsible for the onsite verification that all field activities are performed in compliance with approved Standards Operating Procedures or as otherwise dictated by the approved project plan(s).

Site Health and Safety Officer (SHSO) - The SHSO exercises shared responsibility with the FOL concerning decontamination effectiveness. All equipment arriving on-site (as part of the equipment inspection), leaving the site, moving between locations are required to go through a decontamination evaluation. This is accomplished through visual examination and/or instrument screening to determine the effectiveness of the decontamination process. Failure to meet these objectives are sufficient to restrict equipment from entering the site/exiting the site/ or moving to a new location on the site until the objectives are successfully completed.

5.0 PROCEDURES

The process of decontamination is accomplished through the removal of contaminants, neutralization of contaminants, or the isolation of contaminants. In order to accomplish this activity a level of preparation is required. This includes site preparation, equipment selection, and evaluation of the process. Site contaminant types, concentrations, media types, are primary drivers in the selection of the types of decontamination as well as where it will be conducted. For purposes of this SOP discussion will be provided concerning general environmental investigation procedures.

Non-dedicated equipment and equipment that is not pre-decontaminated will be decontaminated prior to commencing drilling/sampling, between sampling locations, and upon the completion of drilling/sampling activities prior to demobilization.

The decontamination processes are typically employed at:

- Temporary Decontamination Pads/Facilities
- Sample Locations
- Centralized Decontamination Pad/Facilities
- Combination of some or all of the above

The following discussion represents recommended site preparation in support of the decontamination process.

5.1 Decontamination Design/Constructions Considerations

5.1.1 Temporary Decontamination Pads

Temporary decontamination pads are constructed at satellite locations in support of temporary work sites. These structures are generally constructed to support the decontamination of heavy equipment such as drill rigs and earth moving equipment but can be employed for smaller articles.

The purpose of the decontamination pad is to contain wash waters and potentially contaminated soils generated during decontamination procedures. Therefore, construction of these pads should take into account the following considerations

- Site Location – The site selected should be within a reasonable distance from the work site but should avoid:

  - Pedestrian/Vehicle thoroughfares
  - Areas where control/custody cannot be maintained
  - Areas where a potential releases may be compounded through access to storm water transport systems, streams or other potentially sensitive areas.
  - Areas potentially contaminated.

- Pad – The pad should be constructed to provide the following characteristics

  - Size – The size of the pad should be sufficient to accept the equipment to be decontaminated as well as permitting free movement around the equipment by the personnel conducting the decontamination.

  - Slope – An adequate slope will be constructed to permit the collection of the water and potentially contaminated soils within a trough or sump constructed at one end. The collection point for wash waters should be of adequate distance that the decontamination workers do not have to walk through the wash waters while completing their tasks.

  - Sidewalls – The sidewalls should be a minimum of 6-inches in height to provide adequate containment for wash waters and soils. If splash represents a potential problem, splash guards should be constructed to control overspray. Sidewalls maybe constructed of wood, inflatables, sand bags, etc. to permit containment.

  - Liner – Depending on the types of equipment and the decontamination method the liner should be of sufficient thickness to provide a puncture resistant barrier between the decontamination operation and the unprotected environment. Care should be taken to examine the surface area prior to placing the liner to remove sharp articles (sticks, stones, debris) that could puncture the liner. Liners are intended to form an impermeable barrier. The thickness may vary from a minimum recommended thickness of 10 mil to 30 mil. Achieving the desired thickness maybe achieved through layering lighter constructed materials. It should be noted that various materials (rubber, polyethylene sheeting) become slippery when wet. To minimize this potential hazard associated with a sloped liner a light coating of sand maybe applied to provide traction as necessary.

  - Wash/drying Racks – Auger flights, drill/drive rods require racks positioned off of the ground to permit these articles to be washed, drained, and dried while secured from falling during this process. A minimum ground clearance of 2-feet is recommended.

  - Maintenance – The work area should be periodically cleared of standing water, soils, and debris. This action will aid in eliminating slip, trip, and fall hazards. In addition, these articles will reduce potential backsplash and cross contamination. Hoses should be gathered when not in use to eliminate potential tripping hazards.

5.1.2 Decontamination Activities at Drill Rigs/DPT Units

During subsurface sampling activities including drilling and direct push activities decontamination of drive rods, Macro Core Samplers, split spoons, etc. are typically conducted at an area adjacent to the operation. Decontamination is generally accomplished using a soap/water wash and rinse utilizing buckets and brushes. This area requires sufficient preparation to accomplish the decontamination objectives.

Buckets shall be placed within mortar tubs or similar secondary containment tubs to prevent splash and spills from reaching unprotected media. Drying racks will be employed as directed for temporary pads to permit parts to dry and be evaluated prior to use/re-use.

5.1.3 Decontamination Activities at Remote Sample Locations

When sampling at remote locations sampling devices such as trowels, pumps/tubing should be evacuated of potentially contaminated media to the extent possible. This equipment should be wrapped in plastic for transport to the temporary/centralized decontamination location for final cleaning and disposition.

5.2 Equipment Decontamination Procedures

The following represents procedures to be employed for the decontamination of equipment that may have contacted and/or accumulated contamination through site investigation activities.

5.2.1 Monitoring Well Sampling Equipment

5.2.1.1 Groundwater sampling pumps – This includes pumps inserted into the monitoring well such as Bladder pumps, Whale pumps, Redi-Flo, reusable bailers, etc.

1) Evacuate to the extent possible, any purge water within the pump.

2) Scrub using soap and water and/or steam clean the outside of the pump and tubing, where applicable.

3) Insert the pump and tubing into a clean container of soapy water. Pump a sufficient amount of soapy water through the pump to flush any residual purge water. Once flushed, circulate soapy water through the pump to ensure the internal components are thoroughly flushed.

4) Remove the pump and tubing from the container, rinse external components using tap water. Insert the pump and tubing into a clean container of tap water. Pump a sufficient amount of tap water through the pump to evacuate all of the soapy water (until clear).

5) Rinse equipment with pesticide grade isopropanol

6) Repeat item #4 using deionized water through the hose to flush out the tap water and solvent residue as applicable*.

7) Drain residual deionized water to the extent possible, allow components to air dry.

8) Wrap pump in aluminum foil or a clear clean plastic bag for storage.

5.2.1.2 Electronic Water Level Indicators/Sounders/Tapes

During water level measurements, rinsing with the extracted tape and probe with deionized water and wiping the surface of the extracted tape is acceptable. However, periodic full decontamination should be conducted as indicated below.

---

* - The solvent should be employed when samples contain oil, grease, PAHs, PCBs, and other hard to remove materials. If these are not of primary concern, the solvent step may be omitted. In addition, do not rinse PE, PVC, and associated tubing with solvents.

1) Wash with soap and water
2) Rinse with tap water
3) Rinse with deionized water

Note: In situations where oil, grease, free product, other hard to remove materials are encountered probes and exposed tapes should be washed in hot soapy water.

5.2.1.3 Miscellaneous Equipment

Miscellaneous equipment including analytical equipment (water quality testing equipment) should be cleaned per manufacturer's instructions. This generally includes wiping down the sensor housing and rinsing with tap and deionized water.

Coolers/Shipping Containers employed to ship samples are received from the lab in a variety of conditions from marginal to extremely poor. Coolers should be evaluated prior to use for

- Structural integrity – Coolers missing handles or having breaks within the outer housing should be removed and not used. Notify the laboratory that the risk of shipping samples will not be attempted and request a replacement unit.

- Cleanliness – As per protocol only volatile organic samples are accompanied by a trip blank. If a cooler's cleanliness is in question (visibly dirty/stained) or associated with noticeable odors it should be decontaminated prior to use.

  1) Wash with soap and water
  2) Rinse with tap water
  3) Dry

If these measures fail to clean the cooler to an acceptable level, remove the unit from use as a shipping container and notify the laboratory to provide a replacement unit.

5.2.2 Down-Hole Drilling Equipment

This includes any portion of the drill rig that is over the borehole including auger flights, drill stems, rods, and associated tooling that would extend over the borehole. This procedure is to be employed prior to initiating the drilling/sampling activity, then between locations.

1) Remove all soils to the extent possible using shovels, scrapers, etc. to remove loose soils.
2) Through a combination of scrubbing using soap and water and/or steam cleaning remove visible dirt/soils.
3) Rinse with tap water.
4) Rinse equipment with pesticide grade isopropanol
5) To the extent possible allow components to air dry.
6) Wrap or cover equipment in clear plastic until it is time to be used.

5.2.3 Soil/Sediment Sampling Equipment

This consists of soil sampling equipment including but not limited to hand augers, stainless steel trowels/spoons, bowls, dredges, scoops, split spoons, Macro Core samplers, etc.

1) Remove all soils to the extent possible.

2) Through a combination of scrubbing using soap and water and/or steam cleaning remove visible dirt/soils.

3) Rinse with tap water.

4) Rinse equipment with pesticide grade isopropanol

5) Rinse with deionized water

6) To the extent possible allow components to air dry.

7) If the device is to be used immediately, screen with a PID/FID to insure all solvents (if they were used) and trace contaminants have been adequately removed.

8) Once these devices have been dried wrap in aluminum foil for storage until it is time to be used.

5.3 Contact Waste/Materials

During the course of field investigations disposable/single use equipment becomes contaminated. These items include tubing, trowels, PPE (gloves, overboots, splash suits, etc.) broken sample containers.

With the exception of the broken glass, single use articles should be cleaned (washed and rinsed) of visible materials and disposed of as normal refuse. The exception to this rule is that extremely soiled materials that cannot be cleaned should be containerized for disposal in accordance with applicable federal state and local regulations.

5.3.1 Decontamination Solutions

All waste 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 waste solution volumes could vary from a few gallons to several hundred gallons in cases where large equipment required cleaning.

Containerized waste rinse solutions are best stored in 55-gallon drums (or equivalent containers) that can be sealed until ultimate disposal at an approved facility. These containers must be appropriately labeled.

5.4 Decontamination Evaluation

Determining the effectiveness of the decontamination process will be accomplished in the following manner

- Visual Evaluation – A visual evaluation will be conducted to insure the removal of particulate matter. This will be done to insure that the washing/rinsing process is working as intended.

- Instrument Screening – A PID and/or an FID should be used to evaluate the presence of the contaminants or solvents used in the cleaning process. The air intake of the instrument should be passed over the article to be evaluated. A positive detection requires a repeat the decontamination process. It should be noted that the instrument scan is only viable if the contaminants are detectable within the instruments capabilities.

- Rinsate Blanks – It is recommended that Rinsate samples be collected to
  - Evaluate the decontamination procedure representing different equipment applications (pumps versus drilling equipment) and different decontamination applications.
  - Single use disposable equipment – The number of samples should represent different types of equipment as well as different Lot Numbers of single use articles.

5.5 Field Blank Frequency

The collection and the frequency of collection of rinsate samples are as follows:

- Per decontamination method
- Per disposable article/Batch number of disposable articles

The frequency of field blank collection is also discussed in the Quality Assurance Project Plan.

It is recommended that an initial rinsate sample be collected early in the project to ensure that the decontamination process is functioning properly and in an effort to avoid using a contaminated batch of single use articles. It is recommended that a follow up sample be collected during the execution of the project to insure those conditions do not change. Lastly, rinsate samples collection may be driven by types of and/or contaminant levels. Hard to remove contaminants, oils/greases, some PAHs/PCBs, etc. may also support the collection of additional rinsates due to the obvious challenges to the decontamination process. This is a field consideration to be determined by the FOL.

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1.0 PURPOSE

Utilities such as electric service lines, natural or propane gas lines, water and sewage lines, telecommunications, and steam lines are very often in the immediate vicinity of work locations. Contact with underground or overhead utilities can have serious consequences including employee injury/fatality, property and equipment damage, substantial financial impacts, and loss of utility service to users.

The purpose of this procedure is to provide minimum requirements and technical guidelines regarding the appropriate procedures to be followed when performing subsurface and overhead utility locating services. It is the policy of Tetra Tech NUS, Inc. (TtNUS) to provide a safe and healthful work environment for the protection of our employees. The purpose of this Standard Operating Procedure (SOP) is to aid in achieving the objectives of this policy, to present the acceptable procedures pertaining to utility locating and excavation clearance activities, and to present requirements and restrictions relevant to these types of activities. This SOP must be reviewed by any employee potentially involved with underground or overhead utility locating and avoidance activities.

2.0 SCOPE

This procedure applies to all TtNUS field activities where there may be potential contact with underground or overhead utilities. This procedure provides a description of the principles of operation, instrumentation, applicability, and implementability of typical methods used to determine the presence and avoidance of contact with utility services. This procedure is intended to assist with work planning and scheduling, resource planning, field implementation, and subcontractor procurement. Utility locating and excavation clearance requires site-specific information prior to the initiation of any such activities on a specific project. This SOP is not intended to provide a detailed description of methodology and instrument operation. Specialized expertise during both planning and execution of several of the methods presented may also be required.

3.0 GLOSSARY

Electromagnetic Induction (EMI) Survey - A geophysical exploration method whereby electromagnetic fields are induced in the ground and the resultant secondary electromagnetic fields are detected as a measure of ground conductivity.

Magnetometer – A device used for precise and sensitive measurements of magnetic fields.

Magnetic Survey – A geophysical survey method that depends on detection of magnetic anomalies caused by the presence of buried ferromagnetic objects.

Metal Detection – A geophysical survey method that is based on electromagnetic coupling caused by underground conductive objects.

Vertical Gradiometer – A magnetometer equipped with two sensors that are vertically separated by a fixed distance. It is best suited to map near surface features and is less susceptible to deep geologic features.

Ground Penetrating Radar – Ground Penetrating Radar (GPR) involves specialized radar equipment whereby a signal is sent into the ground via a transmitter. Some portion of the signal will be reflected from the subsurface material, which is then recorded with a receiver and electronically converted into a graphic picture.

4.0 RESPONSIBILITIES

Project Manager (PM)/Task Order Manager (TOM) - Responsible for ensuring that all field activities are conducted in accordance with this procedure.

Site Manager (SM)/Field Operations Leader (FOL) - Responsible for the onsite verification that all field activities are performed in compliance with approved SOPs or as otherwise directed by the approved project plan(s).

Site Health & Safety Officer (SHSO) – Responsible to provide technical assistance and verify full compliance with this SOP. The SHSO is also responsible for reporting any deficiencies to the Corporate Health and Safety Manager (HSM) and to the PM/TOM.

Health & Safety Manager (HSM) – Responsible for preparing, implementing, and modifying corporate health and safety policy and this SOP.

Site Personnel – Responsible for performing their work activities in accordance with this SOP and the TtNUS Health and Safety Policy.

5.0 PROCEDURES

This procedure addresses the requirements and technical procedures that must be performed to minimize the potential for contact with underground and overhead utility services. These procedures are addressed individually from a buried and overhead standpoint.

5.1 Buried Utilities

Buried utilities present a heightened concern because their location is not typically obvious by visual observation, and it is common that their presence and/or location is unknown or incorrectly known on client properties. This procedure must be followed prior to beginning any subsurface probing or excavation that might potentially be in the vicinity of underground utility services. In addition, the Utility Clearance Form (Attachment 3) must be completed for every location or cluster of locations where intrusive activities will occur.

Where the positive identification and de-energizing of underground utilities cannot be obtained and confirmed using the following steps, the PM/TOM is responsible for arranging for the procurement of a qualified, experienced, utility locating subcontractor who will accomplish the utility location and demarcation duties specified herein.

1. A comprehensive review must be made of any available property maps, blue lines, or as-builts prior to site activities. Interviews with local personnel familiar with the area should be performed to provide additional information concerning the location of potential underground utilities. Information regarding utility locations shall be added to project maps upon completion of this exercise.

2., A visual site inspection must be performed to compare the site plan information to actual field conditions. Any findings must be documented and the site plan/maps revised. The area(s) of proposed excavation or other subsurface activities must be marked at the site in white paint or pin flags to identify those locations of the proposed intrusive activities. The site inspection should focus on locating surface indications of potential underground utilities. Items of interest include the presence of nearby area lights, telephone service, drainage grates, fire hydrants, electrical service vaults/panels, asphalt/concrete scares and patches, and topographical depressions. Note the location of any emergency shut off switches. Any additional information regarding utility

locations shall be added to project maps upon completion of this exercise and returned to the PM/TOM.

3. If the planned work is to be conducted on private property (e.g., military installations, manufacturing facilities, etc.) the FOL must identify and contact appropriate facility personnel (e.g., public works or facility engineering) before any intrusive work begins to inquire about (and comply with) property owner requirements. It is important to note that private property owners may require several days to several weeks advance notice prior to locating utilities.

4. If the work location is on public property, the state agency that performs utility clearances must be notified (see Attachment 1). State "one-call" services must be notified prior to commencing fieldwork per their requirements. Most one-call services require, by law, 48- to 72-hour advance notice prior to beginning any excavation. Such services typically assign a "ticket" number to the particular site. This ticket number must be recorded for future reference and is valid for a specific period of time, but may be extended by contacting the service again. The utility service will notify utility representatives who then mark their respective lines within the specified time frame. It should be noted that most military installations own their own utilities but may lease service and maintenance from area providers. Given this situation, "one call" systems may still be required to provide location services on military installations.

5. Utilities must be identified and their locations plainly marked using pin flags, spray paint, or other accepted means. The location of all utilities must be noted on a field sketch for future inclusion on project maps. Utility locations are to be identified using the following industry-standard color code scheme, unless the property owner or utility locator service uses a different color code:

white	excavation/subsurface investigation location
red	electrical
yellow	gas, oil, steam
orange	telephone, communications
blue	water, irrigation, slurry
green	sewer, drain

6. Where utility locations are not confirmed with a high degree of confidence through drawings, schematics, location services, etc., the work area must be thoroughly investigated prior to beginning the excavation. In these situations, utilities must be identified using safe and effective methods such as passive and intrusive surveys, or the use of non-conductive hand tools. Also, in situations where such hand tools are used, they should always be used in conjunction with suitable detection equipment, such as the items described in Section 6.0 of this SOP. Each method has advantages and disadvantages including complexity, applicability, and price. It also should be noted that in some states, initial excavation is required by hand to a specified depth.

7. At each location where trenching or excavating will occur using a backhoe or other heavy equipment, and where utility identifications and locations cannot be confirmed prior to groundbreaking, the soil must be probed using a device such as a tile probe which is made of non-conductive material such as fiberglass. If these efforts are not successful in clearing the excavation area of suspect utilities, hand shoveling must be performed for the perimeter of the intended excavation.

8. All utilities uncovered or undermined during excavation must be structurally supported to prevent potential damage. Unless necessary as an emergency corrective measure, TtNUS shall not make any repairs or modifications to existing utility lines without prior permission of the utility owner, property owner, and Corporate HSM. All repairs require that the line be locked-out/tagged-out prior to work.

5.2 Overhead Power Lines

If it is necessary to work within the minimum clearance distance of an overhead power line, the overhead line must be de-energized and grounded, or re-routed by the utility company or a registered electrician. If protective measures such as guarding, isolating, or insulating are provided, these precautions must be adequate to prevent employees from contacting such lines directly with any part of their body or indirectly though conductive materials, tools, or equipment.

The following table provides the required minimum clearances for working in proximity to overhead power lines.

Nominal Voltage	Minimum Clearance
0 -50 kV	10 feet, or one mast length; whichever is greater
50+ kV	10 feet plus 4 inches for every 10 kV over 50 kV or 1.5 mast lengths; whichever is greater

6.0 UNDERGROUND LOCATING TECHNIQUES

A variety of supplemental utility locating approaches are available and can be applied when additional assurance is needed. The selection of the appropriate method(s) to employ is site-specific and should be tailored to the anticipated conditions, site and project constraints, and personnel capabilities.

6.1 Geophysical Methods

Geophysical methods include electromagnetic induction, magnetics, and ground penetrating radar. Additional details concerning the design and implementation of electromagnetic induction, magnetics, and ground penetrating radar surveys can be found in one or more of the TtNUS SOPs included in the References (Section 8.0).

Electromagnetic Induction

Electromagnetic Induction (EMI) line locators operate either by locating a background signal or by locating a signal introduced into the utility line using a transmitter. A utility line acts like a radio antenna, producing electrons, which can be picked up with a radiofrequency receiver. Electrical current carrying conductors have a 60HZ signal associated with them. This signal occurs in all power lines regardless of voltage. Utilities in close proximity to power lines or used as grounds may also have a 60HZ signal, which can be picked up with an EM receiver. A typical example of this type of geophysical equipment is an EM-61.

EMI locators specifically designed for utility locating use a special signal that is either indirectly induced onto a utility line by placing the transmitter above the line or directly induced using an induction clamp. The clamp induces a signal on the specific utility and is the preferred method of tracing since there is little chance of the resulting signals being interfered with. A good example of this type of equipment is the Schonstedt® MAC-51B locator. The MAC-51B performs inductively traced surveys, simple magnetic locating, and traced nonmetallic surveys.

When access can be gained inside a conduit to be traced, a flexible insulated trace wire can be used. This is very useful for non-metallic conduits but is limited by the availability of gaining access inside the pipe.

Magnetics

Magnetic locators operate by detecting the relative amounts of buried ferrous metal. They are incapable of locating or identifying nonferrous utility lines but can be very useful for locating underground storage tanks (UST's), steel utility lines, and buried electrical lines. A typical example of this type of equipment is the Schonstedt® GA-52Cx locator. The GA-52Cx is capable of locating 4-inch steel pipe up to 8 feet deep.

Non-ferrous lines are often located by using a typical plumbing tool (snake) fed through the line. A signal is then introduced to the snake that is then traced.

Ground Penetrating Radar

Ground Penetrating Radar (GPR) involves specialized radar equipment whereby a signal is sent into the ground via a transmitter. Some portion of the signal will be reflected from the subsurface material, which is then recorded with a receiver and electronically converted into a graphic picture. In general, an object which is harder than the surrounding soil will reflect a stronger signal. Utilities, tunnels, UST's, and footings will reflect a stronger signal than the surrounding soil. Although this surface detection method may determine the location of a utility, this method does not specifically identify utilities (i.e., water vs. gas, electrical vs. telephone); hence, verification may be necessary using other methods. This method is somewhat limited when used in areas with clay soil types or with a high water table.

6.2 Passive Detection Surveys

Acoustic Surveys

Acoustic location methods are generally most applicable to waterlines or gas lines. A highly sensitive Acoustic Receiver listens for background sounds of water flowing (at joints, leaks, etc.) or to sounds introduced into the water main using a transducer. Acoustics may also be applicable to determine the location of plastic gas lines.

Thermal Imaging

Thermal (i.e., infrared) imaging is a passive method for detecting the heat emitted by an object. Electronics in the infrared camera convert subtle heat differentials into a visual image on the viewfinder or a monitor. The operator does not look for an exact temperature; rather they look for heat anomalies (either elevated or suppressed temperatures) characteristic of a potential utility line.

The thermal fingerprint of underground utilities results from differences in temperature between the atmosphere and the fluid present in a pipe or the heat generated by electrical resistance. In addition, infrared scanners may be capable of detecting differences in the compaction, temperature and moisture content of underground utility trenches. High-performance thermal imagery can detect temperature differences to hundredths of a degree.

6.3 Intrusive Detection Surveys

Vacuum Excavation

Vacuum excavation is used to physically expose utility services. The process involves removing the surface material over approximately a 1' x 1' area at the site location. The air-vacuum process proceeds with the simultaneous action of compressed air-jets to loosen soil and vacuum extraction of the resulting

debris. This process ensures the integrity of the utility line during the excavation process, as no hammers, blades, or heavy mechanical equipment comes into contact with the utility line, eliminating the risk of damage to utilities. The process continues until the utility is uncovered. Vacuum excavation can be used at the proposed site location to excavate below the "utility window" which is usually 8 feet.

Hand Excavation

When the identification and location of underground utilities cannot be positively confirmed through document reviews and/or other methods, borings and excavations may be cleared via the use of non-conductive hand tools. This should always be done in conjunction with the use of detection equipment. This would be required for all locations where there is a potential to impact buried utilities. The minimum hand-excavation depth that must be reached is to be determined considering the geographical location of the work site. This approach recognizes that the placement of buried utilities is influenced by frost line depths that vary by geographical region. Attachment 2 presents frost line depths for the regions of the contiguous United States. At a minimum, hand excavation depths must be at least to the frost line depth (see Attachment 2) plus two (2) feet, but never less than 4 feet below ground surface (bgs). For hand excavation, the hole created must be reamed large enough to be at least the diameter of the drill rig auger or bit prior to drilling. For soil gas surveys, the survey probe shall be placed as close as possible to the cleared hand excavation. It is important to note that a post-hole digger must not be used in this type of hand excavation activity.

Tile Probe Surveys

For some soil types, site conditions, and excavation requirements, non-conductive tile probes may be used. A tile probe is a "T"-handled rod of varying lengths that can be pushed into the soil to determine if any obstructions exist at that location. Tile probes constructed of fiberglass or other nonconductive material are readily-available from numerous vendors. Tile probes must be performed to the same depth requirements as previously specified. As with other types of hand excavating activities, the use of a non-conductive tile probe, should always be in conjunction with suitable utility locating detection equipment.

7.0 INTRUSIVE ACTIVITIES SUMMARY

The following list summarizes the activities that must be performed prior to beginning subsurface activities:

1. Map and mark all subsurface locations and excavation boundaries using white paint or markers specified by the client or property owner.

2. Notify the property owner and/or client that the locations are marked. At this point, drawings of locations or excavation boundaries shall be provided to the property owner and/or client so they may initiate (if applicable) utility clearance.

   Note: Drawings with confirmed locations should be provided to the property owner and/or client as soon as possible to reduce potential time delays.

3. Notify "One Call" service. If possible, arrange for an appointment to show the One Call representative the surface locations or excavation boundaries in person. This will provide a better location designation to the utilities they represent. You should have additional drawings should you need to provide plot plans to the One Call service.

4. Implement supplemental utility detection techniques as necessary and appropriate to conform utility locations or the absence thereof.

5. Complete Attachment 3, Utility Clearance Form. This form should be completed for each excavation location. In situations where multiple subsurface locations exist within the close proximity of one another, one form may be used for multiple locations provided those locations are noted on the Utility Clearance Form. Upon completion, the Utility Clearance Form and revised/annotated utility location map becomes part of the project file.

8.0 REFERENCES

OSHA Letter of Interpretation, Mr. Joseph Caldwell, Attachment 4
OSHA 29 CFR 1926(b)(2)
OSHA 29 CFR 1926(b)(3)
TtNUS Utility Locating and Clearance Policy
TtNUS SOP GH-3.1; Resistivity and Electromagnetic Induction
TtNUS SOP GH-3.2; Magnetic and Metal Detection Surveys
TtNUS SOP GH-3.4; Ground-penetrating Radar Surveys

ATTACHMENT 1
LISTING OF UNDERGROUND UTILITY CLEARANCE RESOURCES

American Public Works Association
2345 Grand Boulevard, Suite 500, Kansas City, MO 64108-2625
Phone (816) 472-6100 • Fax (816) 472-1610
Web www.apwa.net • E-mail apwa@apwa.net

ONE-CALL SYSTEMS INTERNATIONAL CONDENSED DIRECTORY

Alabama
Alabama One-Call
1-800-292-8525

Alaska
Locate Call Center of Alaska, Inc.
1-800-478-3121

Arizona
Arizona Blue Stake
1-800-782-5348

Arkansas
Arkansas One Call System, Inc.
1-800-482-8998

California
Underground Service Alert North
1-800-227-2600
Underground Service Alert of Southern California
1-800-227-2600

Colorado
Utility Notification Center of Colorado
1-800-922-1987

Connecticut
Call Before You Dig
1-800-922-4455

Delaware
Miss Utility of Delmarva
1-800-282-8555

Florida
Sunshine State One-Call of Florida, Inc.
1-800-432-4770

Georgia
Underground Protection Center, Inc.
1-800-282-7411

Hawaii
Underground Service Alert North
1-800-227-2600

Idaho
Dig Line Inc.
1-800-342-1585
Kootenai County One-Call
1-800-428-4950
Shoshone - Benewah One-Call
1-800-398-3285

Illinois
JULIE, Inc.
1-800-892-0123
Digger (Chicago Utility Alert Network)
312-744-7000

Indiana
Indiana Underground Plant Protection Service
1-800-382-5544

Iowa
Iowa One-Call
1-800-292-8989

Kansas
Kansas One-Call System, Inc.
1-800-344-7233

Kentucky
Kentucky Underground Protection Inc.
1-800-752-6007

Louisiana
Louisiana One Call System, Inc.
1-800-272-3020

Maine
Dig Safe System, Inc.
1-888-344-7233

Maryland
Miss Utility
1-800-257-7777
Miss Utility of Delmarva
1-800-282-8555

Massachusetts
Dig Safe System, Inc.
1-888-344-7233

Michigan
Miss Dig System, Inc.
1-800-482-7171

Minnesota
Gopher State One Call
1-800-252-1166

Mississippi
Mississippi One-Call System, Inc
1-800-227-6477

Missouri
Missouri One-Call System, Inc.
1-800-344-7483

Montana
Utilities Underground Protection Center
1-800-424-5555
Montana One Call Center
1-800-551-8344

Nebraska
Diggers Hotline of Nebraska
1-800-331-5666

Nevada
Underground Service Alert North
1-800-227-2600

New Hampshire
Dig Safe System, Inc.
1-888-344-7233

New Jersey
New Jersey One Call
1-800-272-1000

New Mexico
New Mexico One Call System, Inc.
1-800-321-2537
Las Cruces- Dona Ana Blue Stakes
1-888-526-0400

New York
Dig Safely New York
1-800-962-7962
New York City- Long Island One Call Center
1-800-272-4480

North Carolina
The North Carolina One-Call Center, Inc.
1-800-632-4949

North Dakota
North Dakota One-Call
1-800-795-0555

Ohio
Ohio Utilities Protection Service
1-800-362-2764
Oil & Gas Producers Underground Protect'n Svc
1-800-925-0988

Oklahoma
Call Okie
1-800-522-6543

Oregon
Oregon Utility Notification Center/One Call Concepts
1-800-332-2344

Pennsylvania
Pennsylvania One Call System, Inc.
1-800-242-1776

Rhode Island
Dig Safe System, Inc.
1-888-344-7233

South Carolina
Palmetto Utility Protection Service Inc.
1-888-721-7877

South Dakota
South Dakota One Call
1-800-781-7474

Tennessee
Tennessee One-Call System, Inc.
1-800-351-1111

ATTACHMENT 1 (Continued)

Texas
Texas One Call System
1-800-245-4545
Texas Excavation Safety System, Inc.
1-800-344-8377
Lone Star Notification Center
1-800-669-8344

Utah
Blue Stakes of Utah
1-800-662-4111

Vermont
Dig Safe System, Inc.
1-888-344-7233

Virginia
Miss Utility of Virginia
1-800-552-7001
Miss Utility (Northern Virginia)
1-800-257-7777

Washington
Utilities Underground Location Center
1-800-424-5555
Northwest Utility Notification Center
1-800-553-4344
Inland Empire Utility Coordinating Council
509-456-8000

West Virginia
Miss Utility of West Virginia, Inc.
1-800-245-4848

Wisconsin
Diggers Hotline, Inc.
1-800-242-8511

Wyoming
Wyoming One-Call System, Inc.
1-800-348-1030
Call Before You Dig of Wyoming
1-800-849-2476

District of Columbia
Miss Utility
1-800-257-7777

Alberta
Alberta One-Call Corporation
1-800-242-3447

British Columbia
BC One Call
1-800-474-6886

Ontario
Ontario One-Call System
1-800-400-2255

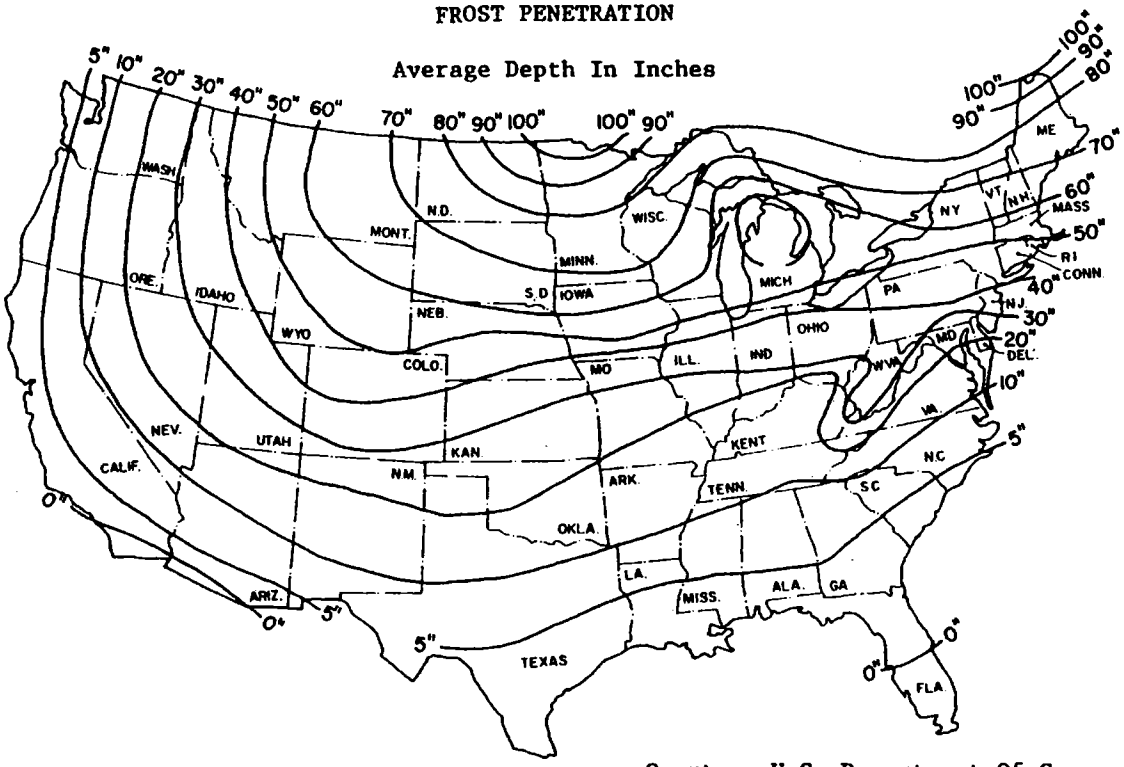
Quebec
Info-Excavation
1-800-663-9228

ATTACHMENT 2

FROST LINE PENETRATION DEPTHS BY GEOGRAPHIC LOCATION

FROST PENETRATION

Average Depth In Inches



Courtesy U.S. Department Of Commerce

ATTACHMENT 3
UTILITY CLEARANCE FORM

Client: _____ Project Name: _____

Project No.: _____ Completed By: _____

Location Name: _____ Work Date: _____

Excavation Method/Overhead Equipment: _____

1. Underground Utilities — Circle One

a)	Review of existing maps?	yes	no	N/A
b)	Interview local personnel?	yes	no	N/A
c)	Site visit and inspection?	yes	no	N/A
d)	Excavation areas marked in the field?	yes	no	N/A
e)	Utilities located in the field?	yes	no	N/A
f)	Located utilities marked/added to site maps?	yes	no	N/A
g)	Client contact notified Name _____ Telephone: _____ Date: _____	yes	no	N/A
g)	State One-Call agency called? Caller: _____ Ticket Number: _____ Date: _____	yes	no	N/A
h)	Geophysical survey performed? Survey performed by: _____ Method: _____ Date: _____	yes	no	N/A
i)	Hand excavation performed (with concurrent use of utility detection device)? Completed by: _____ Total depth: _____ feet Date: _____	yes	no	N/A
j)	Trench/excavation probed? Probing completed by: _____ Depth/frequency: _____ Date: _____	yes	no	N/A

2. Overhead Utilities — Present Absent

a)	Determination of nominal voltage	yes	no	N/A
b)	Marked on site maps	yes	no	N/A
c)	Necessary to lockout/insulate/re-route	yes	no	N/A
d)	Document procedures used to lockout/insulate/re-route	yes	no	N/A
e)	Minimum acceptable clearance (SOP Section 5.2): _____			

3. Notes:

_____

_____

_____

Approval:

_____ _____

Site Manager/Field Operations Leader Date

c: PM/Project File
Program File

ATTACHMENT 4
OSHA LETTER OF INTERPRETATION

Mr. Joseph Caldwell
Consultant
Governmental Liaison
Pipeline Safety Regulations
211 Wilson Boulevard
Suite 700
Arlington, Virginia 22201

Re: Use of hydro-vacuum or non-conductive hand tools to locate underground utilities.

Dear Mr. Caldwell:

In a letter dated July 7, 2003, we responded to your inquiry of September 18, 2002, regarding the use of hydro-vacuum equipment to locate underground utilities by excavation. After our letter to you was posted on the OSHA website, we received numerous inquiries that make it apparent that aspects of our July 7 letter are being misunderstood. In addition, a number of industry stakeholders, including the National Utility Contractors Association (NUCA), have provided new information regarding equipment that is available for this work.

To clarify these issues, we are withdrawing our July 7 letter and issuing this replacement response to your inquiry.

Question: *Section 1926.651 contains several requirements that relate to the safety of employees engaged in excavation work. Specifically, paragraphs (b)(2) and (b)(3) relate in part to the safety of the means used to locate underground utility installations that, if damaged during an uncovering operation, could pose serious hazards to employees.*

Under these provisions, what constitutes an acceptable method of uncovering underground utility lines, and further, would the use of hydro-vacuum excavation be acceptable under the standard?

Answer

Background

Two sections of 29 CFR 1926 Subpart P (Excavations), 1926.651(Specific excavation requirements), govern methods for uncovering underground utility installations. Specifically, paragraph (b)(2) states:

> When utility companies or owners cannot respond to a request to locate underground utility installations within 24 hours * * * or cannot establish the exact location of these installations, the employer may proceed, provided the employer does so with caution, and provided detection equipment or other acceptable means to locate utility installations are used. (emphasis added).

Paragraph (b)(3) provides:

ATTACHMENT 4 (Continued)

> When excavation operations approach the estimated location of underground installations, the exact location of the installations shall be determined by safe and acceptable means. (emphasis added).

Therefore, "acceptable means" must be used where the location of the underground utilities have not been identified by the utility companies and detection equipment is not used.

Subpart P does not contain a definition of either "other acceptable means" or "safe and acceptable means." The preambles to both the proposed rule and the final rule discussed the rationale behind the wording at issue. For example, the preamble to the proposed rule, 52 Fed. Reg. 12301 (April 15, 1987), noted that a 1972 version of this standard contained language that specified "careful probing or hand digging" as the means to uncover utilities. The preamble then noted that an amendment to the 1972 standard later deleted that language "to allow other, *equally effective means* of locating such installations." The preamble continued that in the 1987 proposed rule, OSHA again proposed using language in section (b)(3) that would provide another example of an acceptable method of uncovering utilities that could be used *where the utilities have not been marked and detection equipment is not being used* – "probing with hand-held tools." This method was rejected in the final version of 29 CFR 1926. As OSHA explained in the preamble to the final rule, 54 Fed. Reg. 45916 (October 31, 1989):

> OSHA received two comments * * * and input from ACCSH [OSHA's Advisory Committee on Construction Safety and Health] * * * on this provision. All commenters recommended dropping 'such as probing with hand-held tools' from the proposed provision, because this could create a hazard to employees by damaging the installation or its insulation.

In other words, the commenters objected to the use of hand tools being used unless detection equipment was used in conjunction with them. OSHA then concluded its discussion relative to this provision by agreeing with the commentators and ultimately not including any examples of "acceptable means" in the final provision.

Non-conductive hand tools are permitted

This raises the question of whether the standard permits the use of hand tools alone -- without also using detection equipment. NUCA and other industry stakeholders have recently informed us that non-conductive hand tools that are appropriate to be used to locate underground utilities are now commonly available.

Such tools, such as a "shooter" (which has a non-conductive handle and a snub nose) and non-conductive or insulated probes were not discussed in the rulemaking. Since they were not considered at that time, they were not part of the class of equipment that was thought to be unsafe for this purpose. Therefore, we conclude that the use of these types of hand tools, when used with appropriate caution, is an "acceptable means" for locating underground utilities.

ATTACHMENT 4 (Continued)

Hydro-vacuum excavation

It is our understanding that some hydro-vacuum excavation equipment can be adjusted to use a minimum amount of water and suction pressure. When appropriately adjusted so that the equipment will not damage underground utilities (especially utilities that are particularly vulnerable to damage, such as electrical lines), use of such equipment would be considered a "acceptable means" of locating underground utilities. However, if the equipment cannot be sufficiently adjusted, then this method would not be acceptable under the standard.

Other technologies

We are not suggesting that these are the only devices that would be "acceptable means" under the standard. Industry stakeholders have informed us that there are other types of special excavation equipment designed for safely locating utilities as well.

We apologize for any confusion our July 7 letter may have caused. If you have further concerns or questions, please feel free to contact us again by fax at: U.S. Department of Labor, OSHA, Directorate of Construction, Office of Construction Standards and Compliance Assistance, fax # 202-693-1689. You can also contact us by mail at the above office, Room N3468, 200 Constitution Avenue, N.W., Washington, D.C. 20210, although there will be a delay in our receiving correspondence by mail.

Sincerely,

Russell B. Swanson, Director
Directorate of Construction

NOTE: OSHA requirements are set by statute, standards and regulations. Our interpretation letters explain these requirements and how they apply to particular circumstances, but they cannot create additional employer obligations. This letter constitutes OSHA=s interpretation of the requirements discussed. Note that our enforcement guidance may be affected by changes to OSHA rules. Also, from time to time we update our guidance in response to new information. To keep apprised of such developments, you can consult OSHA's website at http://www.osha.gov.

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1.0 GENERAL

This Standard Operating Procedure (SOP) was prepared in accordance with applicable U.S. Army Corps of Engineers procedures and policies governing field activities requiring Unexploded Ordnance (UXO) and Chemical Warfare Material (CWM) operations. All personnel conducting operations under this SOP must read and understand applicable parts of references listed in paragraph 9.1 below prior to commencing any work described within this SOP. Other documents supporting this SOP include project-specific Work Plans and Health and Safety Plans which are prepared for the purpose of accomplishing work that contain a UXO or CWM component.

2.0 PURPOSE

This SOP applies to all operations involving UXO and/or CWM support during field operations at various sites where Tetra Tech NUS (TtNUS) personnel are present. It provides procedural requirements for any activity involving UXO and CWM, as well as detailed procedures for the location, identification, documentation, and emergency response actions pertaining to UXO/CWM activities.

3.0 APPLICABILITY

This SOP applies to persons who may visit any site where TtNUS is performing work that involve some UXO or CWM component. Compliance the content of this SOP is mandatory for all TtNUS personnel, subcontractors, and visitors to any site where UXO/CWM activities are in progress.

4.0 RESPONSIBILITIES

Project Manager

Effective implementation of this SOP at the project level will be the ultimate responsibility of the assigned TtNUS Project Manager. The Project Manager is responsible for ensuring that all applicable rules and regulations are complied with, and that all necessary safety precautions are taken to conduct operations in accordance with this SOP. To fulfill this responsibility, the assigned Project Manager is required to ensure that appropriately-qualified technical staff are involved in all stages of project planning and field work, as well as for ensuring that appropriate resources are marshaled and used on his/her assigned projects. For projects involving UXO and/or CWM, this will involve ensuring that a suitably qualified and experienced UXO technician and a site Health and Safety Officers are part of the project team. In some cases, the assigned UXO Technician may also serve as the project site Health and Safety Officer.

It is also the responsibility of the Project Manager to ensure that all personnel conducting field activities in accordance with this SOP have proper training (including hazard control briefings) and, if required, the proper certifications for the job being performed.

UXO Technician

A suitably qualified and experienced UXO Technician will be included as part of the project team where these types of concern are known or suspected to exist. The UXO Technician will be primarily responsible for advising the Project Manager on all UXO/CWM matters, including on the measures that will be necessary to effectively implement and adhere to this SOP. Other specific duties will include:

- Providing technical expertise and input into project planning activities and documents such as the project-specific Work Plan and Health and Safety Plan
- Clearing worksite areas of UXO/CWM concerns prior to the initiation of any other onsite activities

- Participating in the development and conductance of site specific training sessions and daily tailgate meetings to communicate UXO/CWM matters to the field personnel
- Maintaining a sound familiarity with the contents of this SOP, the contents of the references listed in section 9.1, and keeping current with new information and technology pertinent to UXO/CWM matters

Site Health and Safety Officer
A suitably qualified and experienced health and safety professional will be assigned to all projects that involve fieldwork. Project-specific responsibilities will include:

- Effectively implementing the requirements and restrictions specified in the project-specific Health and Safety Plan
- Ensuring that all personnel participating in onsite activities have satisfied all appropriate medical and training qualifications prior to participating in any onsite intrusive activities.
- Conduct initial site-specific health and safety training for all personnel participating in onsite activities prior to their participation in any onsite intrusive activities.
- Conduct tail-gate safety briefings prior to the initiation of all tasks, but not less than daily.
- On certain projects, these duties may be assigned to the UXO Technician. This would be considered acceptable on field projects where the predominant concern is contact with UXO and/or CWM, and minimal health concerns or requirements (e.g., chemical exposures or monitoring) exist.

Corporate Health and Safety Manager
Perform periodic project audits and evaluations to determine the ongoing effectiveness of this SOP to address UXO/CWM concerns, and review and evaluate this SOP to determine any revisions that are appropriate.

5.0 LOCATION OF OPERATIONS

Activities where UXO and/or CWM concerns may exist may be encountered in support of various TtNUS contracts, with potential project sites located throughout the continental United States and abroad. Wherever the installation/site is located, it will be necessary to ensure that project planning activities include collecting available historical information that may be pertinent to these issues, as well as identifying and addressing contract/client-specific requirements and any location-specific requirements (e.g., State, local-level, or host-nation requirements). A detailed site description, discussion of known and/or suspected contamination sources, and results of previous studies will be provided to field personnel as part of their field mobilization and initial site-specific training activities.

The initial project evaluation must involve the performance of a preliminary risk assessment, including the investigation of probable contaminants, potential transport pathways, the identification of potential receptors, and a preliminary evaluation of human health and environmental concerns. Preliminary identification of applicable or relevant and appropriate requirements (ARARs) will also be made available to field personnel conducting activities at the installation.

6.0 PERSONNEL QUALIFICATIONS AND REQUIREMENTS

6.1 Personnel Qualifications: Qualifications of those personnel actively involved in UXO/CWM operations shall be as follows:

a. UXO personnel shall be graduates of the U.S. Naval Explosive Ordnance Disposal (EOD) School, Indian Head, Maryland.

b. The Senior UXO Supervisor (SUXOS) for the operation will have been awarded the Master EOD Badge and have served at least 15 years in military EOD assignments, of which more than 10 years were in a supervisory position.

c. UXO personnel are responsible for maintaining current status with training and medical surveillance requirements, as specified in the project-specifc Health and Safety Plans and OSHA 29 CFR 1010.120, paragraphs (e) and (f).

6.2 Personnel Requirements: During any activity where the possibility that UXO and or CWM may be encountered (no matter how remote), the following requirements will be met:

a. One UXO-qualified technician will be required to support each field team engaged in operations in areas that might contain UXO/CWM.

b. One UXO-qualified technician will be present at the site during all activities to provide UXO/CWM support in the event their services are required.

7.0 PERSONNEL LIMITS

The activities to be conducted under most contracts will not normally be conducted in areas requiring maximum personnel limitations except for intrusive UXO activities. Work will not be permitted unless at least two persons are present in the work area. The provisions of 29 CFR 1910.120 concerning personnel qualifications and requirements will be followed while working on-site. Any additional personnel limitation requirements specified by the client or the project work location (e.g., state, local ordnance, host nation, etc.) will also be identified and adhered to at all times.

7.1 Personnel Limits for UXO Operations:

a. UXO Avoidance Operations – Two UXO Technicians (one UXO Technician III and one UXO Technician II)

b. UXO Intrusive Operations - Three UXO Technicians (one UXO Technician III and two UXO Technician II)

8.0 MATERIAL LIMITS

The properties and configurations of specific explosive materials are not addressed in this SOP. That level of detail is required to be addressed in project-specific Work Plans and Health and Safety Plans. This SOP must be maintained onsite along with these project-specific documents to aid in appropriate communication and implementation activities. Bulk liquids to be used for decontamination of equipment will be maintained in 2-gallon containers or less. Material Safety Data Sheets (MSDSs) will be kept on file in the TtNUS Command Post for any chemical substances brought to the project site by TtNUS and TtNUS subcontractor personnel. This is addressed in greater detail in section 5. of the TtNUS Health and Safety Guidance Manual.

9.0 SAFETY REQUIREMENTS

9.1 Referenced Safety Requirements: The safety requirements that apply to the UXO/CWM operations covered under this SOP are:

a. OSHA 29 CFR 1910.120 and 1926.65 – Hazardous Waste Operations and Emergency Response (HAZWOPER). Available online at: http://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=0&p_keyvalue=OSHA_Std_toc.html

b. US Army Corps of Engineers Engineering Regulation 385-1-92, *Safety and Occupational Health Document Requirements for Hazardous, Toxic and Radioactive Waste (HTRW) and Ordnance and Explosive Waste (OE) Activities.*

c. US Army Corps of Engineers Engineering Regulation (ER) 385-1-96, *Safety and Health Requirements.* Available on line at: http://www.usace.army.mil/publications/eng-manuals/em385-1-1/toc.htm.

d. US Army Corps of Engineers Engineering Pamphlet (EP) 1110-1-18, *Ordnance and Explosive (OE) Response.*

e. US Army Corps of Engineers Engineering Pamphlet (EP) 75-1-2, *Unexploded Ordnance Support for Hazardous, Toxic and Radioactive Waste and Construction Activities.*

f. US Army Corps of Engineers Engineering Pamphlet (EP) 75-1-3, *Chemical Warfare Material Response.*

g. US Army Technical Manual 9-1300-206 (TM 9-1300-206), *Ammunition and Explosive Hazards.*

h. Technical Manual 60A-1-1-31, *Explosive Ordnance Disposal Procedures, General Information on EOD Disposal Procedures.*

9.2 Specific Safety Requirements:

a. All site operations will be suspended if any site worker encounters an item of suspected UXO/CWM. Site work will remain suspended until the item is inspected and cleared by the UXO Technician.

b. All site operations will be suspended if so ordered by an authorized client representative (i.e., Installation Range Control and/or Safety Office).

c. A minimum of two UXO-qualified technicians will be present during all UXO-related activities.

d. Standard work practices as outlined in project-specific Health and Safety Plans and/or Work Plans will be observed.

9.3 Inherent UXO/CWM Hazards: UXO/CWM operations have inherent safety and health risks associated with the various field activities conducted. All planned activities will be conducted in accordance with the requirements of the references listed in Section 9.1 above, as safety is the primary consideration in all UXO/CWM activities. Every effort should be made to determine all hazards associated with the site through a thorough research of archives, past site/range uses, and any other available information. Some of the hazards to consider are:

a. Propellant, Explosives, and Pyrotechnics (PEP)
b. Depleted Uranium (DU)
c. White Phosphorus (WP)
d. Corrosive chemicals (acids and bases) and decontamination agents
e. Toxic gases, liquids and solids
f. Corroded and damaged containers, munitions bodies, drums, etc.
g. Fuze conditions
h. Etiological agents

10.0 PERSONAL PROTECTIVE EQUIPMENT (PPE)

Task-specific PPE will be identified in project-specific Health and Safety Plans. Typical PPE for project sites where the principle concern is for UXO/CWM will include the items listed below. Items marked with an asterisk (*) will be available and will be used as specified in the Health and Safety Plan and/or as determined by the TtNUS Site Health and Safety Officer.

a. Safety glasses

b. Safety shoes (and protective over boots or steel-toed rubber boots). NOTE: During geophysical survey operations, the UXO technicians will not wear steel-toed boots as they interfere with the magnetometer survey; however, around heavy equipment and activities where foot and overhead hazards may exist, steel-toed boots and hard hats will be worn.

c. Cotton clothing (with protective coveralls*)

d. Gloves (type to be specified for each project task in the Health and Safety Plan and/or by the site Health and Safety Officer)

e. Respiratory protection equipment* (29CFR1910.134)

f. Hearing protection*

g. Hard hats*

11.0 EMERGENCY RESPONSE AND CONTINGENCY PLANS

11. Emergency Contacts: The identification of (and means to communicate with) appropriate local emergency response agencies must be identified as part of project planning/mobilization activities, and these agencies must be contacted prior to the initiation of any onsite work. These initial communications must determine the capabilitities of these agencies to respond to foreseeable emergency situations, their willingness to respond, and their locations/driving directions/phone numbers. These details must be specified in the project-specific Health and Safety Plan and posted in the site Command Center/Field office.

At a minimum, the names and means of communication (phone number, radio frequency, etc.) of the following parties must be included in the project-specific Emergency Contacts procedure:

a. Local Emergency Fire Response that will respond (i.e., local Fire Department)

b. Emergency Medical Assistance (Hospital, Emergency Room, and ambulance service that will respond)

c. Installation Safety Office or other client safety/emergency response contact

d. Installation EOD Office/Detachment

e. Installation Environmental Office

The senior TtNUS managing employee onsite (Project Manager, Site Manager, Site Supervisor, Field Operations Leader) is responsible for initiating these calls in the event of an emergency where such support is needed. If the Project Manager is not onsite at the time of an emergency event, he/she must be added to the above list of contacts.

In the event of an emergency, all site personnel will be evacuated to a predetermined location away from the work place. Emergency Response Planning will be addressed in the project-specific Health and Safety Plan and will be in accordance with either 29 CFR 1910.38(a) or 1910.120(l). TtNUS will utilize the Installations Base Fire Protection and Emergency Services in emergencies or potential emergencies.

11.2 Contingency Plans: The following contingency plans will be implemented:

a. Pre-Planning – Upon arrival at the site/installation, the TtNUS Field Operations Leader (FOL) and/or the Site Safety Officer will meet with the Base or local Fire Protection Department, Base Security Personnel or local Police Department, and onsite and/or offsite Emergency services to notify them of the activities that are to be undertaken, when, and where. All site personnel will be required to follow established base/local emergency procedures and will rely on base/local services to handle emergency calls when needed.

b. Emergency Escape Procedures and Assignments – Upon notification of a site emergency that requires evacuation, all site personnel will proceed to predetermined locations based on emergency location and wind direction. An alternate assembly point will be designated in case personnel cannot reach these locations without danger to their lives and health. These primary and alternate escape routes and meeting places will be designated during the daily hazard control briefing. Personnel will be trained to remain at the assembly points until directed to either resume work or to leave the site.

c. Procedures to Account for Site Personnel – The site work force is typically small enough that accounting for personnel will not be a problem via visual head counting. On projects with larger field team sizes, roll calls will be taken using the daily sign in logs, logbook entries, or the tail-gate briefing sheets. Accounting for personnel will be the Field Operations Leader's responsibility.

d. Rescue and Medical Duties – TtNUS personnel will not be authorized to participate in emergency rescue operations. Typical first aid response equipment that is to be on hand at a project site includes suitable first aid kit, an emergency eye wash station, and Class ABC fire extinguishers.

e. Activation of Emergency Response Procedures - Should an emergency occur which requires the support of outside services, the appropriate contacts will be made by the senior TtNUS managing employee onsite (Project Manager, Site Manager, Site Supervisor, Field Operations Leader). A list of appropriate contacts will be posted at the Command Post. Cellular phones, land-line phones, or hand-held radios will be the primary means of communication.

f. Airborne Chemical Release Contingency Plan –

(1) Chemical Release Monitoring – every member of the site team will be responsible for observing and reporting any gross chemical releases or conditions that could lead to releases. Air monitoring will be performed as described in the project-specific Work Plans and Health and Safety Plans.

(2) Responses to Measured Airborne Chemical Releases – the readings on monitoring instrumentation will be compared to the action levels specified in the project-specific Work Plans and Health and Safety Plans. The primary purpose of appropriate real-time monitoring instruments will be monitor worker breathing zone areas for the protection of employee health. The project-specific Health and Safety Plan will specify actions that are to be taken in the event that monitoring instrument readings indicate that detected

concentrations may represent a health threat to onsite workers. Area and perimeter monitoring as well as sample screening activities may also be called for in the Work Plan or Health and Safety Plan, but these are *secondary* purposes for the use of these instruments.

Unless otherwise specified in a project-specific Health and Safety Plan, the following monitoring instrument action levels and response measures will be observed on UXO/CWA sites:

Parameter	Action Level
Total Organic Vapors	Any sustained level above background
Airborne particulates	Readings >2.5 mg/m^3
Flammable Vapors	10% of the Lower Explosive Limit (LEL)

If such levels are noted at site perimeters or adjacent to neighboring residential or commercial property, the TtNUS Field Operations Leader and/or the Site Safety Officer will notify the appropriate client or base contacts.

g. Liquid Release Monitoring – All field team members will be responsible for observing and reporting any liquid chemical releases or conditions that could lead to a release. If field operations on site result in a release of liquid chemicals in the absence of vapors, field personnel will attempt to contain the liquid by means of berms constructed with available equipment. If the work team cannot control the spill, they will leave the area for the assembly point quickly, without panic. The TtNUS Field Operations Leader and/or the Site Safety Officer will notify the appropriate client/base contact. This is not considered to be a significant probability during operations. However, in the unlikely instance that it should occur, field personnel may effect these types of defensive efforts, providing that such a response does not appear to present a chemical overexposure or other personal health or safety threat.

12.0 TYPICAL CLIENT/FACILITY SAFETY POINTS OF CONTACT

The following positions are typically encountered on UXO/CWA projects. Communication and coordination with these positions should be implemented and maintained throughout all project activities (from pre-field operations planning through to project close-out).

a. Installation Safety Management Office

b. Installation Ordnance Officer and/or EOD Officer

c. Installation Radiation Officer

d. Installation Environmental Office

13.0 TOOLS AND EQUIPMENT

Tools and equipment necessary to safely and effectively accomplish the objectives of a project will be detailed in the project-specific Work Plans and Health and Safety Plans. Items commonly required for UXO/CWM operations are presented below:

13.1 Personal Protective Equipment

a. Respiratory Protective Equipment (i.e., air purifying or air supplied devices)

b. Dermal (chemical resistant) protective equipment (e.g., coveralls, gloves, eye and face protection)

c. Physical safety PPE (hard hats, hearing protection, safety glasses, safety shoes, etc.)

13.2 Air Monitoring Equipment

a. Explosive/O_2 Meter (Combustible Gas Indicator)

b. Direct reading Organic Vapor Analyzer (PID or FID)

c. Direct reading particulate meter

d. Radiation Survey Meters and TLD Badges

13.3 Geophysical/Hydrology Survey Instrumentation

a. Magnetometers (Cesium Vapor, Schonstedt)

b. Electromagnetic Terrain Conductivity Meter (EM-31)

c. Time-Domain Electromagnetic All-Metals Detector (EM-61)

d. Water Level Indicator/Recorder

e. pH/Temperature/Conductivity Meter for water samples (Horiba, etc.

f. Survey Equipment (transit, tripod, level, etc.) as required

13.4 UXO Support Equipment

a. Schonstedt Magnetic Locators (GA-52Cx or equivalent passive instrument) will be used for UXO surface survey during UXO activities. The GA-52Cx detects the magnetic field of any ferromagnetic object.

b. Schonstedt MG-220 Magnetic Gradiometer (Down-Hole Magnetometer or equivalent will be used to conduct down hole UXO checks. The MG-220 detects the magnetic field of any ferromagnetic object as it is lowered into a borehole.

c. Marking tape, pin flags, stakes, utility spray paints, etc.

13.5 CWM Support Equipment

a. Chemical Agent Identification Kits (M18A2 Kit)

b. ICAMs (Individual Chemical Agent Monitor)

13.6 Decontamination Equipment

As required by the level of protection for each site. See Site Health and Safety Plan for specifics.

13.7 Hand Tools/ Miscellaneous Equipment

As may be required.

14.0 ENVIRONMENTAL CONCERNS

The field operations covered by this SOP will be performed in such a manner as to minimize the effects of pollution of air, water, or land and to control noise and dust emissions within reasonable limits.

Every effort will be made to:

a. Protect the land areas and to preserve them in their existing condition.

b. Protect water resources, including measures for run-off or run-off controls if applicable.

c. Implement sediment control measures, where warranted. These measures will also be implemented to control erosion.

Usually, field operations will generate solid and liquid waste (Investigative Derived Waste – IDW) requiring onsite handling and possible offsite disposal. The major types of waste to be generated, their environmental concerns, and their handling and disposition are summarized below:

a. Personal and equipment decontamination containers disposed offsite following a thorough decontamination. Liquid waste will be included with well purging and development fluids.

b. Personal Protective Equipment (PPE) will be double-bagged and will be the responsibility of TtNUS to dispose of according to applicable regulations. Disposal will normally be offsite.

It is not anticipated that any chemical releases will occur during the field activities.

The MSDSs for chemicals being brought onto the installation for use in field operations will be listed on a site-specific Chemical Inventory and maintained at the TtNUS Field Command Post. Copies of these documents are to be made available to client and offsite representatives who may be called upon to respond to an emergency event.

15.0 UXO/CWM PROCEDURES FOR FIELD OPERATIONS

15.1 General – field procedures for work on any installation can include any or all of the following tasks:

a. Initial entry into suspect areas

b. CWM operations

c. Surface and subsurface sampling

d. Monitoring well installation

e. Exploratory trenching

f. Geophysical surveys

g. Other miscellaneous operations

15.2 Initial Entry – initial entry into suspect areas require an UXO-qualified technician with a magnetometer (GA-52Cx) to screen a path into the area. The screened area is marked with lanes using either pin flags with plastic pins or marking tape. Suspect items on the surface and subsurface magnetic anomalies will be marked, usually with a different color tape or flag, and will be avoided by team members. The site where the work is to be conducted will be thoroughly screened for UXO/CWM contamination prior to any work commencing. All personnel will stay within the cleared areas and not venture out into areas not screened. If an area that has magnetic anomalies cannot be avoided, the UXO-qualified technician will hand excavate down to the anomaly to check to see if a hazard exists. Before excavation begins, the immediate area will be cleared of non-essential personnel outside of what could be a fragmentation zone (as determined by the UXO Technician). If the excavation reveals a hazard, the emergency notification procedures in paragraph 11.0 will apply.

15.3 CWM Operations - prior to conducting CWM operations, an Emergency Response Plan as required by 29CFR1910.120 and DA Pam 50-6 will be developed and implemented. Most of the information required to develop this plan should be obtained from the installation safety office; however, as a minimum, the following elements will be addressed:

a. Pre-emergency planning and procedures for reporting incidents to appropriate government agencies for potential chemical exposure, person injuries, fire/explosions, environmental spills and releases, and discovery of radioactive materials.
b. Personnel roles, lines of authority, communications.
c. Posted instructions and list of emergency contacts: physicians, nearby notified medical facility, fire and police departments, ambulance service, state/local/federal environmental agencies, Certified Industrial Hygienist (CIH), and installation commander.
d. Emergency recognition and prevention.
e. Site topography, layout and prevailing weather conditions.
f. Criteria and procedures for site evacuation (emergency alerting procedures/employee alarm system, emergency PPE and equipment, safe distance, place of refuge (assembly area), evacuation routes, site security and control).
g. Specific procedures for decontamination and medical treatment of injured personnel.
h. Route maps to nearest pre-notified medical facility.
i. Criteria for initiating community alert program, contacts and responsibilities.
j. Critique of emergency responses and follow-up.
k. Material Safety Data Sheets (MSDS) for each hazardous substance anticipated to be encountered on site would be made accessible to site personnel at all times.

15.4 Sampling – sampling will be conducted in accordance with established protocols and methodologies. Site-specific sampling requirements will be presented in the project-specific Work Plans and/or in other project-specific documents such as Field Sampling and Analysis Plans and Quality Assurance Plans.

Prior to initiating any sampling activities, an UXO-qualified technician will screen sites potentially contaminated with UXO/CWM. A magnetometer will be used to screen entry into a suspect area as in paragraph 15.2 above. Lanes will be marked and suspect items and subsurface anomalies will be identified and avoided. The immediate sampling area will be surface-screened prior to the introduction of the sampling team into the area.

Prior to any subsurface intrusive sampling, another check with a magnetometer needs to be accomplished. The GA-52Cx Magnetic Locator (magnetometer) can be used for collecting

subsurface samples not greater than 0.5 feet. If excavation of a borehole or hand auguring hole is to exceed this depth, a MG-220 Magnetic Gradiometer (down hole magnetometer) shall be utilized with readings taken at two feet depth intervals.

If an anomaly is detected, the location will be marked and avoided. If appropriate and acceptable, an alternate sampling location (in a cleared area) will be designated. If the sampling location cannot be relocated them the UXO-qualified technician will hand excavate down to the anomaly to determine if it is hazardous. If it is not hazardous, the object will be set aside and the sampling event will continue. If the object has been determined to be hazardous or suspect, the sampling team will move out of the area and the emergency procedures listed in paragraph 11.0 will be implemented.

15.5 Monitoring Well Installation – the area within a 50-foot radius of the borehole and the off- road access path will be screened with the GA-52Cx magnetometer and be cleared of all metal objects. Once this is accomplished, the areas around borehole sites will be marked using colored marking tape and/or pin flags. Heavy equipment such as front-end loaders, backhoes, and bulldozers will not be used to develop or establish drill sites. The following action will be followed:

a. The GA-52Cx magnetometer will be used directly over the borehole site to check for buried items down to 0.5 feet. After a surface check, the UXO-qualified technician will hand auger down to a depth of two feet and check down the hole using the MG-220 magnetometer.

b. Once the hand-auguring hole has been cleared, the drill rig will be positioned over the proposed borehole. Drilling will commence to a depth of four feet, the drill auger will be removed from the borehole, the drill crew chief and UXO personnel will make observations of the soil from the core barrel and the soil removed from the hole by hand auger (if needed). The drilling log and lithologic log will be maintained in accordance with standard practices, noting any metal objects that may be found.

c. The drilling derrick will be secured and drill rig moved to a position at least 20 feet from the borehole.

d. The borehole will be checked again with the MG-220 magnetometer.

e. If UXO or magnetic anomaly is present, the borehole will be abandoned and another location selected. The new borehole should be at least six feet from the original borehole. If a UXO or anomaly is not detected and the clearance is given, the drill rig shall be positioned back over the borehole, and drilling will proceed to the next depth (6 feet).

f. Repeat above steps at intervals of 2 feet, until a depth of ten feet is reached. At the ten-foot interval, a magnetometer reading shall be taken with the MG-220 set on the maximum sensitivity. The instrument will detect larger objects (approaching 100 lbs.) that could be expected to penetrate to depths of 10 feet or more.

g. After reaching the depth of ten feet, the above steps will be repeated at intervals of 4 feet, until the desired depth is reached.

15.6 Exploratory Trenching and Excavation – at times, exploratory trenching may be required to determine the lateral extent of a landfill, burial pit, or subsurface geophysical anomaly. Trenching and excavation to uncover a subsurface area will be conducted using a backhoe, an excavator, or sometimes a front-end loader. **Any trenching or excavation activities (regardless of depth) must be done in accordance with OSHA 29 Subpart P requirements, which must be considered and addressed in the project-specific Health and Safety Plan.**

On project sites where excavation activities are within the scope of work *and* a UXO/CWM concern exists, the following additional procedures will be utilized to conduct these operations:

a. The surface of the area to be trenched or excavated will first be swept with the GA-52Cx magnetometer. Anomalies will be hand excavated to determine if hazardous.

b. No more than 0.5 feet of surface soil will then be gingerly removed (scraped) from the area of concern.

c. The heavy equipment will be removed at least 20 feet away from the area, and the area will be checked with the MG-220 magnetometer. If the area is a trench, the entire length of the trench will be checked with the MG-220 and the excavation can continue two feet at a time. If the area is a wide-open area, it can once again be checked with the GA-52Cx, but only 0.5 feet of soil removal can be excavated at a time.

d. Anomalies will continue to be uncovered by hand excavation until the desired results are obtained and the trench/area is abandoned and refilled.

e. Excavation will continue another 2 feet if using the MG220 or 0.5 feet if using the GA-52Cx magnetometer. Once again after the proper depth of soil is excavated, the heavy equipment is removed from the area (>20 feet) and the area is rechecked with the magnetometer. If excavation depths reach 4 feet, suitable means of access/egress must be provided (e.g., ladders) and atmospheric monitoring must be performed prior to any entries.

f. The above procedures are followed until the desired depth is reached and/or the desired results are obtained.

Once the area or trench has been cleared, excavation can continue to the proper depth before the equipment is again moved away (at least 20 feet) and the area/trench.

15.7 Geophysical Surveys – there are several instruments that can be used to conduct geophysical surveys. The GA-52Cx (Schonstedt) and the MG-220 are magnetometers and are passive instruments. The Geonics Terrain Conductivity Meter (EM-31) is an active instrument and is commonly used to measure subsurface terrain conductivity. This information can be used geophysical surveys, as well as for locating voids, discontinuities in soil structures such as boundaries of disposal pits and buried conducting objects. An Ordnance Safety Analysis of the Geonics Model EM-61 Non-Contacting Terrain Conductivity Meter was conducted by the Naval Surface Warfare Center at the request of TtNUS in April 1993. The analysis concluded, in summary, that the "Geonics EM-61 poses no ordnance safety hazard when operated in the normal survey mode, where the device is held at hip height." However, the Geonics EM-61 should not be used with the boom on the ground if ordnance is present or suspected.

When using the magnetometer or the EM-61, a UXO-qualified technician will conduct a surface sweep of the area to be surveyed to ensure that no surface ordnance or other hazards exist. The magnetometer is a passive instrument; therefore, no special ordnance safety precautions are required.

Manufacture recommended procedures for the EM-61 must be followed to ensure safe operation during the geophysical survey. Standard survey protocols and quality assurance methods will also be required during survey operations.

15.8 Miscellaneous Operations – due to the potential of UXO/CWM materials being encountered during field activities, UXO support will be provided at all site locations. UXO support will be

provided for any and all field activities that are in areas suspected to contain UXO and/or CWM. These areas also include those areas covered with water and creeks, canals, etc.

Operations that involve the inspection, hazard classification, segregation, and final disposal of UXO and UXO-related scrap will not be covered in this SOP. The demilitarization of UXO and UXO-related scrap is not authorized unless specific work plans, SOPs, health and safety plans and other established procedures are written and approved addressing these operations.

16.0 HAZARD CONTROL BRIEF

A Health and Safety Hazard Control Briefing (i.e., tailgate meetings) will be conducted daily prior to the start of onsite activities. The briefing will be detailed and will cover the information in the Safe Work Permits for the anticipated tasks for the day, as well as applicable portions of this SOP. Additional briefings will be conducted as necessary for tasks that become necessary during the course of a workday, if they were not covered in the morning briefing. These briefings are in addition to (not in place of) the site-specific health and safety training that is required for all onsite personnel prior to their participation in any onsite, intrusive activities.

The following information will be given during the daily briefings:

a. Overview of task(s) to be performed and review of appropriate Safe Work Permits with task participants.

b. Overview of the day's objectives, as well as general site hazards

   - Unexploded Ordnance Hazards
   - Chemical Warfare Agents and Materials
   - Physical Hazards

c. Overview of Standard Work Practices pertinent to the day's planned activities

d. Review of any worker incidents or near-miss events, including a review of corrective/preventive measures to prevent recurrence

e. Overview of Emergency Response Actions, evacuation routes and assembly points

17.0 SECURITY

Field activities under various TtNUS contracts are typically unclassified and normal security measures apply in accordance with above references (paragraph 9.1 above). TtNUS personnel and their subcontractors will check in with the appropriate client/installation's security office and may be issued security badges for entry into certain work areas. This SOP will not cover special security requirements for projects involving UXO/CWM as most installations have established policies and procedures on reporting and securing recovered items that are UXO and/or CWM. The TtNUS Project Manager will incorporate all security procedures required by the installation into the site work plan.